Agricultural Transformation – A Roadmap to New India

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FOREWORD

In accordance with its mission, the National Academy of Agricultural Sciences (NAAS) has been critically discussing and examining important contemporary cross-cutting multidisciplinary issues related to agricultural transformation and suggesting implementable technological, institutional, and policy solutions to build a prosperous and inclusive India. So far 150 Policy Papers, Strategy Papers, Policy Briefs, Proceedings, and Books towards developing a rewarding, resilient, responsive, and remunerative agriculture have been brought out. As elucidated in Chapter 3 of this book, the NAAS publications have addressed 14 groups of challenges whose resolutions will render India free from hunger, poverty and undernutrition, and make our country more inclusive, resilient to climate change and other volatilities, environmentally more sustainable, economically prosperous, and peaceful. These achievements and suggested pathways, as highlighted in the book, are analogous to those for meeting the Sustainable Development Goals – Agenda 2030, which is a must for India.

Overall, the book has identified the following priority areas: nutrition-sensitive sustainable agri-food systems; accelerated and sustainable productivity enhancement, diversification, and intensification; internalization of global trends and macro policies in Indian agriculture; doubling farmers' income and inclusive growth; fostering entrepreneurship for employment and economic security; science, technology, innovation and precision agriculture as main drivers of the transformation; gene revolution for agricultural transformation; liberating science to serve the society; value-chain management, preventing losses and wastes, and linking farmers with markets; remunerative prices and market reforms; climate smart agriculture; water security and development of rainfed areas; soil health and nutrient management; crop health chemicals management; agrobiodiversity and Farmers' Rights Management; renewable energy for sustainable agricultural growth; comprehensive and reliable data, Artificial Intelligence, and Knowledge Platform to reshape India; transforming agricultural education and building human capital; investing in agri-food systems with special reference to research, education and extension; policies for farmers – serving farmers to save farming; and institutionalizing monitoring, evaluation, and impact pathway analysis.

For each of the above priority areas appropriate and associated policy options, actions, and path ahead to transform Indian Agriculture have been elucidated. The outcomes of the suggested programs will meet NAAS's vision of an India free from hunger, undernutrition and abject poverty, where agricultural and food systems are pivotal to improving livelihood security consistent with social, economic, and environmental security. The action points detailed in different chapters of this book will greatly help in finding solutions and strategies for meeting the challenges and achieving the national goals under the SDG umbrella. The book highlights that NAAS policy perspectives evolved during the past nearly 30 years on many of the most important issues facing food and agriculture system will transform our vision to promote multi-stakeholder partnerships to mobilise convergence of technical, policy, and financial resources required by the country for achieving the SDGs.

The author has enriched the NAAS' outcomes by adding new chapters and disruptive innovations and ideas. Thus, the book elucidates the latest and wholesome picture of the enormous progress made globally and in the country in the cutting-edge areas of science, technology and innovations. Likewise, it will be extremely useful both for policy makers and development communities as well as for the academicians. As the book discusses the academic legitimacy and contextuality of the major scientific and policy issues and their resolutions, it will be equally useful for students / scholars in agricultural and other universities and research and extension institutions. I strongly feel that this most topical and timely book will help change mindset of all stakeholders to appreciate the fast changing context and will be used widely for policy making and taking investment decisions. I sincerely hope that the emphasis laid on Monitoring, Evaluation, and Impact Pathway Analysis will strengthen governance and institutions to enhance program implementation efficiency and wholesome outcome to meet the goals of a prosperous New India.

I express my deep gratitude to Prof. R.B. Singh, Former President, NAAS, for assessing the efficacy and impact of NAAS Policy Papers and other publications and further augmenting and enriching them for effective policy formulation and strengthening our Agricultural knowledge pool. I am confident that the science and policy perspective and future outlook for transforming Indian agriculture to meet the SDGs, elucidated in this book, will be extremely helpful in reorienting our policy options and actions as well as NAAS's responsibility towards building a New India.

(Panjab Singh)
President
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PREFACE

Global agriculture is experiencing phenomenal changes due to technological revolution, including digital revolution, sprawling urbanization, accelerated growth in middle income groups, fast changing food habits and preferences, the market oscillations, and above all, due to climate change and environmental degradation. These changes offer unique challenges and opportunities to transform agriculture to be more productive, economically remunerative, socially equitable and inclusive, and environmentally sustainable.

In India, during the last 50 years, with the ushering in of the Green Revolution in the mid-1960s, followed by the White, Yellow and Blue Revolutions – collectively known as Rainbow Revolution, overall agricultural and food production increased over four-fold, several major commodities recorded 4 to 10 fold increases, foodgrains reaching nearly 290 mt, horticultural produce over 315 mt, milk production nearly 180 mt, and fish production approaching 12 mt. India thus globally ranked among the top two producers of several major commodities, rendering the country as the second largest agrarian economy in the world. During the past couple of decades, the GDP overall growth rate has been around 7 to 8 per cent per annum. These trends had transformed the country from the ship-to-mouth status to the Right to Food Bill situation and India became a major agri-food exporter. These developments had helped the nation in reducing its poverty and hunger levels by 50 to 70 per cent.

Despite the excellent progress made in production and economic growth, and the strong political support, India is facing an enigmatic situation. Nearly one-fifth of world's hungry and 35 to 40 per cent of the world's undernourished and stunted children have their homes in India. Unfortunately, India is one of the very few countries in the world where number of wasted children under five has increased during the past decade, from about 22 million in 2005-06 to over 25 million in 2015-16, being home to 50 per cent of the world's wasted children. It is estimated that the high under-nutrition in the country may annually cost about 6-10 per cent of the national GDP, let alone the unethically entrenched human deprivation. Therefore, agricultural development does not only mean increased production, but should simultaneously address related social, economic, and environmental concerns.

Another unique feature of India's agrarian economy is that the country is home to over one-third of the world's small and marginal farmholders, with unabated land splitting, the average holding size has reached almost one ha. And, these small and marginal farmers paradoxically comprise vast majority of the country's hungry and poor who constitute one-fourth of the world's such deprived people. World Bank has recently reiterated that the potential gains in India from reallocating land and labour are not quite promising, whereas increased productivity of agriculture was found to be most effective means of pulling majority of the deprived farmers out of hunger and poverty. Increasing agricultural productivity of the smallholder farmers thus must be central to the growth, poverty reduction, equity agenda, and smashing of the epigenetic fixation of undernutrition.

Soon India will be the most populous country in the world, reaching 1.7 billion by 2050, exceeding China's population by 400 million people. Farmers and their families, numbering nearly 650 million men, women, and children account for 50 percent of the population, and 85 percent of the farmers are small and marginal. Notwithstanding the increasing global food demand, challenged to adequately feed nearly 10 billion people by 2050, India, with only 2.3 percent of the world's land and less than 4 percent of the global fresh water, will be required to feed 18 percent of the world's population. And, this will have to be achieved from declining natural resources, especially land, water and biodiversity resources, and without further damaging the agro-ecological system and accentuating the carbon footprints.

The above challenges notwithstanding, respecting the aspirations of over 1.3 billion Indians, the Hon'ble Prime Minister Narendra Modi, pledged on 15 August 2017 to build a New India by 2022. He envisioned an innovation-driven, vibrant, healthy, prosperous, and peaceful India which must also be free from abject poverty, hunger and under-nutrition – the foremost Sustainable Development Goals - SDG1 and SDG2. Within a few months, he also pledged to Double the Farmers' Income by 2022-23. Towards building New India, in this year of 150th birth anniversary of Mahatma Gandhi, Prime Minister Narendra Modi has envisioned a $ 5 trillion Indian economy by 2024-25. Experts opine that a real GDP growth rate of 8 per cent based on complementary inter-linkages among major macro-economic variables, especially agriculture, will be needed, to achieve the targets.

A recent Economic Survey, Times of India, July 5, 2019 suggests that focus on productivity and exports will revive and enhance investment, which alongwith policy predictability and promotion of entrepreneurship will help achieve the target. To achieve the desired GDP growth, Agriculture in a comprehensive sense taken as agri-food system for development (AFS4D), must attain a stable growth rate of 4 per cent and above. Farmers being the largest private partners in the national investment platform strengthened through the upcoming 10,000 FPOs, the growing agri-entrepreneuship, as detailed in Chapter 6, should become a national movement to enhance rural income as well as employment security, helping to build a 5 trillion dollars economy.

This book, comprising 17 chapters, captures latest frontier agro-biological scientific, technological and innovative developments and highlights the major trends, issues, challenges and their resolutions, main messages, policy options, strategies, and actions emerging from the 150 plus Policy and Strategy Papers/Briefs, books and other publications of the National Academy of Agricultural Sciences (NAAS). It underpins the urgency and importance of breaking the Indian enigma and of transforming Indian agriculture to be more rewarding, resilient, and responsive to free the nation of hunger, undernutrition and abject poverty to build an ever prosperous New India. As detailed in chapters 2 and 3, the NAAS commends that the national development goals should be closely aligned with the SDGs which India must meet. The book highlights the contextuality of high incidences of hunger, malnutrition, poverty, depleting natural resources (land, water, biodiversity), increasing incidences of biotic and abiotic stresses, declining benefit cost ratios, low total factor productivity and slow growth, high volatility due to climate change, and market uncertainties.

Besides analyzing the trends and challenges, the publication elucidates the academic legitimacy of bridging the social, economic, and sustainability gaps, new technologies and innovations, including biotechnology, nano-technology, precision agriculture, artificial intelligence, information and communication technology, and space technology which ought to be developed and deployed in convergence with appropriate policies to meet the challenges and uncommon opportunities.

The book internalizes the voices and views not only of scientists/academicians, but also those arising from grassroot levels. Underpinning the dynamic nature of science-led growth and development, the publication shows the pathways for building on the ongoing efforts and internalizing emerging and anticipatory issues and opportunities, market shifts, political and international alignments etc. in the transformational development. Messages emerging from political thought processes, the PM's pledges for New India, Doubling Farmers' Income, the five trillion $ economy and others, governmental priorities, policies, initiatives, international trade and trends, and related UN priorities, especially the SDGs, treaties and declarations are also duly elucidated. Above all, the human face and voice of science have always been kept in mind while making recommendations.

The book emphasizes "Measure to Manage" and institutionalization of monitoring, evaluation, and output-outcome-impact pathway assessment as there exists huge technology transfer gap, and several important targets stand unmet (chapter 17). It reiterates that lately several scientifically unauthenticated technologies, such as Zero Budget Natural Farming, are being advocated, whereas many scientifically proven technologies, *viz.* genomics, are being discouraged. Scientifically evidenced outlines and criteria for evaluating research, technology, innovation, and education outcomes for development are available and ever-evolving and should be used for creation of reliable databases. Cloud computing and measuring veritable main and interaction effects in a multidisciplinary holistic system for developing effective indicators and sound plans and implementation pathways, especially for assessing progress in hunger, malnutrition and poverty reduction and elimination have been emphasized. The chapter highlights that the approach must be able to determine the differentiated accountability of all stakeholders along the value chain. It can hardly be overemphasized that monitoring progress towards achieving a New India free from hunger and malnutrition within the framework of SDGs is essential to drive the necessary structural and policy reforms - "leaving no one behind".

Given the above details, I sincerely hope that policy makers, scientists, academicians, planners, corporate sectors, students, farmers, and other stakeholders will greatly benefit from the book, and shall synergistically converge to disruptively transform agriculture to be socially, economically, and environmentally responsive to build a New India. I trust, the Government will provide adequate financial, institutional, policy and political support to science and innovation-led transformation of Indian agriculture to meet the SDGs. I am sure, the book will enthuse scientists, academics, and the NAAS for increasingly enriching the national and global knowledge platforms and benefitting from a collaborative World Grant system to actively participate in program implementation.

I am grateful to Prof. Panjab Singh, President, NAAS, for giving me the opportunity, guidance, and encouragement to review the usefulness of NAAS Policy Papers and other publications in formulation of national policy options and research priorities for transforming India's agri-food system. Special thanks are due to Dr. Anil Kumar Singh, Secretary, NAAS and Dr. B.S. Dwivedi, Head of Soil Science & Agri. Chemistry, IARI, for their invaluable inputs respectively for chapter 8 (water security) and 9 (soil health). My thanks are also due to Dr. Trilochan Mohapatra, Secretary DARE & DG ICAR, Dr. Vinod K. Prabhu, Chairperson PPV&FRA, and Dr. Gita Kulshrestha, Former Head, Agricultural Chemicals, IARI for their invaluable academic inputs.

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Chapter 1
Agricultural Transformation: the Road to New India:
Policy Options and Scientific Interventions

1.1 Shared Dreams - Vibrant Future

Hon'ble Prime Minister Narendra Modi, respecting the dreams, wishes, aspirations, hopes, and desires of 1.3 billion Indians, pledged on 15 August 2017, the 71st Independence Day, to build a New India by 2022. He envisioned an innovation-driven, vibrant, healthy India free from corruption, communalism, casteism, terrorism, and illiteracy. He further envisioned a clean (*swachh*) India characterized by peace, prosperity, unity, plurality, transparency, inclusiveness, and compassion. To be prosperous, inclusive, and at peace, **New India must also be free from abject poverty, hunger and under-nutrition** – the foremost Sustainable Development Goals - SDG1 and SDG2.

In consonance with the pledge for a New India, the Prime Minister had also pledged to Double the Farmers Income by 2022-23. The two pledges are not a coincidence, but interdependent and complementary. India's economy being largely agrarian, agriculture (in a comprehensive sense including all allied sectors) anchors livelihood security of over 120 million farm families, 85 per cent being small and marginal farmers, comprising 55 per cent of India's population, nearly 700 million real people – children, women, and men. But, agriculture contributes only 15 per cent to the nation's GVA. Consequently, average income of farmers in India is about one-sixth of that of non-agriculturists, and real income of farmers has declined.

The low and often uncertain level of farmer's income is the root-cause of the widespread agrarian distress. Further, the proverbial income asymmetry has greatly accentuated the widespread poverty, under-nutrition, poor health, and inequality in the country. Thus, the future of farmers, farming and the agrarian people in villages is closely linked with the future of India. The call of the Prime Minister to Double Farmers Income evoked the recommendation of the National Commission on Farmers (2006) "To increase focus on the economic well being of the farmers rather than only on production … measure the agricultural progress by farmers' net income growth", as also reiterated by the Committee on Doubling Farmers Income (CDFI) stating that "farming must be treated as an enterprise, and that future agricultural development will have the returns and not just the output from the farm as its prime objective". It further highlights that the road to New India must pass through the farmers' fields. We shall achieve "Poorna Swaraj" only when we have achieved "Gram Swaraj", had said Mahatma Gandhi.

Towards building New India, in this year of 150th birth anniversary of Mahatma Gandhi, Prime Minister Narendra Modi has envisioned a $ 5 trillion Indian economy by 2024-25. Experts opine that a real GDP growth rate of 8 per cent based on complementary inter-linkages among major macro-economic variables will be needed. A recent Economic Survey, Times of India, July 5, 2019 suggests that focus on productivity and exports will revive and enhance investment, which alongwith policy predictability and promotion of entrepreneurship will help achieve the target. To achieve the desired GDP growth, Agriculture in a comprehensive sense taken as agri-food system for development (AFS4D), must attain a stable growth rate of 4 per cent and above. Farmers being the largest private partners in the national investment platform strengthened through the upcoming 10,000 FPOs, the growing agri-entrepreneuship, as detailed in Chapter 6, should become a national movement to enhance rural income as well as employment security, helping to build a 5 trillion dollars economy.

1.2 The Indian Enigma

India, through the Green Revolution process ushered in the 1960s, and followed by White, Yellow and Blue Revolutions, had witnessed unprecedented gains in agricultural and food production, registering record productions of nearly 290 million tonnes of foodgrains, over 310 million tonnes of fruits and vegetables, over 176 million tonnes of milk (highest in the world) and 12 million tonnes of fish, rendering India the second largest agrarian economy of the world. Importantly, the Rainbow Revolution had more than halved the incidences of poverty and hunger in the country and transformed the nation from the state of ship-to-mouth to the state of Right-to-Food based on home-grown food, and the country became a net exporter of several agricultural commodities valued at 33.87 billion US$ during 2016-17. The revolution was largely due to the synergy of technologies, policies, services, farmers' enthusiasm and strong political will.

Despite the Rainbow Revolution and high overall economic growth rate of about 8 per cent during the past decade or so, nearly one-fifth of world's hungry and 35 to 40 per cent of the world's undernourished, stunted, and wasted children have their homes in India. Unfortunately, India is one of the very few countries in the world where number of wasted children under five has increased during the past decade, from about 22 million in 2005-06 to over 25 million in 2015-16, being home to 50 per cent of the world's wasted children.

The first Comprehensive National Nutritional Survey (Times of India, October 8, 2019) reveals that less than 7 per cent of under-2 kids in India get adequate diet, varying from 1.3 per cent in Andhra Pradesh to 35.9 per cent in Sikkim. Further, 33 per cent under-5 kids are underweight, 35 per cent stunted, 17 per cent wasted, and 2 per cent are obese. It is estimated that the high under-nutrition in the country may annually cost about 6-10 per cent of the national GDP, let alone the unethically entrenched human deprivation. Moreover, the epigenetic effect of hunger has aggravated the intergenerational injustice. Obviously, the "Pot of gold", meaning eternal justice, inclusiveness, prosperity, peace, happiness, and vibrancy, at the end of the Rainbow (Revolution) has remained elusive. A big question is: how a 'tall' vibrant New India could be built on the shoulders of stunted and wasted children?

1.3 A Transformational Vision Needed to Build Vibrant Future

The current global economic slowdown and downturn is exacerbating the food and nutritional security and poverty. In the last quarter, India, for the first time during the past seven years, had recorded a GDP growth rate of only 5 per cent. The slowdown has kept India and several other developing countries off-track the SDG targets, especially SDG1 and SDG2. The slowdowns disproportionately challenge food and income security of the majority smallholders, who comprise the larger proportion of hungry and poor. The increasing climate change volatilities have exacerbated the situation, fuelling the recent increase in incidences of hunger, undernutrition and poverty. Thus, in this fast changing world, to meet Agenda 2030, especially SDGs 1, 2, and 13 (climate smart agriculture), a transformational vision and action is called for. To overcome the emerging unfavorable situations, suitable economic and social reforms and application of best of science, technology, and innovations are needed. Guaranteed funding is a must for education, social safety nets, and healthcare. Concerted efforts are called for reducing inequality especially to fight poverty, and building resilience to climate volatilities and market instabilities. Bolder actions will be needed in different policy domains, including social protection, development planning, and economic policy.

1.4 The National Academy of Agricultural Sciences (NAAS) Leads the Transformational Path

The National Academy of Agricultural Sciences (NAAS), a national think tank, established in 1990, provides a neutral and intellectually empowered national forum for scientists, academicians, policy makers, NGOs, farmers, and other stakeholders to critically discuss and examine important cross-cutting multidisciplinary issues related to agricultural transformation and to suggest implementable technological, institutional, and policy solutions in a dynamic mode. For this purpose, since its inception, it has been organizing Brainstorming Sessions, Round Tables, National Agricultural Science Congresses, General Body Meetings, Foundation Day and Memorial Lectures, and other consultations.

Arising from the veritable deliberations, the Academy has brought out and widely shared nearly 150 Policy and Strategy Papers/Briefs, Proceedings and Books towards developing a rewarding, resilient, and responsive agriculture. In doing so, NAAS has internalized the voices and views not only of scientists/academicians, but also those arising from grassroot levels. Messages emerging from political thought processes, the PM’s pledges for New India, Doubling Farmers Income and others, governmental priorities, policies, initiatives, international trends, and related UN priorities, especially the SDGs, treaties and declarations are also duly considered. Drawing from the past experiences and present trends, the topics chosen for the deliberations were based on contemporary, new, and emerging issues and opportunities. Anticipatory events, *viz.* climate change, demand and market shifts, political and international alignments etc. were also internalized in our discussions. Above all, the human face and voice of science have always been kept in mind in all our pursuits and recommendations.

This publication, comprising 17 chapters, highlights the major trends, issues, challenges and their resolutions, main messages, policy options, strategies, and actions emerging from the 150 plus publications of the Academy. It underpins the importance of breaking the Indian enigma and of transforming Indian agriculture to free the nation of hunger, undernutrition and abject poverty to build an ever prosperous New India. As detailed in chapters 2 and 3, the NAAS commends that the national development goals should be closely aligned with the SDGs which India must meet. High incidences of hunger, malnutrition, poverty, depleting natural resources (land, water, biodiversity), increasing incidences of biotic and abiotic stresses, declining benefit cost ratios, low total factor productivity and slow growth, high volatility due to climate change, and market uncertainties were identified as main issues and challenges. Overall, besides analyzing the trends and challenges, the publication elucidates that alongwith bridging the social, economic, and yield gaps, new technologies and innovations, including biotechnology, nano-technology, precision agriculture, artificial intelligence, information and communication technology, and space technology etc. ought to be developed and deployed to meet the challenges.

Based on contextuality and to promote a World Grant approach through international cooperation, synergy between NAAS goals and the SDGs have been emphasized, and development and adoption of effective policies and technologies coupled with complementary judiciously monitored and evaluated implementation pathways have been reiterated.

The Policy options, strategies, and actions which have emerged as the highest priority to meet the major challenges are summarized below.

1.4.1 Nutrition Sensitive Sustainable Agri-Food System – Foremost National Priority

Recalling the unethically persistent hunger, malnutrition and abject poverty, in line with the recently announced Government's initiatives *viz.,* Kuposhan Mukt Bharat, and National Nutrition Strategy : Vision 2022, and other related national and international developments, it is obvious that promoting growth and development in the agriculture sector is most crucial to alleviating hunger, poverty and undernutrition. In the life cycle approach it must be prevented as early as possible to avert irreversible deficits in development of individuals, societies, and the nation as a whole. Intergenerational continuity of high incidences of undernutrition are fraught with the epigenetic fixation of the malady. And, this inhuman development must be averted soon (Singh, 2015). Agricultural policy must focus to promote smallholder agriculture, especially their access to production resources, land entitlement, technology, knowledge, credit, market, and price realization. Access to clean drinking water and sanitation is equally important for accomplishing One Health.

As detailed in chapter 4, the following statement from Policies without Politics: Analysing Nutrition Governance, sums up the need for holistic governance to address the problem of malnutrition in India, "It is widely believed that India's limited success in dealing with undernutrition is linked to poor governance, including lack of a strong national agenda against malnutrition within the highest executive offices; lack of consistent monitoring of the situation based on reliable data; and an inability to comprehend malnutrition as a holistic issue, unsatisfactory quality of interventions across a number of sectors, including water and sanitation, education, agriculture, and others. Malnutrition is viewed primarily as a problem of hunger and food distribution, requiring supplementary feeding and subsidized distribution systems". While we must overcome these limitations, as a policy matter, India must reposition nutrition as central to development.

As defined by Pingali and Sunder (2017), nutrition-sensitive agri-food system goes beyond staple grains productivity and places emphasis on the consumption of micronutrient-rich non-staples through a variety of market and non-market interventions. The nutrition sensitive approach, congruently considers the macro level availability, and household- and individual-level determinants of improved nutrition. In addition to agriculture, intra-household equity, behaviour changes, food safety, and access to clean water and sanitation are integral components of the food systems. Thus, food systems encompass all activities involved in the production, distribution and consumption of food - the entire value chain. The policies on nutrition thus must address all the components of the food system in a holistic policy framework aiming to enhance the diversity, quality and safety of the food system and make it more accessible and inclusive to all people at all times.

Government schemes such as Public Distribution System (PDS) and National Rural Employment Guarantee (NREG) must improve access to food through increasing physical and economic access to food. The Food Security Act is a step in the right direction, provided it is backed up by nutrition communication to ensure that money saved in buying staple cereals is used for purchasing other protective foods. Development of warehousing and proper food storage should receive immediate attention for the act to be implemented successfully. Every effort should be made to enlarge the basket of foods in the PDS/FSA, to include pulses, oilseeds and vegetables even if not as entitlement.

Therefore, Agriculture for development is no longer limited to only agricultural production and food security. A paradigm shift is needed to pursue food security and comprehensive nutritional security - nutrition being the focus, and agricultural production should mean sustainable agri-food system. Thus, new policy options and actions should comprise:

- Make nutrition key goals of agriculture, and keep the smallholder farmer at centre stage
- Nutrition-specific allocation of adequate funds
- Collection of right data, deploy Artificial Intelligence for need-based specific interventions
- Scale-up and invest in carrying out proven and evidence-based solutions
- Undertake need-based diversification and intensification
- Tackle nutrition in all its forms, and adopt the One Health approach
- Raise awareness on nutrition
- Ensure effective implementation pathways

1.4.2 Accelerated and Sustainable Productivity Enhancement and Intensification

Fuelled both by swelling population (expected to surpass China by 2027 and reach 1.7 billion by 2050 as per the UN 2019 World's Population Prospects Report) and rising income levels (hoping to recover soon from the current economic slowdown to attain steady annual GDP growth rate of about 7-8 per cent), accelerated urbanization, and fast rising middle income group, the expanding food demand, especially for high value nutritious food, seeks 70 per cent increase in India's food availability by 2050. And, as commended in the Right to Food Bill, 2013, the demand has to be met essentially from home-grown food. As the production resources (land, water, biodiversity) are shrinking, we will be required to produce more from less for more (MLM) and that too sustainably (sustainable intensification) in face of the volatilities of climate change and markets.

The World Bank reiterates that productivity accounts for 50 percent of the differences in GDP per capita across countries. Identifying policies to stimulate TFP is thus critical to alleviating poverty and fulfilling the rising aspiration of global citizens. Yet productivity growth has slowed globally in recent decades, and the lagging productivity performance in developing countries constitutes a major barrier to convergence with advanced-economy levels of income.

To meet the challenges, we must commit ourselves to generate and deliver the best of science and technology to enhance TFP and its growth rate to accelerate productivity growth and pursue disruptive innovations to serve the humanity and embrace Scientific Social Responsibility (SSR) towards heralding a New India. In order to integrate and synergize the SSR with Corporate Social Responsibility (CSR), effective and extensive public-private-peasant-partnership (PPPP) should be established. The private (corporate) sector must be sensitized and supported to substantially enhance its investment in Agriculture-Food System, which has remained rather low. This synergy is needed to boost TFP as improvement in TFP accounted for over two-thirds of agricultural growth globally from 2001 to 2015, and nearly 60 per cent of the agricultural growth in developing countries (Word Bank, 2019). As the production resources (land, water, biodiversity) are shrinking, increased production will accrue only through increasing input and resource use efficiency i.e. by enhancing the total factor productivity of the resources. Knowledge platform, knowledge capital and innovations will play increasing role in increasing TFP growth, which must be accomplished in alliance with environmental and ecological sustainability.

As we marry the SSR and CSR, our transformational vision must be pro-poor and inclusive. Our efforts for ensuring comprehensive food and nutritional security, poverty alleviation, reducing inequality, especially gender inequality should be synergized. Policies and investments should be balanced to achieve a structural transformation that also fosters poverty reduction and more egalitarian societies. Polices related to diversification, intensification, integrated farming system, and trade should synergistically strengthen nutrition and income security, and be part of transformation (FAO, 2019). The CSR funds should be pooled and allocated to specific development programs. The concerned corporate partners should monitor the outcomes and impacts of such investments and, if needed, make necessary adjustments to achieve the targets. The upcoming New Scientific Social Responsibility Policy envisages ethical obligation of knowledge workers in all fields of science and technology to voluntarily contribute their knowledge to the concerned platforms to mutually benefit all stakeholders and partners.

The recent World Bank's Report (Fuglie *et.al.,* 2019) on technology and productivity growth in agriculture has emphasized that large potential exists for increasing agricultural productivity, hence income, precisely where vast majority of the extreme poor are found – in rural areas and engaged in small-scale farming, as in India. The increasing agricultural productivity must be central to the growth, poverty reduction, and equity agendas. It reiterates that the potential gains from reallocating land and labour are probably less promising than previously thought. The generation and dissemination of new, more productive practices & technologies and removing the barriers farmers face to adopting them is more effective. But additional reforms and new policy environment and incentives are needed.

1.4.3 Doubling Farmers' Income

This clarion call of the Prime Minister has been discussed in chapter 5, which elucidates various on-going programs and structural transformations being brought about to achieve the goal. The contexuality and complementarity of this national movement with the alleviation of rampant poverty and inequality, meeting the SDG1 and SDG2, has been analysed. The centrality of the smallholder farmer and his linkage with reliable and remunerative markets has been highlighted. Given the high pressure on land, the unmindful splitting of cultivated land – often rendering the holdings un-economical, off-farm and non-farm employment of the farming families is a must. On-farm and rural storage, processing, value addition, marketing, especially through Farmer Producer Organizations (FPOs), should enhance the employment opportunities.

Education and training of women to empower them with knowledge and to improve their employment potential will be a lasting approach to overcome the maladies. Moreover, there should not be pay disparity among women and men for equal job done. This parity alone will enhance agricultural production and income by about 30 per cent.

With the above backdrop, and also in line with the National Policy for Farmers, the Doubling Farmers' Income (DFI) Committee headed by Ashok Dalwai had suggested a redefined mandate for agriculture as "to generate both food and raw material, to meet the requirement of modern society for feed, fibre, fuel and other industrial uses, and in a manner that is sustainable and aims to bring economic growth to farmers." This mandate emphasizes the following aspects, which should be adopted by all stakeholders:

a) Agriculture has the moral responsibility of meeting food and nutritional security of the country in consonance with the agro-ecological backdrop

b) It has to generate gainful employment resulting in income gains to make the farmers more economically secure

c) It has to generate raw material that will directly support agro-processing of food and non-food products to support secondary agriculture

d) It has to support agro-processing industry to produce primary and intermediate goods, which will feed the manufacturing sector

e) Agricultural practices need to be on a sustainable basis.

1.4.4 Foster Agri-Entrepreneurship for Employment and Economic Security

In an agrarian economy of India's dimension, predominated by unemployed youth and smallholder farmers, entrepreneurship must be a key driver for agrarian transformation and socio-economic uplift of the majority youth and farmers who often operate on the edges of the economy in an ever-changing and increasingly complex and competitive global economy. Thus, agriculture should be promoted as an enterprise and farmer as an entrepreneur (chapter 6). The agri-entrepreneurs will greatly strengthen employment security and help harness the huge demographic dividend.

The Prime Minister's vision of Startups and role of technology and innovation in India's transformation should be realized on priority basis. The efficacy of recent government initiatives such as Make-in-India, Atal Innovation Mission, Digital India, Skill India, ASPIRE, MUDRA, and Stand-up-India in entrepreneurial development should be analyzed and converged for greater impact. The Amul Model, showcased as one of the world's leading Group Entrepreneurship model, should be applied also in other sub-sectors and value-chain systems. Concomitantly, our agricultural education system backed up by programs like student READY, RAWE and ARYA should ensure that every agriculture graduate could become an entrepreneur to accelerate equitable economic growth and employment security to build New India.

1.4.5 Towards Oilseeds and Pulses Self-Sufficiency

As highlighted in chapter 7, India has no reason to waste its hard-earned foreign exchange and hurt its agrarian economy by annually importing 14-15 million tonnes of edible oil, about 70 per cent of the total consumption, valued at 11 billion dollars. India has amply demonstrated that with proper congruence of appropriate technologies, agro-ecologically differentiated strategies, pricing support and market linkage, the country can increase its pulses production by 5 to 6 million tonnes in one year, thus eliminating its annual drain of US$ 2 to 3 billion in one go. Besides becoming self-sufficient in this widely consumed rich source of dietary protein, the country is benefitting from additional soil nutrient enrichment and environmental enhancement. Oilseeds production should be strategized on the same pattern as given in the pulses strategy NAAS paper, which has elucidated production strategy and implementation plan for each important pulses producing district.

The export of oil meals for animal feed and castor oil has to some extent plug the import bill of vegetable oil. However, the policy of exporting oil meal may not be desirable in long run as the domestic animal industry is deprived of high value feed to increase the milk and meat production. There are also arguments that instead of importing crude or refined oil, why not import oilseeds so that the local crushing industry also prospers and at the same time oil cake as animal feed is also made available. Policies that balance all these factors should be formulated through PPP mode. The partnership can be useful in several aspects of oil economy such as seed production, forward-backward linkages for processing, value addition, contract research in niche areas, contract farming and joint ventures for higher order derivatives and specialty products and so on. Therefore it is essential to create an enabling environment for private sector participation in such areas.

1.4.6 Value Chain Management, Prevention of Losses and Food Wastes, and Linking Farmers with Markets

Harvest and post-harvest loss of major agricultural produce in 2018 was estimated at Rs. 92,651 crore ($ 13 billion) (Ministry of Food Processing) per year largely due to storage, logistic, and financing infrastructure inadequacies. Prevention of these losses could feed 50 million people per year. About 30-45 per cent of the loss is due to food wastage – a crime indeed. One of the five pillars of Zero Hunger Challenges is “Zero loss or waste of food”, seeking change in the mindset of people to adopt “Save and Grow”. Cost-effective on-farm and near-farm processing, value addition along the value-chains, packaging, cold chains, product quality, product safety, and prolonged shelf-life technologies are need of the hour. Let us remember that “*a grain saved is a grain produced*”, and “*unsafe food is no food*”.

To achieve the above goal, farmers, especially smallholder farmers should be directly linked with markets. In this fast changing liberalized and globalized world, greater understanding of market intelligence mechanisms, good trade practices, and legal aspects of the multilateral trade regime and agreements and intellectual property rights is absolutely necessary. This calls for the development and institutionalization of user-friendly knowledge systems to support decision-making by various client groups. In line with the nation’s Food Bill and Right to Food, trade must first be a component of food security before meeting other obligations. New Initiatives of the Government on e-NAM, creating a common Indian Market and investment in establishing additionally 22,000 village markets will directly link the farmers with markets and help them realize remunerative prices for their produces, thus enhancing their incomes and access to adequate nutritive foods. Operation Greens are increasingly focusing on agri-logistics, processing, and professional management. Farmer Producer Organizations (FPOs) and Village Producer Organizations (VPOs) clusters are varyingly incentivized to remuneratively link the farmers with markets directly through the e-NAM platforms. This move has truly created pan-India markets for farmers who could sale their produces at best prices offered from any corner of the country. Sixteen states and 585 APMC markets are now integrated with e-NAM platform.

1.4.7 Saving the Planet Earth

The Planet Earth, the one and only, is already under stress. Of the nine interconnected planetary boundaries with defined tipping points in the Earth system, three, namely, climate change, biodiversity loss, and nitrogen cycle have been crossed. True to its name, this "Anthropocene" era reflects the consequences of human driven actions impacting health of our planet. The overall challenge before us is to achieve: (i) sustainable intensification of production to meet demand for food quantity and quality, (ii) profitability and social attractiveness to agriculture as a profession, and (iii) ecosystem services that improve water quality and quantity, soil health, carbon capture, and biodiversity. We should be able to differentially predict the future needs of food and other agricultural products and match them with the projected natural and other endowments in the foreseeable future. Towards a Green Economy with agriculture, we must enhance our ability to manage natural resources sustainably and with lower negative environmental impacts, and to increase resource efficiency and reduce waste. Adopting Climate Smart Agriculture (CSA), with its triple wins of enhanced productivity, resilience (adaptation) and mitigation, and the associated technological, policy, and investment implications, will facilitate the way to an evergreen future.

1.4.8 Climate Smart Agriculture

Use of the various climate-related indicators shows that climate change volatilities have been one of the main reasons for recent increase of incidences of hunger, malnutrition and poverty. The cumulative effect of changes in climate is adversely impacting all dimensions of food security – food availability, access, utilization, and stability. The climate aberrations impair the nutrient quality and dietary diversity, impact water and sanitation, and increase diseases and health risks. India being most vulnerable to climate changes, people's nutritional and overall livelihood security is further threatened.

It is thus imperative that we accelerate and scale-up actions to build Climate Smart Agriculture and Food System (CSAFS). Currently, both at national and international levels, several policy and action platforms are striving to achieve CSAFS, but these are not aligned. We must integrate these platforms to pursue coherent objectives to insulate people from the veritable vagaries and help achieve comprehensive food and nutrition security and safe health. It calls for increased partnerships and multi-year, large-scale funding of integrated disaster risk reduction and management and climate change adaptation programs that are short-, medium-, and long-term in scope (FAO, 2018). The Climate Smart Village initiative of CCAFS deserves specific allocations to make it a pan-India movement to curb the risks to rural prosperity.

1.4.9 Water Security

As also highlighted by the Prime Minister at the 73rd Independence Day, 2019, in view of the vital importance of water for human and animal life, for maintaining ecological balance and for economic and developmental activities of all kinds, and considering its increasing scarcity, the planning and management of this resource and its optimal, economical and equitable use has become a matter of utmost urgency as detailed in chapter 8. Having reviewed various aspects of water security since its inception, the Academy has emphasized that the availability of water is declining day by day, while on the other hand, there is no dearth of field-tested efficient water conservation and management technologies developed by the national agricultural research system, such as micro-irrigation, sub-surface irrigation and sensor-based water management, and these technologies should effectively be adopted at the grassroot level through creating appropriate institutional mechanisms and policy actions towards all time comprehensive food, water, and nutritional security. The gap between the irrigation potential created and utilized has widened to 25 m ha. Bridging this gap must be the main task of the Govt's Accelerated Irrigation Benefits Program (AIBP).

It is atrocious that India uses the largest amount of ground water amounting to 24 per cent of the world's total, which was more than that of China and the US put together. New initiatives by the Government, including PMKSY, DIPs, Composite Water Management Index (CWMI), and monitoring of State's performance across critical indicators schemes should be judiciously integrated to save the precious water – the basis of life on the planet, and achieve "per drop more crop", which underpins the urgency of improving water use efficiency. The newly launched ***Ministry, Jal Shakti,*** by merging the Ministry of Water Resources, River Development and Ganga Rejuvenation and Ministry of Drinking Water and Sanitation should coherently help achieve food, nutrition, quality water, health, and sanitation security. The expected outcomes of the Paris Water Conference organized by UNESCO on 13-14 May, 2019, should also be internalized in the national program. It is gratifying that in accordance with Paris Agreement, at the UN Climate Action UN Summit, 24 September 2019, Prime Minister Modi pledged that India will invest $50 billion on water conservation in the next five years under the "Jal Jeevan Mission" announced simultaneously. Allocation, use and outcome of this huge investment should to monitored by a national committee.

1.4.10 Soil Health and Nutrient Management

It should be emphasized that a series of ecosystem services, crucial for attaining comprehensive food and nutritional security, are provisioned by soil. The centrality of healthy soil for healthy life should guide all efforts to transform our agriculture-food systems. As detailed in chapter 9, seven major soil issues deserve priority attention. These include: Residue Management, Reclamation of Degraded and Polluted Soils, Monitoring Soil Health, Nutrient Management, Fertilizer Policies, Organic Farming, and Zero Budget Natural Farming. Recently NAAS had examined the efficacy of Zero Budget Natural Farming and found that the proposal needs scientific investigation as the preliminary results do not approve of its adoption. As regards organic farming, there is need to promote strong research backup to develop national standards for organic certification coherent with the international protocols. The high productivity zones of irrigated ecosystems practicing intensive cropping should be kept out of the ambit of organic farming or other such alternate farming options, for these zones are critically important to sustain national food security.

A Land Development Department as well as a National Mission on Soil Carbon Improvement should be created under the Ministry of Agriculture and Farmers Welfare to ensure effective collaboration among various stakeholders. The Soil Health Card initiative has not been received well by the farmers. The soil testing service needs revamping. Proliferation of small STLs in the name of strengthening soil testing service is not a professional approach, and should no longer be continued. The ecosystem services provisioned by soil are strongly interconnected and promote the One Health concept – indivisibility of soil – plant – animal – human health. This integrated outlook should guide our policy options and actions to attain the SDGs, especially the SDG1 (poverty alleviation), and SDG2 (Zero Hunger).

1.4.11 Crop Health Chemicals Management for Agricultural Transformation

A science-informed balanced and integrated approach is needed to save our precious harvests and to maintain social, economic, ecological, and environmental balance (chapter 10). Heavy presence of spurious and hazardous pesticides and unsafe use of pesticides, non-adoption of IPM and other recommended pesticide use technology packages for decades have ruined the entire pesticide system in the country, resulting in colossal losses, health hazards and economic and environmental disasters. In line with the SDGs, indicators and targets should be fixed and honoured so that the Indian market and the farmers have zero access to spurious pesticides within the next three years. The technology transfer (extension and training) should be strengthened to ensure safe use of agro-chemicals along the value chain.

The Government must pass the pending latest/updated 2017 Pesticide Management Bill and strictly enforce regulations to ensure effective implementation of all the rules and laws, especially the elimination of the unethically high incidences of spurious, counterfeit, banned, misbranded and substandard agro-chemicals. The farmer's protection mechanism in case of spurious products must be strengthened. Transparent system of licensing should be established and popularized. As the bill seeks to improve the regulations in the manufacture, inspection testing, and distribution of pesticides, a Central Pesticides Board to advise the Government should be constituted, which among other things, should also oversee fixation of tolerance limits by Food Safety and Standards Authority of India (FSSAI) for pesticide residues on crops and commodities. The state governments are envisioned to implement the provisions. While FSSAI is mandated to fix the MRL, the relevant provisions of the Food Safety and Standard Acts should be enforced simultaneously.

1.4.12 Agro-biodiversity and Farmers Rights Management for Sustainable Development

As highlighted in chapter 11, the accelerated erosion of agro-biodiversity and its negative impacts on ecosystem services are threatening productivity and sustainability of agriculture and food systems. Agrobiodiversity associated with a large number of neglected and underutilized species (NUS), several land races and wild relatives of cultivated species is fast disappearing, thus closing our options for diversification for nutritional and pharmaceutical resources. NAAS, as also strongly advocated by FAO, has strongly commended use of NUS, often called as orphan species, as Future Smart Food (FSF) to fight hunger, malnutrition and poverty. These crops, which enrich dietary diversification and micro-nutrient intake, are also generally climate resilient and agro-eco-friendly. Of the several NUS, based on soil, water, and ecological compatibility, the most potential species, complementing the existing staple crops, should be identified for each zone and the AFS should be evolved along the value chain – production, processing, marketing, and consumption of FSF for judiciously harnessing the bio-treasure. Accelerated collection and conservation of these species must be accompanied with their judicious characterization and evaluation, especially for nutritional, pharmaceutical and climate resilience traits, to harness their multiple benefits.

Urgent actions are needed to arrest the erosion. Most importantly, it has been highlighted that the progress in judicious conservation and benefit sharing has been slow. Having taken the leadership in establishing the national PPV&FR Authority and the National Biodiversity Authority (NBA) and the corresponding Acts, most of the developing world has been looking towards India for sustainable models for biodiversity conservation, management, use, and realizing the Farmers Rights, which is still a far cry. Asymmetries between PPV&FRA and NBA should be ironed out and the two authorities should be harmonized. The project module suggested by the NAAS should be implemented to actualize the Farmers' Rights.

1.4.13 Science, Technology and Innovation as Main Drivers of the Needed Transformation

Science, technology and innovation are key drivers for empowering individuals, societies and nations to meet the challenges, and richness of this continuum will underpin competitiveness at various levels in this fast expanding knowledge economy era. Launching the Technology Vision 2035 document at the 103rd Indian Science Congress, January 03, 2016, Hon'ble Prime Minister Shri Modi had said "India will be the country of young for the next few decades. It is imperative that every youth blossoms to his/her full potential and that the potential is fully tapped for the benefit of the nation". He added that this in turn requires that needs of our children and youth for nutrition, health, knowledge, skill, connectivity, and identity are met, and all stakeholders should actively work for fulfilling the Vision.

Trilochan Mohapatra, Secretary DARE and DG, ICAR recently (February 2019) revealed that the Government of India and ICAR are proposing several innovative technologies and policy pushups to ensure that India remains self sustained as far as food production is concerned. Convergence of agriculture, digital and engineering technologies with modern biotechnological tools would revolutionize the Indian agriculture in coming years. However, we need to enhance investment in agriculture for sustainable increase in production and productivity with enhanced inputs and resource use efficiency. He emphasized that India's population would touch 1.7 billion by 2050 and ensuring food and nutritional security for such a large population would be a great challenge. Use of technology and innovation in Indian agriculture would only be the way out. All out efforts have to be a made on generation, transfer and adoption of technologies during coming two decades. ICAR's vision for the future is to encourage "SMART FARMS" with greater technological support to reduce post-harvest losses, strengthen value chain, and provide markets to increase farmer's income. Agriculture being the main driver of livelihood and economic security of the masses, we need to regularly innovate, invest and support to strengthen agricultural research and development in the country.

The quality and relevance of agricultural research must be enhanced to bring within its domain cutting-edge technologies like biosensors, genomics, biotechnology, nanotechnology and alternative energy sources. For instance, biotechnology, encompassing wide range of technologies such as cloning, marker assisted selection, transgenics, gene editing and veritable 'omics' should judiciously be used for augmenting tolerance/resistance to biotic and abiotic stresses, improved nutritional quality, enhanced physiological efficiency, nutrient use efficiency, and bio-products. Recent developments in genome editing have far reaching implications for future agricultural and food systems.

Central and State Governments, in the spirit of cooperative federalism, must develop science-informed policies (science for policy making) and institutions to enable the best of science, technology and product to quickly reach the farmers and other users along the value chain. Appreciating that unsafe food is no food, we must ensure that safe, nutritive, quality, and cost-effective food is not denied to reach the hungry in time. Unfortunately, this is not happening in India, particularly in case of several biotechnological products. Emotions, unfounded fear and un-scientific personal belief have shrouded science-based objective facts, which are referred to as 'post truth' – our policy makers should particularly commit themselves to scientific truth.

1.4.14 Innovations for Transforming Agriculture

It need hardly be over emphasized that for feeding 1.7 billion by 2050 from ever shrinking land, water and biodiversity resources, More from Less for More will need innovations and innovative approaches. Frontier Biological Innovations (Green Revolution, Gene Revolution, Innovative Biofortification, Speed Breeding, and Innovative Food Fortification), renewable energy, and Innovative Viable Solutions to Rice Residue Burning in Rice-Wheat Cropping System should be judiciously scaled-up (chapter 12). The way forward is to strengthen innovation drives, leveraging agritech startups in India's Innovation Ecosystem, and Atal Innovation Mission.

1.4.15 Precision Agriculture: Need of the Day

Defined as a system, chapter 13 brings forth that precision agriculture exploits all the modern tools and technologies (nanotechnology, genetic engineering, Cloud Computing etc), innovations, Artificial Intelligence etc. leading to economically improved and environmentally sustainable agriculture - an Evergreen Revolution. The role of precision agriculture for the majority smallholder farmers is manifested through (i) increased land and labour productivity, (ii) intensification, diversification and off-farm employment, (iii) granting property rights, entitlements and land rights, and (iv) balanced agro-ecological settings compatible with minimum risk. In particular, roles of information technology as the backbone of precision agriculture, and of geospatial technologies such as GPS-based soil sampling, drones, robotics, and sensors etc. as framework support are immense. It may be reiterated that "doing the right thing at the right place at the right time" to ensures high efficiency and sustainability are the "watchwords" for Doubling Farmers' Income.

1.4.16 Renewable Energy for Sustainable Agricultural Growth

Agri-food systems use about 30 per cent of the global energy supply relying heavily on fossil fuel and contribute about 20 per cent of the greenhouse gas emissions. The agri-food system thus must become "Energy Smart" as well as "Climate Smart". Accordingly, FAO (2012) had recommended establishment of a major long-term multi-partner program based on three pillars – (i) improving energy efficiency in agrifood systems (ii) increasing the use of renewable energy in these systems, and (iii) improving access to modern energy services through integrated food and energy production. Needless to assert, this will improve productivity in the food sector, reduce energy-poverty in rural areas and contribute to achieving goals related to national food and nutritional security, and climate change and sustainable development.

Renewable energy has been an important component of India's energy planning process under the Ministry of New and Renewable Energy (MNRE), perhaps the first of its kind in the world. Given the increasing prices of fossil oil, the share of renewable energy in the total national requirement must be enhanced rapidly. The XIIth plan had flagged "Securing the Energy Future" as a major challenge, and sought fortification of research and development t o render solar, wind, water, biomass residue and agro-waste as major sources of renewable energy.

Hon'ble Prime Minister Modi highlighted India's commitment to reducing global warming, International Solar Alliance, and Coalition for Disaster Resilience Infrastructure (CDRI) at the 74th UNGA on September 26, 2019. Addressing the International Solar Alliance first Assembly in Delhi on 2nd October 2018 (149th birth anniversary of Mahatma Gandhi), PM Modi underpinned the Alliance as "One World, One Sun, One Grid" to propel "poverty to power" and to ensure climate justice. By 2030, India should meet 40 per cent of its energy requirement from renewable resources. The Ministry of New and Renewable Energy, in collaboration with all concerned ministries, the states, and international alliances/agreements, must ensure judicious implementation of all the action plans and programs, including the 12 recommendations made in chapter 14.

1.4.17 Comprehensive and Reliable Data Bank and Knowledge Platforms to Reshape India

In a country of our size and magnitude with varying agro-climatic situations, we need a centralized agriculture data base on a variety of issues that are of interest to scientists, farmers, and industry. Through such an arrangement, in line with the Big Data movement, the data can be easily accessed by one and all. Satellite imagery should become a regular feature for data collection for future prediction of produce and price. It is extremely important to use modern information and communication systems for marketing, sales and pricing activities, e-NAM, to move with the time. Such developments will be intellectually attractive to the youth and should help increase their interest in agriculture and food systems.

The digital India movement, the PM's remarks that "Data is the New World" on September 22, 2019, at "Howdy Modi" celebration in Houston, and the highest cost-effectiveness of data packs in India, renders the country as the global data hub and offers uncommon opportunities to the young minds to benefit both economically and scientifically. The data mines should, however, not mean only cold numbers, but the faces behind those numbers are to be read properly and cared for. Thus, the digital revolution should greatly enhance translational abilities of veritable stakeholders in planning, programming, and implementation with human face in mind.

Within the framework of the Sustainable Development Goals, monitoring progress towards a Zero Hunger and prosperous India should become a priority activity, and should provide an analysis of the underlying causes and drivers of observed trends. While prevalence of undernourishment is the commonly used indicator for hunger, assessment of the prevalence of severe food insecurity based on the "Food Insecurity Experience Scale" (FIES) introduced by FAO in 2017, provides an estimate of the proportion of the population facing serious constraints on their ability to obtain safe, nutritious, and sufficient food. As this indicator is extremely helpful in identifying the hungry individuals and communities, India should adopt it quickly to direct its effort in a disaggregated and more targeted manner. The Data Bank and Cloud Computing systems must help in designing more sensitive and relevant indicators and provide the necessary feedback of the outcomes and trends emerging from such indicators.

1.4.18 Artificial Intelligence

Comprehensive and reliable data resources are conducive to augment Artificial Intelligence, defined as intelligence exhibited by machines, can be applied cross disciplines and can bring a paradigm shift in how we see farming today. More specifically, by using artificial intelligence, we can develop smart farming practices to minimize losses along value chain and maximize outputs and farmers' income. Using artificial intelligence platforms, one can gather large amount of data from government and public websites or real time monitoring of various data is also possible by using IoT (Internet of Things) and then can be analyzed with accuracy to enable the farmers to address all the uncertain issues faced by them in the agriculture sector.

AI-powered solution will not only enable farmer to do more with less, it will also improve quality and become the major driver for providing the Digital solutions to uplift the conditions of farming community while providing yet a new opportunity for business and entrepreneurs by enabling smart farm as a service, and help in identifying most suited farming system for specific locations. AI can also be used for precision high throughput plant phenotyping in controlled and field experimental conditions and also for Precision Farming using all latest sensors both on ground and UAV platform. This technique can extensively be used also for monitoring crop residue burning and occurrence of drought at district level.

1.4.19 Gene Revolution for Agricultural Transformation

Innovations in the field of biotechnology, molecular biology, genomics, and synthetic biology have rendered crop, livestock, fish and microbe improvements highly precise, targeted, and accelerated – known as gene revolution. Starting from hardly 2 million ha under GM crops in 1996, today nearly 200 million ha in over 30 countries, of which over 20 are developing countries, including China and India, grow GM crops. During the past 20 years or so, farmers gained from increased productivity and production and reduced cost of production to the tune of nearly US$ 160 billion at the farm level, let alone the huge environmental gains due to reduced pesticide use.

Innovations to promote genomics and gene editing must be priority novel approaches to ensure comprehensive food, nutritional, economic, social and environmental security (chapter 12). In the new era of genomics, phenomics, proteomics and other omics, the availability of high quality reference genomes of crop plants has accelerated the discovery of genes, QTLs and DNA markers linked to the traits of agronomic importance, which are now being routinely applied in molecular aided selection (MAS) of crop varieties for increased selection efficiency with utmost precision, heralding a new thrust area called Molecular Breeding. The genomic selection approach, which has become popular to introgress several genes with small additive effects in breeding programs, is enriched by technologies like mining superior haplotypes, haplotype-based breeding, single cell sequencing, Drop Synth technique for synthesizing large genetic libraries, and rewriting genome techniques for creating and harnessing desired genetic variability for enhanced productivity, resilience and sustainability. But, progress in the use of GM crop technology on the other hand has suffered due to the lack of clear policy, and so far Bt-cotton remains the only commercialized GM crop in India.

1.4.20 Liberate Science to Serve the Society

Baseless, ill-informed, unscientific and illogical opposition of several modern technologies, such as genetical engineering, GM organisms and other proven safe products arising from new sciences and innovations is most unscientific. The recalcitrance of the policy makers and the governments in delivering the proven safe products/technologies to the farmers and end users along the value chain amounts to denying India from achieving comprehensive food and nutritional security, climate resilience and accelerated sustainable agricultural development. Further, this trend thwarts development of cutting-edge technologies, innovations, and the development of human resources and institutions, thus hindering India to emerge as a New India. The Government must develop appropriate science-evidenced policies and action plans to transfer proven safe, productive and remunerative technologies, especially genetically enriched quality seed, to meet the social, economic and environmental needs of people, and create the necessary ambience to ensure uninterrupted generation and use of new technologies to help meet our goals.

NAAS has issued several guidelines and policy options for developing and commercializing transgenics and other biotech products. These include the NAAS Policy paper 52 "Biosafety Assurance for GM food Crops in India", 2011; Policy Brief "to Accelerate Utilization of GE

Technology for Food and Nutrition Security and Improving Farmers' Income", 2016; and the Declaration on Transgenic Mustard (chapter 15). These recommendations have been widely circulated in the country and outside and specifically brought to the attention of the Government. The baseless fear, emotion and non-scientific considerations continue to deny the farmers, consumers, and other stakeholders the disruptive technologies and innovations, which will sustainably transform their socio-economic status.

Seventeen noted Indian biotechnologists, in their most recent joint paper entitled India needs genetic modification technology in agriculture, Current Science, August 2019, have emphasized that "it would not be appropriate to discard the technology based on propaganda without a scientific basis. One needs to assess the technology and products rationally on a case-to-case basis and adopt the most appropriate ones. Given the task of adequately feeding 1.7 billion by 2050 in face of the shrinking natural resources and aggravating climate change, India must employ and adopt genetic modification technologies for improved agricultural productivity and profitability, and contributing to sustainable food and nutrition security. Ambivalence and indecision will hurt us deeply, and ultimately the country would be the loser."

1.4.21 Transforming Agricultural Education

It is well known that globally education, research, and extension systems, particularly in agriculture and food systems, have been instrumental in bringing transformational changes in a dynamic mode to ensure livelihood security for all for all times. Yet, the system suffers from the following shortcomings, among others (i) Inadequate and declining investment and financial resources in agricultural universities/colleges; opening of new universities without matching resources; unmindful splitting of agricultural universities, and poor resources planning; (ii) Disconnect among agricultural education, employment, and industries' requirements; lack of adequate skill, entrepreneurship and experiential learning; overall poor employability of the graduates; (iii) Extensive inbreeding and associated depressions; low access of agricultural education to rural students, especially to the tribals and socially-deprived communities; and (iv) Lack of evaluation, monitoring, impact assessment, accountability and incentive systems (chapter 16).

Having listed the veritable challenges and issues, a question is raised whether India has the necessary quality financial and other resources, commitment and political will to lead India to be a major knowledge hub in the world geared towards an all-time Zero Hunger World? Effective implementation of the suggested policy and quality measures should render agriculture as an intellectually more stimulating discipline and an economically rewarding profession to attract talent and investment. The academic and economic legitimacy thus provided to contemporary challenges and opportunities should inspire the youth to find agriculture, agribusiness, agriculture related service sector, and the pursuit of agricultural science and technology generation as an attractive vocation, career and profession. The agricultural education and universities thus transformed will attract also foreign students and render the Government's "Study in India" initiative a great success. Splitting of the agricultural universities must be decried in the interest of multidisciplinary collaborative and multi-sectoral synergistic cost effective wholesome outcomes.

As we consolidate our efforts to build an eternally prosperous, inclusive and economically green India in face of the diminishing and shrinking natural resources, intensifying volatilities of climate change, and increasing market uncertainties and global competitiveness, we will need new breeds of human resources geared to meet the demand of New Agriculture. Among other things, our students and young scientists should have greater appreciation of global resources systems; green studies; sustainability, and environment; entrepreneurship; student READY; Big Data; knowledge platform and communication; and of food, nutrition, health, education, and agriculture nexus – New Normal. Besides being professionally competent, our graduates and scientists must also be socially sensitive and ethically strong to build New Agriculture and Food System for a New India.

1.4.22 Investing in Agriculture-Food Systems with Special Reference to Research, Education, and Extension

Globally, studies have shown that in agriculturally important countries, like India, growth in Agriculture and Food System (AFS) is almost three times more effective in alleviating hunger, poverty and undernutrition than analogous growth in other sectors. Being the second largest agrarian economy in the world, India must harness its AFS effectively to break the enigmatic co-existence of high economic growth and the deprivations.

Public sector investment has been instrumental in creating infrastructure and support services to promote agriculture-led development. During the Green Revolution, public sector investment, being 33 per cent of the investment in agriculture sector in 1985, was the main driver of the Revolution, but now it has reduced to only 17 per cent. In absolute terms, the real agricultural investment during the year 2016-17 was 2.6 lakh crores accounting to about 2.2 per cent of GDP. The remaining 83 per cent of the investment has come from the private sector, primarily by farmers. The contribution of the corporate sector is hardly 2 per cent. The investment capacity of the majority smallholder marginal farmers being low, public sector investment in the regions crowded by such smallholders *viz.* eastern and north-eastern regions, should be substantially enhanced. The level and scale of public investment has direct impact on overall GDP growth. Hence, the public sector investment should steadily be enhanced to accelerate the overall GDP growth rate, which will directly help in increasing farmers' income. The corporate sector must be boosted to strengthen R&D, inputs supplies like quality seeds, agrochemicals, machinery, processing, and value addition. The recent initiatives of the Government related to Make-in-India, even upto 100 per cent FDI, tax reliefs for small scale enterprises have huge scope in the agricultural sector.

Technology being the main driver of productivity and income enhancement, investment in agricultural research, education and extension must match with that potential, opportunities, and prospects. The total R&D budget of the nation, covering all sectors, in 2014-15 was Rs. 35034 crore. Of this, 11.37 per cent ie. Rs. 3983 crore was allocated to the ICAR. Despite increasing allocation to agricultural sciences and technology in recent years, being Rs. 13,786 crore in TE 2017-18, India's agricultural research intensity is only 0.37 per cent, as compared to 0.62 per cent in China, 1.82 per cent in Brazil, 2.0 per cent in South Africa, 3.2 per cent in USA, and 3.3 per cent in Australia. Both Centre and States have contributed almost equally to R&D funding, despite agriculture being a state subject. The financial status of most SAUs is deplorable. Further, there is large inter-state variation, research intensity being as low as 0.1 per cent in UP, the largest agricultural and food producing state with more than 85 per cent of its farmers being small and marginal. For the last two decades, NAAS, as several other concerned organizations, have been pleading for doubling the national research intensity, taking it to about 1 per cent.

The recent heightened attention to agriculture is reflected in the increased budgetary allocations to agriculture. For instance, the major highlights of the Budget 2018-19 are as below:

- Finance minister announced raising institutional credit for agriculture sector to Rs. 11 lakh crore in 2017-18
- Facility of Kisan Credit Cards extended to fisheries and animal husbandry farmers to help them meet their working capital needs; Rs. 10,000 crore funds announced cumulatively for infrastructure development in the two sectors
- Rs. 500 crore 'operation greens' announced to address price volatility of perishable commodities like potato, tomato, and onion and benefit both producers and consumers
- Rs. 200 crore allocated to support organized cultivation of highly specialized medicinal and aromatic plants and associated industry
- 22,000 rural haats to be developed and upgraded into Gramin Agricultural Markets (GrAMs) for farmers to directly sell to consumers and bulk purchasers
- Rs. 2,000 crore fund to be set up for developing and upgrading agricultural marketing infrastructure in the 22,000 GrAMs and 585 APMCs
- Doubling allocation for food processing sector to Rs. 1,400 crore, government to promote establishment of specialized agro-processing financial institutions
- Rs. 1,290 crore re-structured national bamboo mission announced to promote bamboo sector in a holistic manner
- Special scheme to be implemented to support Haryana, Punjab, Uttar Pradesh and the Delhi to address air pollution and to subsidize machinery required for *in-situ* management of crop residue.

The recent Report on Policies and Action Plan for a Secure and Sustainable Agriculture, prepared by an expert committee Chaired by Dr. R.S. Paroda submitted to the Principal Scientific Adviser to the Government of India (30 August, 2019), has internalized several of the policy options and strategies elucidated by the NAAS. New strategies suggested in the Report emphasize the efficacy of efficiency, inclusiveness, ecology, innovative institutions, public-private partnership, and higher public investment. Towards enhancing farmers' income, focus should be on pre- and post-harvest management, value addition and diversification. Further, the centrality of harnessing science, technology and innovations alongwith policy reforms and blending of farm household priorities with national and global development agenda have been underpinned. The Report thus augurs well with NAAS's effort.

The food and agriculture system must be transformed coherently and synergistically by concerned Ministries and Departments so that the related development should not mean only enhanced production, instead it should mean production plus plus, with equal emphasis on remunerative net income of the farmer, ecological efficiency, environmental health, nutritional adequacy, inclusiveness, and sustainability. In the fast expanding liberalized economy and the changing global context, the concerned Departments and Stakeholders have to urgently comprehensively conceptualize the agriculture development process and our efforts should be multisectoral, wholesome and integral.

1.5 Policies for Farmers

The National Commission on Farmers, Ministry of Agriculture, Government of India, 2006, had prepared Polices for Farmers, first of its kind in the world, as reproduced below.

1.5.1 Ten Major Goals of the Policy

- To improve the economic viability of farming by ensuring that farmers earn a "minimum net income", and ensure that agricultural progress is measured by the advance made in improving that income
- To mainstream the human and gender dimension in all farm policies and programmes and give explicit attention to sustainable rural livelihoods
- To complete the unfinished agenda in land reforms and to initiate comprehensive asset and aquarian reforms
- To develop and introduce a social security system and support services for farmers
- To protect and improve the land, water, biodiversity and climate resources essential for sustained advances in the productivity, profitability and stability of major farming systems by creating an economic stake in conservation
- To foster community-centred food, water and energy security systems in rural India and to ensure nutrition security at the level of every child, woman and man
- To introduce measures which can help to attract and retain youth in farming by making it both intellectually stimulating and economically rewarding, by conferring the power and economy of scale to small and marginal farmers both in the production and post-harvest phases of farming
- To strengthen the biosecurity of crops, farm animals, fish and forest trees for safeguarding both the work and income security of farmer families, and the health and trade security of the nation

- To restructure agricultural curriculum and pedagogic methodologies for enabling every farm and home science graduate to become an entrepreneur and to make agricultural education gender sensitive
- To make India a global outsourcing hub in the production and supply of the inputs needed for sustainable agriculture, and products and processes developed through biotechnology and Information and Communication Technologies.

1.5.2 Definition of Farmers

For the purpose of this Policy, the term "farmers" will refer to both men and women, and include landless agricultural labourers, sharecroppers, tenants, small, marginal and sub-marginal cultivators, farmers with larger holdings, fishers, livestock and poultry rearers, pastoralists, small plantation farmers, as well as rural and tribal families engaged in a wide variety of farming related occupations such as apiculture, sericulture and vermiculture. The term will include tribal families sometimes engaged in shifting cultivation and in the collection and use of non-timber forest products. Farm and Home Science Graduates earning their livelihoods from crop and animal husbandry, fisheries and agro-forestry will have their rightful place in the world of farmers and farming. The gender-specific needs of women in each category will also be recognized.

1.5.3 Public Policies for Sustainable Livelihoods of Farmers

i. A National Land Use Advisory Service should be immediately established and linked to State and Block Level Land Use Advisory Services on a hub and spokes model. These can be virtual organisations with the capacity to link land use decisions with ecological, meteorological and marketing factors on a location and season specific basis. They should provide proactive advice to farmers on land use. Land use decisions are also water use decisions and hence it is important that the proactive advice is based on both an estimate of likely water availability and the opportunities available for enhancing income per unit of water.

ii. The MSP should be at least 50 per cent more than the weighted average cost of production. The scope of the Minimum Support Price (MSP) programme should be expanded to cover all crops of importance to food and income security for small farmers. Arrangements should be made to ensure MSP at the right time and at the right place, particularly in the areas coming within the scope of the National Rainfed Area Authority. Also, advice to farmers on crop diversification should be linked to the assurance of MSP. Small farm families should not be exposed to administrative and academic experiments and gambles in the market.

iii. A Market Price Stabilisation Fund should be established jointly by Central and State Governments and financial institutions to protect farmers during periods of violent fluctuations in prices; as, for example, in the case of perishable commodities like onion, potato, tomato.

iv. An Agriculture Risk Fund should be set up to insulate farmers from risks arising from recurrent droughts and other weather aberrations.

v. The scope of Agricultural Insurance Policies should become wider and should also cover health insurance, as envisaged under the Parivar Bima Policy. Seed Companies should provide insurance in the case of GM crops.

vi. A Food Guarantee Act should be formulated and enacted. Farmers, who are also the largest consumer group, will produce more if there is greater consumption and consequently greater demand for farm produce and products. Such an Act that combines the principal features of Food for Work programmes and the National Employment Guarantee Programme would help make food serve the role of currency. Such a procedure will help improve household nutrition security as well as farmers' income.

vii. A well-defined, pro-farmer and pro-resource poor consumer Food Security Policy is an urgent necessity. Food security with home grown foodgrains can alone eradicate widespread rural poverty and malnutrition, since farming is the backbone of the livelihood security system in rural India. This will enable the Government to remain at the commanding height of the national food security system. Building a food security system and containing price rise with imported foodgrains may sometimes be a short term necessity, but will be a long term disaster to our farmers and farming.

viii. The time has come for the Government to set up a multi-stakeholder National Food Security and Sovereignty Board chaired by the Prime Minister with its membership including the Minister for Agriculture and Food and other concerned Ministers of GoI, the Deputy Chairman of the Planning Commission as well as a few Chief Ministers of food surplus and deficit States, leaders of all national political parties, a few experts including specialists in the gender dimension of agriculture and food security, and mass media representatives. We are confronted with the need to conserve prime farmland and to safeguard the food security requirements of both resource poor farmers and resource poor consumers. The bulk of such resource poor consumers are small or marginal farmers and landless agricultural labour in unirrigated areas. It is these linkages which need to be understood and attended to. The proposed National Food Security and Sovereignty Board can attend to these complex linkages in a holistic manner and provide policy guidelines for developing and implementing a socially and economically sustainable food security programme catering to the interests of all regions of the country and all sections of our population.

ix. Farm families should also be protected from becoming victims of HIV/AIDS and tuberculosis (TB). Anti-retroviral drugs should be made available in villages free of cost. Also the approach to the treatment of HIV/AIDS and TB in villages should be a food cum drug based one. Nutrition support to rural families affected by HIV/AIDS, TB, malaria and leprosy is needed to assist in recovery and restoration to a productive life. There is evidence to suggest that a pure drug based approach alone is not adequate to help economically underprivileged rural women and men recover from diseases involving prolonged treatment. The foodgrains allotted to such a programme can be distributed through the normal channels on the production of a Food Coupon issued by the appropriate government agencies. For example in the case of HIV/AIDS, the National AIDS Control Organisation (NACO) would be the appropriate agency for the issue of food coupon to children, women and men affected by this debilitating and killing disease. The Food-cum-Drug based approach to healthcare should become an integral part of the National Rural Health Mission.

x. There is need for a Rural Non-Farm Livelihood Initiative for rural areas. The initiative could have as its core a more market oriented and professionalized KVIC and a restructured and financially strengthened SFAC and bring all rural non-farm employment programmes together in order to generate convergence and synergy among them. The initiative should be integrated with on-farm employment generation through a pan-GoI programme to establish 'Rural Business Hubs' on the lines of China's Township and Village Enterprise (TVE) programme. A consortium approach involving the different agencies concerned is needed.

xi. An Indian Trade Organisation (ITO) should be established to help the Government to operate a Livelihood Security Box and link global policies with local action in a manner beneficial to farmers.

xii. Since agriculture is a State subject, every State Government should set up a State Farmers' Commission with an eminent farmer as Chairperson. The membership of the Commission should include all the principal stakeholders in the farming enterprise. Such Commissions should submit an Annual Report to be placed before the respective State Legislature for discussion and decision.

xiii. Agricultural progress should be measured by the growth in the net income of farm families. Along with production growth rates, income growth rates should also be measured and published by the Economics and Statistics Directorate of the Union Ministry of Agriculture.

xiv. Article 243 G of the 11th Schedule of the Constitution (73rd Amendment) Act, 1992 entrusts Panchayats with responsibility for agriculture including agricultural extension. They will have to be empowered with the needed information, training and tools for discharging this responsibility. At the moment there are about 2,25,000 panchayats in the country. The problems facing Indian farmers are generally dealt with in an aggregated manner – i.e., taking into consideration the problems of over 100 million farming families as a whole which make them appear formidable. However, if such problems are disaggregated and dealt with by Gram Sabhas and Panchayats, location-specific problems can be attended to speedily and effectively. Therefore it is time that the provisions of Article 243 G are implemented, both in letter and spirit.

xv. There are nearly 1.2 million elected women members in panchayats throughout the country. They can play a pivotal role in improving the quality of life in villages and in areas like sanitation, drinking water, child care, early childhood education and nutrition security. They should be empowered to take up such leadership roles in rural transformation through appropriate training and capacity building opportunities. An earmarked Gram Mahila Fund should be available to them for meeting gender-specific needs.

xvi. Mass media (conventional, electronic and the internet) constitute an important pillar of our democratic system of governance. Serious famines do not occur in countries with independent mass media, since they play the role of an early warning system. The green revolution of the 1960s would not have happened, but for the enthusiastic support of the media, particularly radio and language newspapers, which not only spread a message of hope, but also took the latest information on the new technologies to villages. This aroused enormous enthusiasm among farmers resulting in a small Government programme becoming a mass movement. There is need now for spreading messages of hope and information on the agricultural bright spots of the country. In order to assist the mass media with timely and scientifically accurate information on issues relating to agriculture, food security and farmers' welfare, it will be useful to establish a few Regional Media Resource Centres, in whose management farmers, media representatives and scientists including extension personnel should play an important part.

xvii. The Ministry and Departments of Agriculture both in the Centre and States may be restructured to become Ministry / Department of Agriculture and Farmers' Welfare in order to highlight their critical role in ensuring the income and work security of over 600 million members of India's population. The change of name should be accompanied by structural changes which permit the induction of active farm women and men in senior positions in Government for specific periods and specific tasks.

xviii. We urge the Central and State Governments to consider seriously the question of including Agriculture under the Concurrent List in Schedule VII, Article 246 of the Constitution. Important policy decisions like those relating to prices, credit and trade are taken by the Government of India (GoI). Also, several pieces of legislation including the Protection of Plant Varieties and Farmers Rights Act, the Biodiversity Act, the Food Bill, etc., are administered by the GoI. Substantial funds are provided by GoI for rural infrastructure development including irrigation, village roads and markets. By placing agriculture on the Concurrent List, serving farmers and saving farming becomes a joint responsibility of the Centre and States, i.e. a truly national endeavour in raising the morale, prestige and economic well being of our farm women and men.

1.5.4 Matching National Policy with Local Diversity and Implementation

Indian agriculture is rich in diversity of soils, climate, farming systems, and resource endowments. Hence, a broad national policy will have to be tailored to suit different agro-climatic, socio-economic and socio-cultural factors. The framework for a National Policy for Farmers presented in this Report will have to be suitably adapted and elaborated to suit local realities in different parts of the country, particularly with reference to priorities in action points. State level policies can aim to convert national goals into local action. The State Farmers' Commissions could be entrusted with the task of preparing an operational plan for implementing the National Policy for Farmers on a location-specific basis.

The government has implemented some of the policies *viz*. renaming the Ministry as Ministry of Agriculture and Farmers Welfare, implementation of the MSP (CII + 50% of CII), creation of Market Price Stabilization Fund, National Food Bill, and Farmers Parivar Bima Policy etc. At times, there are gaps in implementation which should be critically analyzed and judiciously resolved.

1.6 Fostering International Collaboration

Recent changes in global landscape of Agriculture and Food Systems such as antiglobalization sentiments of some of the most developed countries, trade disputes and withdrawal of some major countries from major international agreements, *viz*. Paris Agreement, are bound to negatively impact international trade and sharing of technologies, knowledge and human resources, thus exacerbating the under-nutrition, hunger, and poverty situation. While such international developments should be internalized in national policies and programs on food and nutrition security and national prosperity, India through national efforts and international collaboration should continue to promote the humanistic approach to reach the unreached.

1.7 Emerging Issues Seeking NAAS's Attention

Some of the new and emerging thoughts contained in our recent publications could be developed into full concept papers for future brainstorming sessions and other meetings to help the Government in internalizing latest trends and aspirations. For instance, the chapter on Education (Chapter 15) has taken due notice of the recent declaration of GoI on "Study in India" and has suggested to transform the Land Grant Agricultural University System into World Grant Institutions. Towards this end, the Academy has strongly pleaded to reverse the unmindful splitting of our Agricultural Universities and disintegration of the Agricultural-Food Systems. The recent draft report on National Education Policy 2019 implicates possible abolition of DARE and is at odds with the World Grant Approach of Developing Agricultural Universities with full integration of sciences, education and extension. It needs to be examined by the Academy together with other stakeholders.

Another emerging issue is that nationalist populism is endangering global commons. Appreciating that India would account for almost one-fifth of the world's population and nearly one-fourth of the world's agricultural population, the country should emerge as a global leader to save the global commons through promoting international collaboration. The NAAS should be able to visualize global *vis-a-vis* Indian agriculture towards 2030 and prioritize the nation's plans and activities in the areas of science, technology, innovation, knowledge domains, climate smart agriculture, farmers income and welfare, common markets, natural resources conservation and equitable sharing, and communication – the commons which will catalyze and strengthen international collaboration to serve the humanity at large.

The recent promotion of Zero Budget Natural Farming System (ZBNF) and other such nonscientific moves in India need scientific scrutiny and evidence-based policy formulation. The NAAS Brainstorming Workshop on ZBNF held on 21 August 2019 discussed the issue threadbare and found that ZBNF is a myth and not a reality as it is not supported by any science-led information. Most of the experiments conducted or in progress favouring ZBNF were statistically unsound. The data from the farmers' fields could not be relied upon as each farmer had added or deleted one or more of the treatments and customized it as per his own need, resources and wisdom. The preliminary short term results obtained from ICAR institutes did not support ZBNF. It is a matter of concern as to how the NITI Aayog and the Finance Minister's recent Budget Report have endorsed the ZBNF for country-wide adoption. Considering the long term food and nutrition security and agrarian prosperity needs of the country, ICAR institutes and SAUs should scientifically verify the claims. The Government bodies should wait for the scientific results before making unfounded endorsement.

The Global Thought Report, based on FAO analysis, highlights that most developing countries, including India, are off-track in meeting SDGs1 and 2. It estimates that the climate change, especially due to increasing incidence of pests and diseases is reducing 35 trillion calories/year, enough to feed 50 million people. The Report also reiterates that by ensuring gender parity in agricultural wages, the production can increase by 20 to 30 per cent. These findings must be kept in mind while formulating policies/strategies/action plans. India had already missed the most important MDG-1, halving of number of hungry people by 2015. We cannot afford to miss the SDGs, especially SDG1 and SDG2 – ending poverty and hunger.

1.8 Institutionalize Monitoring, Evaluation and Impact Pathways Analysis

"Measure to Manage" is most crucial in India as there exists huge technology transfer gap, and several important targets stand unmet (chapter 17). Lately, several scientifically unauthenticated technologies, such as Zero Budget Natural Farming, are being advocated, whereas several scientifically proven technologies, *viz.* genomics, are being discouraged. Scientifically evidenced outlines and criteria for evaluating research, technology, innovation, and education outcomes for development are available and should be used for creation of reliable databases, cloud computing and measuring veritable main and interaction effects in a multidisciplinary holistic system for developing effective indicators and sound plans and implementation pathways, especially for assessing progress in hunger, malnutrition, income and poverty reduction and elimination. The approach must be able to determine the differentiated responsibility and accountability of all stakeholders along the value chain and timeline. It can hardly be overemphasized that monitoring progress towards achieving a New India free from hunger and malnutrition within the framework of SDGs is essential to drive the necessary structural and policy reforms - "leaving no one behind".

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Chapter 2
Major Trends of Production, Productivity, Socio-Economic, and Agro-Ecological Milieu in India's Agriculture and Food System

2.1 The Rainbow Revolution

India, through the Green Revolution process ushered in the 1960s, and followed by White, Yellow and Blue Revolutions, had witnessed unprecedented gains in agricultural and food production, registering record productions of nearly 300 million tonnes of foodgrains, 315 million tonnes of fruits and vegetables, 176 million tonnes of milk (highest in the world), and 12 million tonnes of fish, rendering India the second largest agrarian economy of the world.

As seen from Table 1 and Figure 1, the production gains have been steadily increasing during the past six decades or so. Furthermore, the coefficient of variation of production has somewhat declined despite increasing volatility of climate change, suggesting increased resilience to the uncertainties. Foodgrain production driven primarily by wheat and rice, the main Green Revolution crops, between 1951 and 2017 had increased nearly 6 times, oilseeds 6 times, cotton almost 11 times, and milk more than 10 times. Pulses production had generally remained stagnant, but due to special initiative of the Government it took off during the past three years, making the country more than self-sufficient in pulses. A similar approach/strategy is needed for oilseeds economy where the yields are still low and India is meeting global 70 per cent of its edible oil demand through imports.

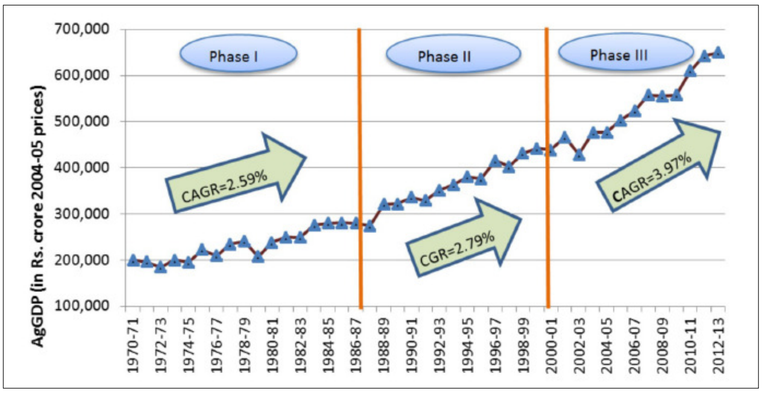
Table 1. Production of food grains, pulses, oilseeds, milk, fruits and vegetables, meat (mt) and eggs (billion).

Year	Food grains	Pulses	Oilseeds	Milk	Eggs(b)	Fruits-Veg.	Meat
1951-52	50.82	8.41	5.16	17.0	1.832	166.94*	1.9*
2016-17	275.68	22.95	32.10	165.4	18.139	299.85	7.4
2017-18	284.83	25.23	31.31	176.3	27.950	305.40	11.4

(*data for 2004-05)

Source: Agriculture Statistics, MoA&FW, GoI, 2018

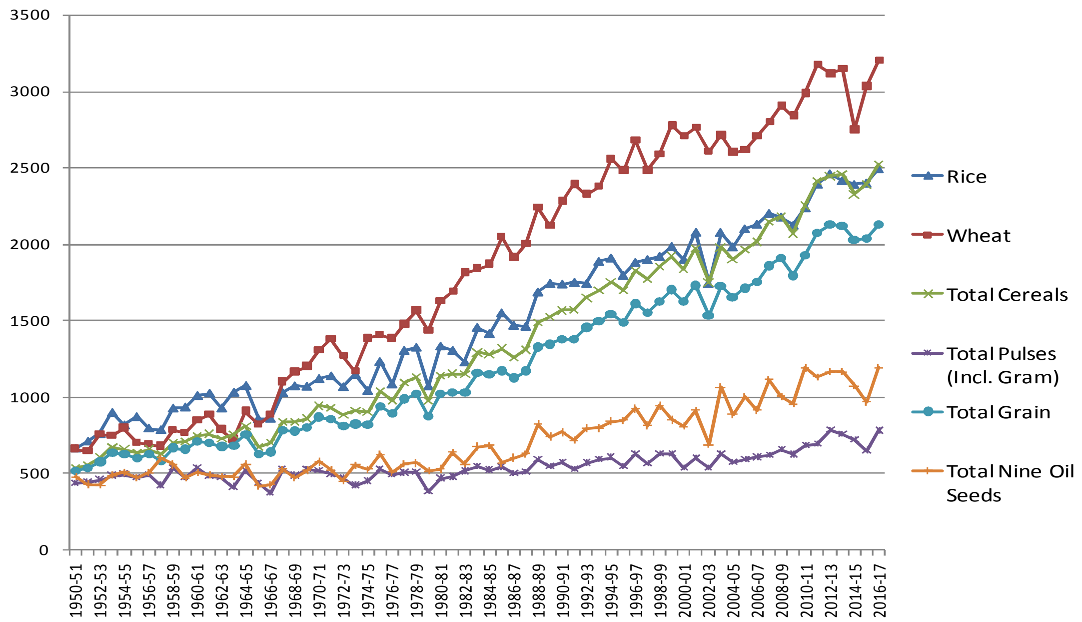
Figure 1. Growth trends in Indian agriculture



Source: Agriculture Statistics, MoA&FW, GoI, various years

The cereals yield was triggered through the large scale adoption of the semi-dwarf, input responsive, photo-nonsensitive, nonlodging , diseases resistant and widely adapted HYVs of rice and wheat – the Green Revolution varieties, and later the adoption of single cross maize hybrids (Figure 2). The production under coarse grains – sorghum, pearl millet and other coarse grains – often referred to as nutri-cereals had declined, barring Ragi in Karnataka and adjoining states. Another notable feature is that in recent years, the area under cereals has slightly declined, but the production maintained a steady trend due to steadily enhancing yield/ha (Table 2). The production gains in cotton were mostly due to the increase in yield of Bt hybrid cotton varieties.

Figure 2. Average yield (in kgs per hectare) of selected crops - India



Source: Agriculture Statistics, MoA&FW, GoI, various years

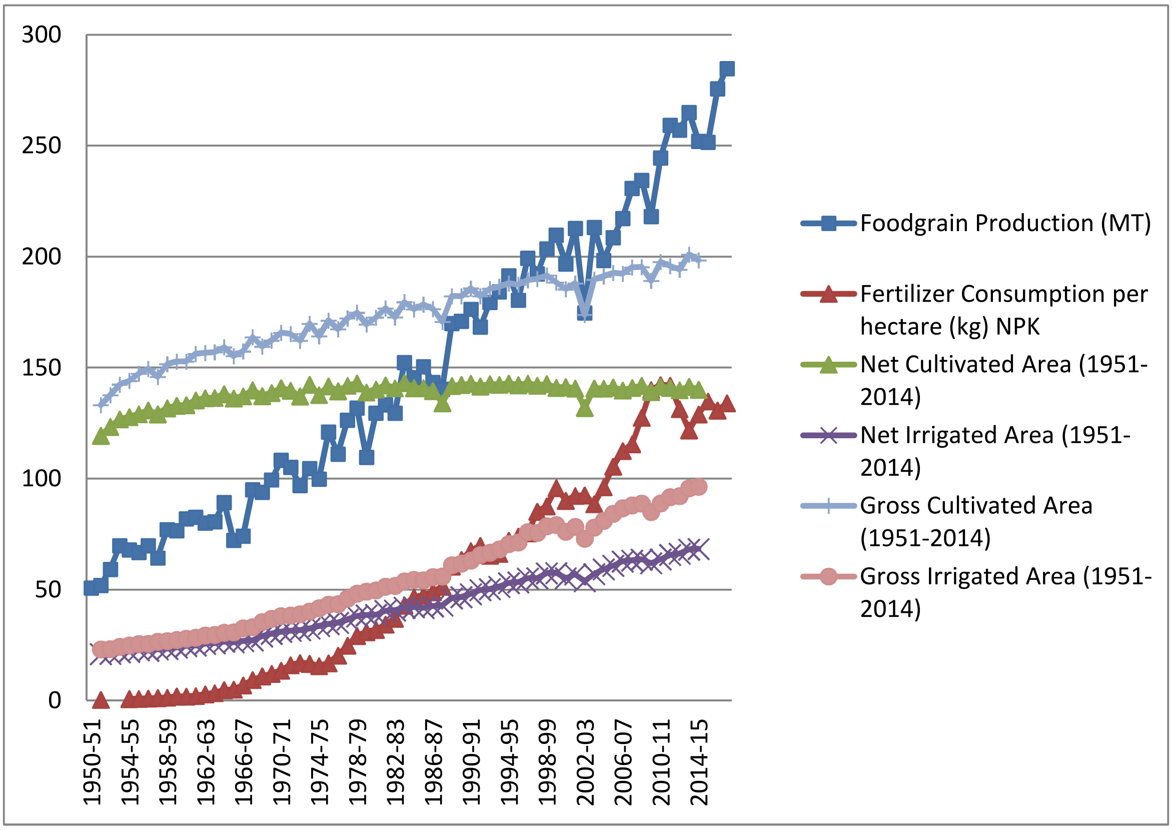
Table 2. Area and yield of cereals, foodgrains, pulses, oilseeds and cotton

Commodity	Area (m ha)			Yield (kg/ha)		
	1950-51	1990-91	2016-17	1950-51	1990-91	2016-17
Cereals	78.2	103.2	99.8	487	1318	2049
Foodgrain	97.3	127.8	127.8	522	1380	2129
Pulses	19.1	24.7	24.7	441	578	786
Oilseeds	10.7	27.2	24.2	481	771	1195
Cotton	5.9	7.4	7.4	88	225	512

Source: Agriculture Statistics, MoA&FW, GoI, various years

The overall agri-food systems production gains were due to the synergy of the increasing use of genetically improved input responsive HYV seeds, enhanced fertilizer use, expanding irrigation, and increased cropping intensity (Figure 3) (Singh, 2019). While the net cropped area remained around 140 m ha, the gross cropped area increased to nearly 200 m ha – increasing the cropping intensity to over 140 per cent. The fertilizer use increased to around 135 kg/ha, and the net irrigated area increased to about 65 mha now from 21 mha in 1950-51; and the gross irrigated area has reached 100 m ha. Ultimately a socio-economically desirable and agro-ecologically compatible cropping system should be evolved to ensure sustainable development.

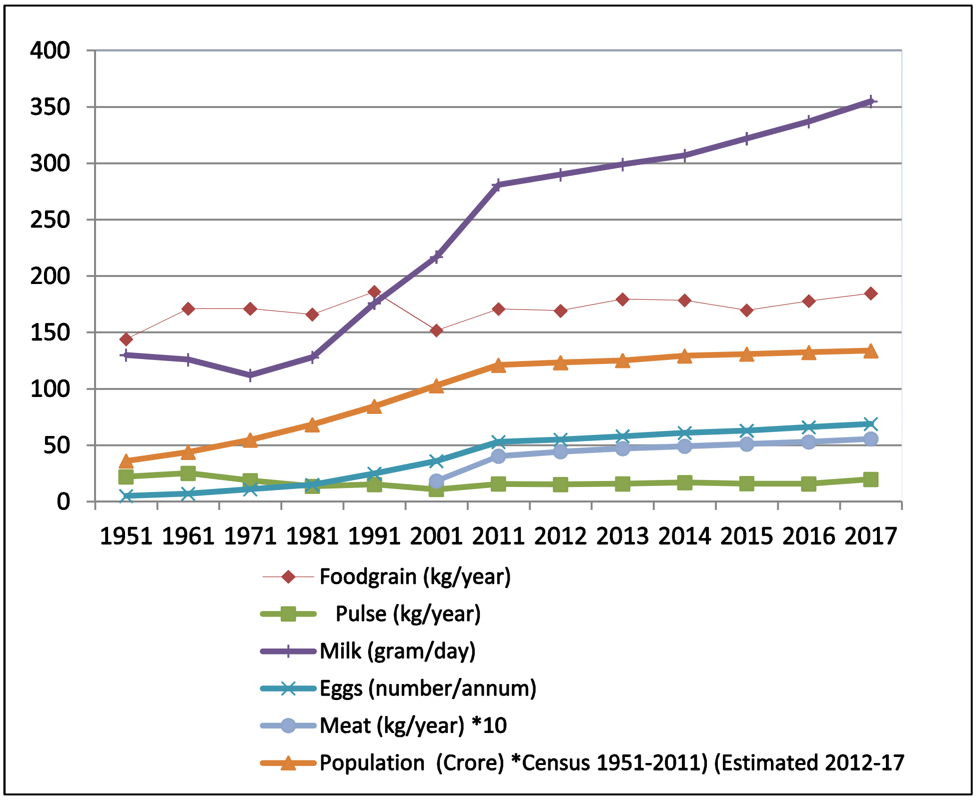
Figure 3. Food Production, fertilizer consumption and gross and net cultivated and irrigated area



Source: (FAI, 2018)

Importantly, despite the addition of nearly one billion people to India's population during the past 70 years, the per capita availability and consumption of food in the country had not only increased (Figure 4), but also the country had become a major exporter of foodgrains and other agricultural products. For instance, net trade of rice today is valued at US$ 6 billion per year. And, the Rainbow Revolution had more than halved the incidences of poverty and hunger in the country and transformed the nation from the state of ship-to-mouth to the state of Right-to-Food based on home-grown food. The revolution was largely due to the synergy of technologies, informed policies, services, farmers' enthusiasm and strong political will.

Figure 4. Population and per capita availability of commodities (Anon, 2017)



Source: Agriculture Statistics, MoA&FW, GoI, 2017

Production trends of major individual crops and commodities reveal that the production gains have been uninterrupted amidst the changing agri-food scenarios and the climate change, showing no signs of technology fatigue. Thus, ***the often-expressed opinion that the Green Revolution has waned is not substantiated.*** As discussed later, this continued enhanced production has occurred at a cost - the benefit-cost ratio of the increasing inputs has decreased (efficiency-loss), the depletion of soil, water, and environmental health, and increased cost of production, and lessening growth in net income of farmers. Much of this loss is essentially due to non-judicious adoption of the recommended technology packages. In order to render the Green Revolution an Evergreen Revolution, it is a must not only to adopt the proven/recommended technologies most judiciously, but also to develop and adopt/adapt new modern cost-effective, environment-friendly and high-yielding technologies and innovations (Singh, 2011). Had this path been adopted, the slopes of the per capita food availability lines would have been much steeper.

Cautioning against exploitative agriculture pursued with greed for immediate profit and production motive, M.S. Swaminathan had advocated for adoption of an "Evergreen Revolution" approach, the term he had coined to realize synergistic integration of economy, ecology and equity in perpetuity. He had pleaded that the paradox of co-existence of revolutionary technologies and poverty ought to be resolved, and had hoped that "Science for Inclusive Human Development" will be the way forward. Advocating a differentiated approach to meet the farmers needs, Swaminathan (2007) had identified three categories of farm families: first, those possessing assets like land, livestock or fishponds; second, those without the assets, who earn their livelihood through wage employment; and third, rural artisans working in the secondary and tertiary sectors of the economy. Accordingly, a three pronged strategy was suggested consisting of: (i) improving the productivity of natural resources, (ii) converting unskilled agricultural labour into skilled entrepreneurs, and (iii) organizing market driven non-farm enterprises and enhancing skills of the families involved in these sectors.

2.2 Unethical Persistence of High Incidences of Hunger and Poverty - the Indian Enigma Had Persisted Long, but Poverty is Now Declining Fast

While India registered an unprecedented increase in food production during the past 20 years, of the world's 821 million undernourished people in 2017, 196 million, more than 16 per cent of the world, were from India (Table 3). As regards poverty, the high overall economic growth rate of 7 to 8 per cent during the past 10 to 15 years has finally started trickling down to the lower levels. The multidimensional poverty index (MPI) (not 1.9 $ a day criterion) released on September 20, 2018 by UNDP and Oxford Poverty and Human Development Initiative (OPHI), states "In India 271 million people moved out of poverty between 2005/06 and 2015/16. The poverty rate here has nearly halved, falling from nearly 55 per cent over the 10-year period. Over half of all multi-dimensionally poor in India live in the four poorest states – Bihar, Jharkhand, Uttar Pradesh, and Madhya Pradesh, accounting for 196 million MPI poor people."

In Asia and the Pacific Region food insecurity and malnutrition are at odds with the Region's high economic growth. Progress towards SDG2 & other goals are unsatisfactory. In fact, in recent years, the rate of hunger reduction has slowed down. Poverty and inequity reduction is slow, especially in rural areas which housed over 80 per cent of the poor in South Asia. Thus, agriculture, despite its decreasing share in GDP, should continue to get high attention for development.

Table 3. Number of undernourished people, 2017 (million)

Geographic entity	Number of undernourished people	Number of children under 5 wasted	Number of children under 5 stunted
World	821	51	151
India	196	26	47
China	125	1.6	6.9
Asia	515	35	84
Africa	257	14	59

Source: FAO, The State of Food Security and Nutrition in the World, 2018

2.3 Agriculture and Food Systems to Break the Enigma and to Help Achieve the Sustainable Development Goals (SDGs)

As mentioned earlier, in agriculturally important countries, like India, growth in Agriculture and Food System (AFS) is almost three times more effective in alleviating hunger, poverty and undernutrition than analogous growth in other sectors. In order to maintain the climb town of poverty and hunger, India must register an over 4 per cent growth rate in agri-food systems. Having already attained the desired food production level, now with the emphasis on DFI and alleviating the glaring inequity between farmer and non-farmer income, we have to redefine our agriculture development strategy as proposed by the DFI Committee (Dalwai Report 2018) "to generate both food and raw material, to meet the requirement of modern society for feed, fibre, fuel and other industrial uses, and in a manner that is sustainable and aims to bring economic growth to farmers." In order to impart a more robust and comprehensive mandate to the agriculture sector, the Report suggested as below:

a) Agriculture has the moral responsibility of meeting food and nutritional security of the country in consonance with the agro-ecological backdrop
b) It has to generate gainful employment resulting in income gains to make the farmers more economically secure
c) It has to generate raw material that will directly support agro-processing of food and non-food products to support secondary agriculture
d) It has to support agro-processing industry to produce primary and intermediate goods, which will feed the manufacturing sector
e) Agricultural practices need to be on a sustainable basis.

Analogous suggestions were also made by NAAS in its policy papers and its recent Congress discussing agricultural transformation to attain the SDGs. Towards these goals NAAS had also emphasized equality and equity and women empowerment.

Being the second largest agriculture economy in the world, India must harness its AFS effectively to break the enigmatic co-existence of high economic growth and the deprivations (an infamous Indian Enigma). The food and agriculture system must be transformed so that the related development should not mean only enhanced production, instead it should mean production plus plus, with equal emphasis on remunerative net income of the farmer, physical and economic access to adequate quality food, safe drinking water, sanitation and hygiene, ecological efficiency, environmental health, nutritional adequacy, inclusiveness, and sustainability, seeking a wholesome and integral approach – the cherished Sustainable Development Goals.

The projected production growth shows that towards the year 2030 the trend will be maintained and supply will mostly exceed demand, resulting in sizable exportable surplus, except in case of edible oils. As regards pulses, having already produced nearly 25 million tonnes during 2018-19, India will have surplus pulses production in 2030 (Table 4). The challenges in future will thus be to achieve these gains with enhanced input use efficiency and equitable economic and social access to adequate nutritious food, and the "cost-risk-return" structure of farming must be significantly improved in face of the increasing volatilities of climate change and markets.

Table 4. Supply - demand gap of foodgrain and high value commodities in 2030

Commodities	Supply	Demand	Gap (+/-)
Rice	122.1	122.4	-0.3
Wheat	128.8	114.6	14.2
Coarse cereals	64.2	47.2	17.0
Pulses*	23.7	26.6	-2.8
Foodgrain	338.8	310.8	28.0
Sugar	40.3	39.2	1.1
Edible oils	19.1	21.3	-2.1
Milk	179.4	170.4	8.8
Fish	11.9	11.1	0.8

Source: Kumar & Joshi (2016)
** To be revised based on the 2018-19 performance*

2.4 Population: By 2027 India will be Most Populous Country of the World

By 2027, India will become the most populous country of the world, housing nearly 1.4 billion people. It is projected to reach 1.52 billion by 2030 and 1.7 billion by 2050. China's population by then would have stabilized at 1.3 billion, thus India would be having 400 million more people than China in 2050.

The world population will increase from its present level of 7.4 billion to about 9.0 billion in 2050 and nearly 10 billion in 2100. This growth will be primarily driven by high population growth rates in developing countries, mostly in Africa and South Asia and Asia as a whole. It is projected that by 2100 when the world population is stabilized, more than 85 per cent of the world's people will be housed in Africa and Asia. India, one of the densest countries in the world will be housing 1.7 billion people in its land area of only 3.3 million sq/km, while China's 1.3 billion will be housed in its huge land mass of 9.6 million sq/km – India thus will be carrying about four time greater population pressure on its land resources as compared to China.

Nearly 60 per cent of India's population will be in the age group of 18 to 35, a huge demographic dividend. However, as per the current trend, the youth is generally not interested in adopting farming as a career, and out migration has been steadily increasing, adding to the poverty hubs in the cities – the preferred emigration destinations. Since generally males migrate in search of jobs leaving their families behind, the increased migration flow has enhanced feminization of agriculture. Clearly, policies should be formulated to promote decent employment and income generating opportunities, especially in rural areas, and agricultural operations should be rendered women-friendly.

In order to harness the dividend judiciously, Indian agriculture must be commercialized. A sizable part of the youth must become entrepreneurs to accelerate the overall economic growth as well as to create new jobs and enhance employment security. This should be coupled with a strong push for agricultural export and skill development. The Prime Minister, addressing the Governing Council of NITI Aayog on 15th June 2018 asked the Chief Ministers to focus on export promotion for boosting income and jobs (see chapter 8 for the prospect of entrepreneurship in India).

2.5 Climate Change: India Highly Vulnerable to CC

Climate change, the volatile fluctuation in rainfall, temperature, drought, floods, and frost are overwhelmingly impacting food and livelihood security of all. Threats of new pests and diseases and epidemics have greatly increased.

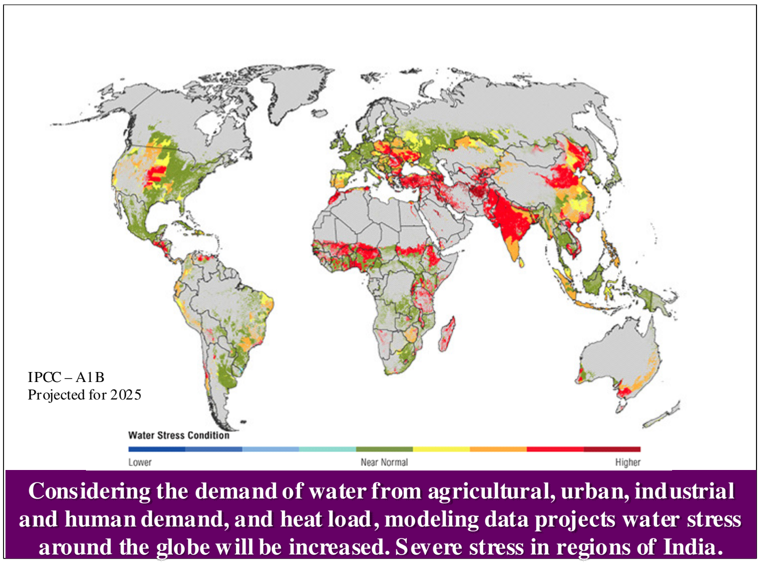
- Impacts of climate change on crop yields are already evident across several regions of the world. On an average, although some positive impacts are evident in certain areas/pockets, largely the impacts are negative, net global yields of maize and wheat will be suppressed by 4 and 5 per cent, respectively by 2050s, average yields for eight major crops in South Asia will decline by 8 per cent

- Tropical crops, livestock and fisheries are most affected by current climate change; regions of major exposure to climate change coincide with high prevalence of poverty and food insecurity. India and other South Asian countries are most vulnerable to climate change and it is this region which has the highest concentration of food-insecure people and undernourished children

- Greater exposure to climate risks increases the vulnerability of food insecure individuals and households, particularly the marginal and sub-marginal farmers. High recurrences of climate extremes, such as droughts, floods, heat, and cold waves exacerbate the vulnerability of the hungry. Intense seasonal hunger further deepens chronic hunger, nutritional insecurity, and overall livelihood insecurity.

Freshwater availability in South Asia is likely to decrease. Even the most optimistic studies indicate that agriculture in India and South Asia will be particularly hard hit by water stress by 2025 (Figure 5). During the last 130 years, the region has faced more than 26 droughts. Nearly 70 per cent of the land is drought prone, 12 per cent flood-prone and 8 per cent cyclone-prone. While frost is common in northern regions, heat is a frequent incidence at many places.

Figure 5. Future Climate Change: Water Stress



Source: IPCC

While South Asia as a whole is projected to suffer highly from the climate volatilities, India is projected to suffer the most in the world in terms of loss of agricultural productivity (Table 5).

Table 5. Projected changes in agricultural productivity from climate change at 2050

Country	per cent change
Australia	-17
Canada	-1
United States	-4
China	-4
India	-25
Brazil	-10
European Union	-4
Least developed countries	-18
Poorest are Hardest Hit by CC, India has largest no. of poor & hungry	

Source: IPCC

The Crisis Management Plan of the GoI (2012) reported that annually 50 million people are exposed to chronic drought. Sixteen per cent of India's land area is drought prone and 68 per cent of the land area sown is exposed to drought. The Southwest monsoons account for 86 per cent of rainfall occurring in 100-120 days. Thirty three per cent of land receives less than 750 mm of rainfall, and is classified as chronically drought prone. Rainfall is erratic in four out of ten years. Per capita water availability is rapidly declining due to population and urban growth, industrialization, cropping intensity and depleting groundwater. The entire country had already become water stressed in 2006. Today the per capita water availability is around 1400 m^3/year, in between the water stress and water scarcity lines. Unfavorable rainfall pattern and frequency of occurrence of extreme events such as drought and temperature events are becoming highly discernible over the years. It is estimated that 5700 sq. km of coastal area in India will be lost due to 1 m sea level rise, displacing 7.1 million people.

John Dixon (2019), at the XIV Agricultural Science Congress of NAAS, had concluded "Policy makers and science leaders need to be aware of the tight nexus between climate, agriculture and economic growth. The challenge of maintaining food security while reducing green house gas emissions was a central challenge. But the most important challenge for farmers in low income countries has been adapting to the increased variability and frequency of extreme events which are occurring. Considerable investment in Climate Smart Agriculture has created frameworks at the international and regional (e.g., South Asia) levels. Fortunately, there are a sub-set of CSA practices which foster mitigation while building resilience and adaptive capacity of farmers, *i.e.* a win-win way forward. Effective CSA implementation requires appropriate technologies, social capital, institutions and enabling policies. Because of the diversity of farming systems and seasons, big data and modelling will contribute to progress with CSA technologies. Policy makers need good targeting approaches such as the FAO/World Bank farming systems framework to optimise investments."

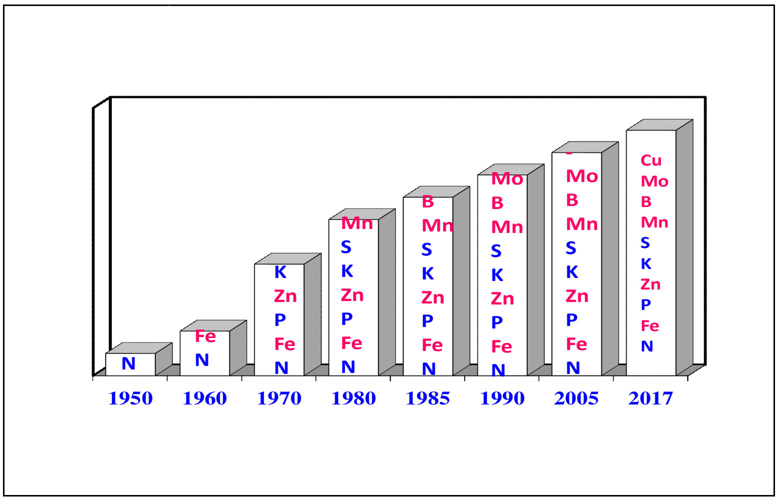
2.6 Increasing Pressure on Diminishing Natural Resources

India has been able to feed its vast population and enacted the National Food Security Act which legally empowers the population below the poverty line to be provided with the basic food requirements. But with the population expected to reach 1.7 billion by 2050, the pressure on land, water and other resources to meet its food and development needs is going to be very intense. Food and nutritional security of India is threatened by issues like severe decline in the health and productivity of the soil and water leading to decline in total factor productivity, low nutrient content in the food, poor health of the crops predisposing them to severe insect-pests and diseases, ultimately resulting in poor health of human beings and animals.

As regards share of agriculture in total production and employment will continue to decline at varying rates in different economies. While new technologies and investments are increasing agricultural productivity, the slowing growth of yield is a matter of concern. Food losses and wastes are substantial and must be reduced to lessen the pressure on production - save and grow. Moreover, the degradation of natural resources, the loss of biodiversity, increasing competition for use of the shrinking resources, and the spread of transboundary pests and diseases continue unabated.

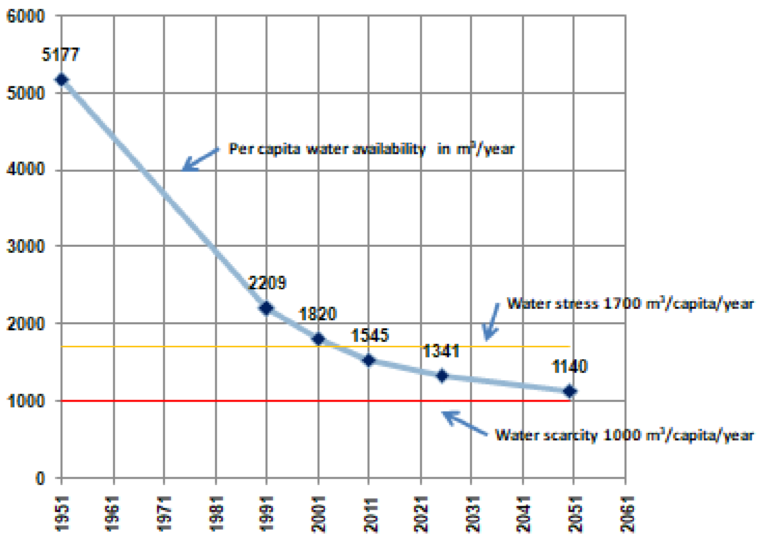
Chapters 7,9,10,11 give detailed account of state of biodiversity, soil, water, and agro-chemical resources and their sustainable use consistent with the socio-economic development. It will be noted that nutrient deficiency in our soils is ever-increasing (Figure 6).

Figure 6. Progressive expansion in the occurrence of nutrient deficiencies



Similarly, with the business as usual, per capita water availability will hit the critical level by 2051 (Figure 7), decreasing from 5171 m^3/year in 1951 to 1140 m^3 /year in 2051; 1000 m^3/capita/year means water scarcity level.

Figure 7: Change in per capita water availability since 1951.



Often the Green Revolution is blamed for the soil, water, agro-chemicals-based pollution and biodiversity loss. This is largely not true. The packages of practices recommend for different sets of varieties, the recommended balanced use of fertilizers and pesticides, the application of organic manures, integrated nutrient management, irrigation intensity, schedule, practices and infrastructure, integrated pest management, eliminating use of spurious pesticides and other agro-chemicals, and appropriate cropping and farming system practices have seldom been adopted and followed in entirety. Policy-induced inappropriate use of fertilizers and water mining are some of the main causes of the deteriorating soil health, decreasing water availability and water quality. Our weak extension services, awareness raising activities, farmer's participation in decision making, timely and affordable availability of quality resources, poor infrastructure, and highly asymmetrical social protection and support are the main causes of the natural resources degradation. The "efficiency" and "accountability" aspects are seldom respected.

2.7 Predominance of Smallholder Farmers and increased Fragmentation of Farm Holdings

India will be having one-fourth of the world's smallholder and marginal farmers. With the current trend of fragmentation of landholdings, the average farm size is expected to reach 1.1 ha by 2030 and nearly 90 per cent of the farmers will be in the marginal and smallholder category. But, they will be producing only 42 per cent of the total agri-foods. Since marginal and sub-marginal farmers comprise the majority of the rural poor and hungry (Table 6), a holistic pro-smallholder approach should be adopted for averting risks and acceleration of inequity.

Table 6. Proportion of poor and undernourished persons in different farm-size groups in rural India, 2004

Farm Size	Share of each group in total poor, per cent	Share of each group in total under-nourished, per cent
Agrl. Labourer	26.4	22.0
Marg. Farms	56.8	51.3
Small Farms	2.9	3.9
Med. Farms	1.3	2.1
Large Farms	0.4	0.6
Other Rural	12.2	20.1

Source: Kumar P, 2004

The business as usual has failed to adopt a holistic pro-smallholder approach for the entitlement to land and other production resources, acquisition of agricultural knowledge, technology generation and transfer, linking farmers with markets, enhancing their incomes, and management of climate change and risks. We need to answer the questions as to how can the requisite empowerment be accomplished, and the smallholders are enabled to accept the challenges and opportunities of new developments, such as bio-technology, informatics, and globalization? What socioeconomic policies shall facilitate the empowerment?

The land reforms and land use policies must not encourage conversion of rural poor into urban destitute. Fragmentation of farms below a certain size, say 0.5 ha, should be stopped. Land lease markets should be liberalized to promote scale of economy and to aggregate miniscule holdings. Land acquisition rules and guidelines should not only be transparent, but also be pro-poor and improve farmers' income and employment security (Singh, *et.al.,* 2002).

The potential of smallholders will be realized only when the smallholders are empowered to access the crucial resources and entitlements *viz.* land, water, energy, credit, insurance, markets and appropriate technologies. They should have opportunities to develop skills and to access the information wherewith to use them. They should be linked with functional and fair markets both for products and inputs and reduced market risks and transaction costs. Enhanced employment and income security, health care and sanitation, and education and social services will go a long way in empowering the smallholder farmers.

Small Farmer's Agribusiness Consortium of the Ministry of Agriculture could proactively develop agribusiness projects and arrange venture capital flow for development of agribusinesses in the country in association with commercial banks. Rural India will have to take a plunge in the main stream of globalization and compete globally for gaining leadership to generate wealth and job opportunities in order to remove hunger and alleviate poverty. The "Rural Business Hubs" concept of corporate sector should become a popular movement. Agri Marts, Agriclinics, Contract Farming (farmer-friendly), Agri Parks, Special Agri Zones, Farmer Producer Companies, Primary Cooperatives etc. could all become instruments of farmer-market-rural employment linkage design and strategy. IFPRI studies have shown that farmers could substantially enhance their incomes through contract farming. Government should play a facilitating role to empower farmers to come on grips with market mechanisms and, if necessary, provide support in form of direct subsidies to the deprived ones.

Research must become more development oriented with focus on the resource-poor smallholder farmer. Some of the issues which should be researched on priority basis to inform policies are: (i) reliable biosecure measures towards harnessing biotechnology and other cutting-edge technologies with smooth and cost-effective flow of quality seeds, (ii) insulating the poor from the uncertainties of market and climate change and translating price incentives into increased net income and welfare of farmers, especially the smallholders, and (iii) prospects of agricultural diversification and enhanced labour-productivity.

Besides addressing the challenges of the widening farmers-nonfarmers and rural-urban inequity and divides, India is managing 18 per cent of world population (and will soon be the most populous country of the world) from only 2.4 per cent of the world's arable land and 4 per cent of the world's agricultural water, whereas the land : man ratio is worsening and rural youth population is bulging and most of them are under-employed or unemployed and their employability is low due to defective educational and human resources development spread. The situation is further exacerbated due to shrinking land, water and biodiversity resources and the accelerating climate change volatilities and market uncertainties.

With the above backdrop, India must adopt More from Less for More (MLM) approach, establish agricultural product-industry linkage, transform subsistence agriculture to commercial agriculture, an agri-entrepreneurial and agri-business approach along the entire value chain, and update the university curricula to promote ARYA (attracting and retaining youth in agriculture) and MAYA (motivating agricultural youth for agri-business). We must also take note of the fast increasing feminization of agriculture and have special programs empowering women farmers by enhancing their entitlements, entrepreneurial skill along the value-chain - processing and value addition.

2.8 Urbanization

Urbanization in the world will increase from the present level of 55 per cent to 68 per cent in 2050. In India also, urbanization is increasing fast, reaching 35 per cent now from 30 per cent in 2007, and is expected to reach 60 per cent by 2050. Simultaneously, the middle class is increasing annually by 10 per cent. These trends have accelerated the dietary transition, increasing demand for processed foods, as well as animal-source food, fruits and vegetables. New technologies, particularly machines and tools are being developed to meet the labour shortages, and off-farm employment opportunities in processing, transport, wholesaling, retailing and vending are increasing.

2.9 Agrarian Economy

India today is the second largest agrarian economy in the world, being a leading producer of food grains, cotton, horticultural commodities, dairy and poultry, aquaculture, and spices. Agricultural production is valued at $401 billion in 2017, which is more than that of US ($279 billion). India's global trade in agricultural produces also fetches higher revenue for the country than the services and the manufacturing sectors. Over the three decades from the 1970s until the year 2001, India's agricultural GDP rose from $25 billion to $101 billion, witnessing an absolute growth of $76 billion. However, during the next 16 years from 2001 to 2017, it leapfrogged from $101 billion to $401 billion, an unprecedented increase (Shroff, 2019), as shown in Table 7.

Table 7. India's agricultural output (in billion $) since 1960

Year	**1960**	**1970**	**1980**	**1990**	**2000**	**2010**	**2014**	**2017**
Agriculture output ($ bn)	15	25	61	86	101	290	342	401

Source: (Shroff, 2019)

With a high diversity of topography, climate and soil, India is inherently an agricultural powerhouse harvesting multiple produces, an uncommon situation. India's cropping intensity is the highest in the world. The small-sized, family farms in India have imbibed integrated farming systems, which is a synergistic mix and match of agriculture, horticulture, fish farming and livestock farming.

As expected, agriculture's contribution to the national GDP has been decreasing and is presently around 15 per cent, from 54 per cent in 1950-51, but still agriculture provides employment to about 48 per cent of the Indian workforce. This has widened the income gap between farmers and non-farmers, currently being around 1:6. Income inequality is rising fast often due to inequality in skill level and access to modern technologies, automation, digitization and artificial intelligence (AI).

Earlier the Planning Commission and now NITI Aayog had suggested an agricultural GDP growth rate of 4.0 per cent per annum to support the overall desired national GDP growth rate of 8 to 9 per cent. Agricultural growth rate was around 1 per cent per annum in the 1960s, ranged from 2.2 per cent to 2.7 per cent per annum in the post reform period, touched 3.7 per cent per annum during 2004-05 to 2013-14, and touching the cherished growth rate of 4.3 per cent per annum in the period 2009-10 to 2013-14. But, during the last five years it has dipped back to 2.7 per cent per annum, brought down due to two drought years during the period. The low and fluctuating rates are non-conducive to steady and increased farmer's income.

2.10 Socio-Economic Support – Protection Floors

Credit has played an important role in agricultural development in India, and the GoI has to expand the outreach of institutional credit. The recent initiatives are: Kisan Credit Card (1998-99), the Doubling Agricultural Credit Within Three Years (2004), the 2008 Agricultural Debt Relief Scheme, the Interest Subvention Scheme (2010-11), and the 2014 Jan Dhan Yojana. Other measures to enhance the flow of credit to rural poor include: the Lead Bank Scheme, the Differential Rate of Interest Scheme, the Service Area Approach, the Self-Help Group Banks, Special Agricultural Credit Plans and Rural Infrastructure Development Plan resulting in increasing the ratio of agricultural credit to agricultural GDP from 10 per cent in 1999-2000 to 43 per cent in 2016-17. These supports have generally contributed to increase in agricultural productivity and household income.

In recent years loan waivers have emerged as major options for alleviating agrarian distress. Starting from the first loan waiver in 1987 by the Haryana Government, 22 loan waivers were effected upto 2018, 20 by State Governments and two by Central Government in 1990 and 2008. The waivers during the past five years, 2014-2018, ranged from Rs. 8,165 crore in Karnataka in 2017 (188 per cent of the State's agricultural budget of that year) to Rs. 36,359 crores in Uttar Pradesh (314 per cent of the State's agricultural budget of the same year), as detailed below (Table 8). In Percentage term, the waiver was most intense in Karnataka during 2018.

The highest loan waiver of 2008 by the Central Government of Rs. 717 billion was about 1.3 per cent of the country's GDP (De and Tantri, 2014). Studies have shown that (a) loan waiving is not a fiscally prudent measure, (b) loan waving is not inclusive across different categories of farmers, regions and gender, (c) loan waiving leads to credit rationing in loan allocation in subsequent years, and (d) loan waiving has deleterious effect on the repayment culture among the borrowers, Moreover, loan waiving is not a prudent measure from political economy perspectives, and it does not even provide guarantee to the incumbent political party to return in power.

Table 8. Opportunity cost of loan waiver policy

State	Year	Waiver (Rs. in crore)	Agri. Budget (Rs. in crore)	Wavier as per cent of Agri. budget
Karnataka	2018	34,000	5,080	669
Rajasthan	2017	20,000	3,072	651
Karnataka	2017	8,165	4,344	188
Maharashtra	2017	34,022	10,344	329
Punjab	2017	10,000	2,548	392
Uttar Pradesh	2017	36,359	11,589	314
Telangana	2014	16,374	6,312	259
Andhra Pradesh	2014	24,000	10,424	230
Uttar Pradesh	2012	1,650	7,650	22

Source: Phadnis A and Gupta A (2017) cited in NAAS Policy Paper 91, 2019

Joshi *et.al.,* in their article "Why Punjab needs incentives, not loan waivers" in Financial Express May 3, 2017 had highlighted that the average outstanding loan was nearly three times higher in Punjab compared with the rest of India. But, 80% of the loan was with large farmers, hence being of little assistance to the smallholders. They suggested that instead of loan waivers the Government should offer farmers incentives to adopt technologies facilitating crop diversification, providing crop insurance, reduced use of water, promoting solar energy, and better rice residue management leading to enhanced sustainability, productivity and income.

On the other hand, better economic policy and instruments are available to address agrarian distress more efficiently and effectively, such as direct benefit transfer to farmers like Rythu Bandhu, KALIA, PM-KISAN, /NYAYA etc. can be more effective than loan waiving. Loan waiver 'crowds-out' long-term public investment in agriculture. These trends question the efficacy of loan waiving in serving the masses. Several other measures, particularly the Pradhan Mantri Kisan Samman Nidhi (PM-KISAN), have emerged as social transfer mechanisms. These need to be analyzed scientifically to provide evidence-based sound policy options and actions for social and economic protection to serve the poor and revitalize the agrarian economy.

2.11 Doubling Farmers Income

The Situation Assessment Surveys of NSSO show that the average monthly income of agricultural households in current prices increased from Rs. 2115 in 2003 to Rs. 6426 in 2012-13. The share of cultivation in total income is the highest at 46 per cent in 2003 and 48 per cent in 2013. The share of income from animals rose while that the wages and non-farm business declined in 2013 as compared to those of 2003. A strategy paper released by the Ministry of Agriculture and Farmers Welfare gave the estimated farmers monthly income of Rs. 8059 in 2015-16. This was about one-fourth of the national average per capita income.

With the agricultural growth rate hovering around 3 per cent annually, farmers have felt severe economic distress, hence the clarion call by the Prime Minster to Double Farmers Income by 2022.

The Hon'ble Prime Minister's call for Doubling Farmers Income (DFI) by 2022 conveys the strong message that "farming must be treated as an enterprise, and the future agricultural development will have the returns first and not the outputs from the farms as its prime objective". Thus it is agriculture Plus Plus with comprehensive strategic geo-political significance, especially for minimizing the widening inequalities and the huge income gap, between farmers and non-farmers. The entire Government, especially those in Agri-food system and the Ministry of Agriculture and Farmers Welfare, the NITI Aayog, and other related Ministries, are highly sensitized to take this call as a national cause and work together to achieve the goal.

The NAAS, other concerned think tanks, individuals and institutions have suggested varying yet converging strategies for DFI. The inter-ministerial committee on Doubling Farmers' Income, Chaired by Dr. Ashok Dalwai, has made comprehensive recommendations to achieve the goal. Adopting a differentiated and disaggregated approach through a holistic, multidisciplinary and inter-ministerial process of agri-food system management, the country should meet this difficult but noble goal. It is projected to raise the average annual income of farmer household to Rs. 2,19,724 by 2022-23, from Rs 96,703 in 2015-16 with the help of additional public and private investment of Rs. 6.4 lakh crore. Research, technology, and innovation synergized with pragmatic policies, targeted budget allocations, and governance should be able to achieve the target.

The following seven sources of growth were identified by the DFI Committee:

Within the agriculture domain

- Improvement in crop productivity.
- Improvement in livestock productivity.
- Resource use efficiency or saving in cost of production.
- Increase in cropping intensity.
- Diversification towards high value crops.
- Improvement in real prices received by farmers.

Outside the agriculture domain

- Shift from farm to non-farm occupations. A differentiated and disaggregated approach will be need at the Central and State levels with strong Implementation teams.

For further details please see Chapter 5.

2.12 Inequality and Inequity

As discussed earlier, the wide income gaps between farmers and non-farmers, serious economic and social inequities and inequalities exist at various levels *viz* rural *vs* urban; farmers *vs* nonfarmers; small farmers *vs* large farmers; male *vs* female etc. These pervasive and persistent inequalities are leaving too many rural people mired in hunger and rural poverty. High levels of youth unemployment and underemployment in rural areas prevent households from escaping poverty for good. Population growth is outpacing the creation of off-farm jobs, thus perpetuating the inequality.

Marginal, sub-marginal and smallholder farmers comprise nearly 50 per cent of the country's population. They are generally poor and under-nourished as they were largely bypassed in the rural development process. The high GDP growth registered in the country was thus less effective in reducing poverty and under-nutrition, especially in rural areas. Recent research confirms that "high initial levels of inequality limit the effectiveness of growth in reducing poverty, while increasing inequality reduces the impact of growth on poverty for any given level of growth". The World Bank had also stated that "economic growth has little power to reduce absolute poverty in countries with income inequality".

The United Nations Conference on Sustainable Development held in Rio de Janeiro from June 20 to 22, 2012 in its Resolution document "The Future We Want" reiterates the global "commitment to sustainable development and to ensuring the promotion of an economically, socially and environmentally sustainable future for our planet and for present and future generations". Promoting inclusive and equitable economic growth for reducing inequalities was a major resolution. The support to developing countries to help eradicate poverty and to empower the poor and vulnerable people, complemented by effective social policies, including social protection floors was emphasized. Social systems that address and reduce inequality, essential for eradicating poverty should strongly be supported.

Pro-poor or inclusive growth was emphasized in the XI Plan, and the emphasis continued in the XII Plan. Notwithstanding the desirability of assessing and monitoring the impact of this thrust on key indicators of human development and inequality, a set of actions (as reproduced below) are implied for translating the policy options into tangible AREE4D outcomes to enhance equality.

- Critically review gaps in productivity, technology options and human resources, and strengthen capacity at various levels to ensure technology generation, assessment and diffusion as well as for scaling-up and scaling-out of best practices identified through using the filters of efficiency, effectiveness, economic viability and sustainability

- Undertake a massive mission mode programme on rural employment security much beyond MNREGA and institutionalise on-farm and non-farm employment, including post-harvest management, agro-processing, value addition, value chain management and developing infrastructure for reaching the unreached

- Target and monitor both income and non-income equality within the development framework of the National Development Plan by developing and rigorously using socio-economic and environmental indicators in order to measure cross-sectoral impact on the poor

- Substantially increase development grants to the hot spots and rigorously monitor coherent implementation of the programmes specifically designed for alleviating poverty and hunger

- Develop/refine/adopt adaptation measures and most vital mitigation measures such as insurance and other risk proofing steps to attain climate resilient agriculture and

- Provide targeted subsidies, hassle-free credit flow and market linkage through smallholder estates and producers' companies to the resource-poor farmers and other rural poor who are most vulnerable to the market volatility.

2.13 Economic Growth, Population Dynamics, and Diversification Driving Structural Changes

Since 2004-05, entire growth of employment in rural areas was due to non-farm employment – a major structural change (NABARD, 2018). And this trend must be fortified for Doubling Farmers Income. With the Hon'ble Prime Minister's call for Doubling Farmers Income (DFI) by 2022, structural changes will be needed in both output and employment of agriculture. Thus it will mean Agriculture in comprehensive sense including the entire value chain – processing and value addition, which will enhance inter-sectoral linkages as well as employment opportunities.

A grain saved is a grain produced. Food losses and waste claim a significant proportion of agricultural output. And, much of it could be and must be saved. Despite tremendous potential for agro-processing and creation of off-farm employment, India is far behind in this aspect. Current agro-processing intensity is hardly 10 per cent. With the strengthening of the value-chain concept in the segments of food-processing, cold chains, wholesellers, retail trades and foreign direct investment, various linkages can be strengthened ultimately leading to emergence of supermarkets, thus establishing effective farmer-market links.

Diversification within agriculture sector, diversification from agriculture to allied activities like livestock and fisheries, and structural changes from agricultural and allied sector to rural non-farm sector are evident (Dev, 2018). Shares of cereals and nutri-cereals have declined whereas those of livestock plus fisheries and fruits and vegetables have significantly increased (Table 9). Contribution of these allied sectors to the Agriculture GDP has increased to around 60 per cent, and these are growing at a satisfactory rate of 5 to 6 per cent per annum. The Amul management model led by Dr. Kurien – Father of White Revolution, spearheaded by National Dairy Development Board, is an innovative approach of mutually reinforcing linkages among milk production, processing and marketing. Similar approach could be adopted in other sub-sectors. Further, both marine and inland fisheries had registered impressive growth based on scientific advances made in the production of seed, feed, and captive breeding as well as crafts and gear.

Table 9. Share in value of production (2004-05 prices) per cent

Crops	1960-61 to 1968-69	1975-76 to 1988-89	2004-05 to 2014-15
Paddy and Wheat	18.2	21.2	17.9
Nutri-cereals	6.9	5.0	2.7
Pulses	7.3	5.0	3.0
Oilseeds	7.1	6.3	6.7
Sugar	4.5	4.1	4.5
Cotton and Jute	2.9	2.4	3.3
Condiments and spices	1.7	1.7	2.6
Fruits & Vegetables	10.6	14.7	18.8
Floriculture	0.3	0.4	0.9
All Crops	77.1	75.4	69.6
Livestock	20.1	21.4	25.8
Fisheries	2.9	3.3	4.6

Source: GOI (2017)

Current Gross Value Addition for agriculture sector in India was Rs. 17.7 trillion (USD 274 billion), expected to grow at 2 per cent annually. Top five trends to shape Indian agriculture sector are:

1) Digital innovation
2) Effective climate risk mitigation strategy
3) Developing vibrant startup ecosystem
4) Leveraging the Farmer Producer Organization (FPO) movement
5) Water management initiative.

As regards water, recently the Centre has set up team for water harvesting involving 550 senior officers to work in 1593 water-stressed blocks falling under 255 districts – a Jal Shakti Abhiyan. It has also been highlighted that, only 18 per cent of India's 17.9 m rural homes have tap water. The coverage varies widely from state to state, being as high as 99 per cent in Sikkim and 78 per cent in Gujarat to as low as 1 per cent in UP, West Bengal, Meghalaya and 2 per cent in Bihar and Assam.

2.14 Farmer-Market Linkage and Value Chain Management

Assured and remunerative markets hold the key to retaining the interest of farmers in farming, and also to attract the youth in farming. While FDI in agriculture is bound to be promoted under "Make-in-India" thrust, farmers should be looked at as agri-preneurs who interact with corporate entrepreneurs, needing business models to be worked out to provide win-win options. Appreciating that agriculture is the biggest private sector economic activity in India, we must move from 3Ps to 4Ps i.e. Public- Private-Producer-Partnership.

Prevention of post harvest losses, processing and product development deserve priority in our agricultural policy framework. Post-production losses of perishables and semi-perishables especially in milk, meat, fish, fruit and vegetables are high, estimated at Rs. 50,000 crore annually. About 50 per cent of these losses are preventable using suitable post-harvest technologies. Cost-effective processing, value addition, packaging, cold chain, product quality and safety and prolonged shelf life technologies are the need of the hour, not only for saving the harvest, but also for providing additional off-farm employment. Let us remember, that a grain saved is a grain produced, and an unsafe food is no food, and is also a health hazard.

As we live in a globalized and liberalized world, greater understanding of market intelligence mechanisms, good trade practices, and legal aspects of the multilateral trade regime and agreements and intellectual property rights is absolutely necessary. This calls for the development and institutionalization of user-friendly knowledge systems to support decision-making by various client groups. In line with the nation's Food Bill and Right to Food, trade must first be a component of food security before meeting other obligations, as recently pursued by the Government at WTO and other bilateral and multilateral negotiations.

New Initiatives of the Government on e-NAM, creating a common Indian Markets and investment in establishing additionally 22,000 village markets will directly link the farmers with markets and help them realize remunerative prices for their produces, thus enhancing their incomes and access to adequate nutritive foods.

As highlighted in the DFI Report, the following actions should be taken:

(i) Create Agricultural Value System (AVS) as integration of the supply chain and to drive market led value system to promote individual value chains to collaborate and integrate into a sector-wide supply chain

(ii) Establish Farmer-centric National Agricultural Marketing System by restructuring for a new market architecture, consisting of Primary Retail Agriculture Markets and Primary Wholesale Agricultural Markets, as also secondary & tertiary agricultural markets, all of which are networked by online platforms to facilitate a pan-India market access; as also integrating the domestic market with export market

(iii) Develop Hub and Spoke System at back-end as well as front-end to facilitate and promote an Agri-Value System (AVS) (which includes a combination of input providers, farmers, transporters, warehousing, wholesalers, food and agro-processors, retailers, etc)

(iv) Establishing Marketing Intelligence System to provide demand led decision making support system – forecasting system for agricultural produce demand and supply, and crop area estimation to aid price stabilization and risk management

(v) Institutionalize Agricultural Risk Assessment and Management including drought management, demand & price forecast, weather forecast, management of biotic stress including vertebrate pests, access to credit among farmers for farming operations;

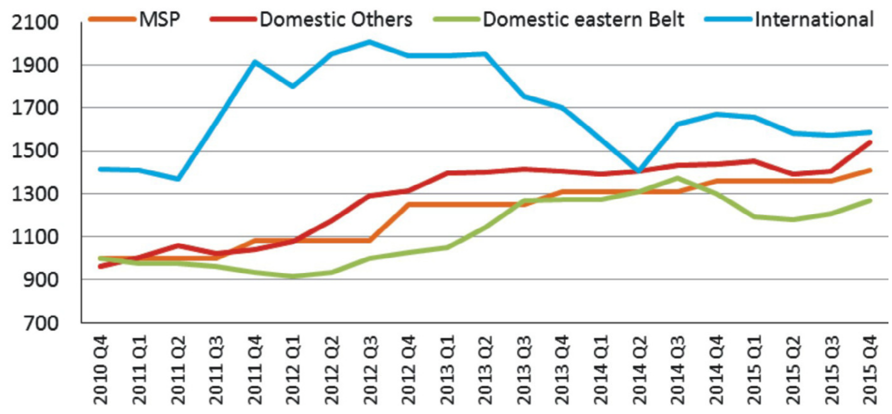
providing long term credit, post-production finance to preventing distress sale by farmers, and crop & animal risk management through insurance.

NAAS (2016) analyzed the issue and reiterated that agricultural marketing is primarily regulated by the APMC Act which prohibits purchase of farm produce outside the regulated markets. However, a model act is proposed to liberalize this, which allows products like fruits and vegetables to be transacted outside the regulated market. The market reforms are also directed to attract private investment in market infrastructure and enhance value creation, so that there is greater competition facilitating improved marketing efficiency and price discovery. The progress in terms of market reforms is, however, mixed across the states and the same holds true for their impacts (NITI Aayog, 2015). In successful examples of market reforms, supply chains are getting shorter by the elimination of those intermediaries, which do not add any value.

The institutional innovations reduce the marketing cost, link production with consumption and improve the overall efficiency. These innovative business models emphasize three things: (a) farmers' access to information on prices, etc, (b) the model with adequate institutional and technological support, and (c) preferably, desirability of having farmers as partners in the value chains for increasing their share in value distribution. One of the important concerns is to serve smallholders who now occupy more than 44 per cent of agricultural lands. There are a few examples, which suggest the possibility of inclusion of smallholders. These are mostly high value products where size of operation is rather small, but amount of turnover is high. Notable examples are high value vegetables, floriculture, poultry and milk.

There are efforts to promote farmers organizations, which are very thin and likely to be more successful in high value, commercial products, and products with high price volatility. Therefore, institutional support required for linking farmers with markets is critical. In fact, small farmers will have limited access to the markets of field crops like paddy, wheat, cotton, pulses and oilseeds because of size of their marketable surplus and local traders shall continue to play role of aggregator, albeit comparative lower prices realized by farmers. This is more visible for paddy in eastern India where prices realized by farmers are much lower than the minimum support prices (Figure 8). FPOs can overcome this loss.

Figure 8. Trends in MSP and market prices of paddy (in Rs./quintal)



Source: CACP, 2016

Despite success of contract farming in different regions, its large scale application is limited, which is possible when the business model meets the requirements amenable to scaling up, financial sustainability and better economic efficiency. The following measures will be helpful: (a) application of existing stock of knowledge to harness productivity potential, (b) access to proprietary technology, (c) farm mechanization for higher input use efficiency, and (d) technology for agro-processing. There are some technologies, especially related with resource and crop management, which have not reached farmers.

A suitable strategy to use IPRs is needed to evolve diversified innovation systems and to realize their potential to access improved technology. Cost-effectiveness of R&D regulations, including those of biotechnology shall, therefore, affect participation of private sector. This is more visible from a concern relating to regulation of licensing of proprietary technology which has come up recently, and this concern should be addressed without compromising interest of farmers

The demand for farm mechanization is increasing with the shortage of labour and rising agricultural wages, but concerted efforts shall be needed to develop and popularize farm machines for small farmers. Access of small farmers to these machines can be facilitated by custom hiring of these machines. However, financing of long-term loan for purchase of these machines must be scaled up. Also, there shall be greater pressure on improving availability of energy, mainly diesel and electricity, to utilize them optimally. Development of agro-processing sector needs lot of investment from business sector, availability of required infrastructure like road and electricity and technology suitable for Indian raw material.

The Government has improved foreign direct investment in this sector, but the progress is rather limited. There are some successful examples like potato, tomato and mango where processing and entire value chain has gone significant transformation. This success should be replicated to other products to create value and reduce losses, particularly in fruits and vegetables. Adoption of APMC reforms by the states, allowing private sector to buy directly from farmers and promotion of organized food retail chains will further increase demand for processed products and thereby promote food-processing.

2.15 Agricultural Research, Education and Extension for Development

Science, research, technology, and innovation are the main drivers of agricultural transformation to free the world of hunger, poverty, undernutrition and livelihood insecurity. Since the unprecedented success of the green revolution, which was based essentially one public good research, there have been significant advancements in science, its organization and management and transfer of technology to end users. The research system has expanded considerably and extension system has also tried to change accordingly. Science and technology coupled with social engineering had helped promote conservation, restoration and commercial forestry and restoration and commercial forestry and the regeneration of coastal mangrove wetlands. Advancements in molecular biology and information technology have taken shape and research on animals and horticultural crops has expanded. Great progress has made in space technologies, peaceful uses of nuclear energy, and generation of renewable energy. Food-cum-fortification approaches were available to address many nutritional disorders like those arising from micronutrient deficiencies.

A number of international agreements were put in force, which have significant implications for development and dissemination of agricultural technology. Important among these agreements are protection of intellectual property, conservation and sustainable use of biological diversity and regulation of transgenic products. It is helped that Paris Agreement on Climate Change and Global Fund for Carbon Economy will go a long way in minimizing global warming.

The fundamental principle of Indian agricultural R&D policy has been public funding and provision of R&D services for sustainable growth in productivity and self-reliance in food production. There has also been a marked shift in the funding pattern of the Union and State Governments. During 1960s and 1970s, with the establishment of the state agricultural universities (SAUs) there was a significant growth in the state funding. But since the early 1990s, the central funding has outpaced the state funding and a part of this was transferred to SAUs through sponsored programmes and development grants. On the other hand, agricultural extension was mainly funded by the State Governments, and the centre's support was available through development programs like *Rashtriya Krishi Vikas Yojana,* extension reforms, and technology missions. As a result, India is one of the few countries with sustained growth in funding for agricultural R&D (Beintema *et. al.,* 2012).

The second important element of agricultural R&D policy has been 'open access' to public research products for further use or commercialization. This policy in fact paved the way for public-private partnership, transfer of technology and diversification of input markets like seed. A deliberate attempt was also made to coordinate research being done under various organizations, largely under the coordinated programmes of ICAR with funds earmarked for this activity. Nearly ten per cent of ICAR budget is now spent on demonstration of new technology and skill development of farmers, in partnership with private and civil society organizations.

Research funding in India has been growing annually by 7 per cent since 1981-83, and had reached 3533 million PPP dollors during 2012-2014, touching the peak of 4,000 million PPP dollar in 2011. The Research Intensity has hovered around 0.4 per cent against the targeted 1.0 per cent. Comparing with other agriculturally important countries, China in 2013 spent 9366 million 2011 PPP dollars, and research intensity was 0.6 per cent. The intensity was 2.0 per cent in South Africa and 1.8 per cent in Brazil (Table 10). As regards allied sectors, in India the allocation to livestock and horticulture was relatively much lower.

Table 10. International comparison of agricultural research funding, 2011-12

Sl No.	Country	Number of scientists, Full-time equivalent	Funding in million 2011 PPP dollars	Research intensity (per cent)
1.	Brazil	5,869.4	2,704.0	1.8
2.	Bangladesh	2,121.0	250.6	0.4
3.	China	43,000.0	9,366.0	0.6
4.	Malaysia	1,609.4	592.3	1.0
5.	Pakistan	3,678.3	333.0	0.2
6.	Sri Lanka	618.8	61.8	0.3
7.	South Africa	746.3	294.5	2.0
8.	India	10,242.0	3,533.0	0.4

Source: Based on ASTI database (www.asti.cgiar.org) and our own data for India; India funding data are for 2014 and FTE scientists data for 2009; data for China are for 2013.

Strengthening of SAUs shall be a major challenge, especially when ICAR has no or limited administrative control over them. There are concerns in terms of mobilizing operating funds, modernizing infrastructure, and most importantly maintaining critical minimum faculty strength in various disciplines. ICAR can provide necessary support in terms of seed fund and leadership, but efforts made by SAUs in mobilizing support of state governments will go a long way in their revival and bring them back on board as they employ two-thirds of the country’s scientific manpower. This shall help restore research-education linkages and promote integration of knowledge and technology at regional level and facilitate their flow to farmers (see Chapter 16 for details).

Research – extension linkages and public extension are weak, thus huge technology transfer and yield gaps exist. The extension system needs revitalization and should play a larger role in developing linkages with various stakeholders and help farmers gain access to markets and farm services and acquire necessary technical and organizational skills. The gap between scientific “know how” and “do how” should be filled. The necessary condition for this is to create an enabling environment for interactions and knowledge sharing among multiple-stakeholders and to create capacity to innovate products, processes and institutions to respond to market opportunities and enhance economic efficiency. Development of these conditions will again require substantial public investment, especially for human resource development at all levels, including farmers and strengthening responsive rural institutions like farmers organizations, ATMA, KVKs, FPOs etc.

Towards DFI, ICRISAT has emphasized the role of Science of Delivery to promote Demand-Driven Innovation that leverages participatory research to engage farmers and key value chain actors to design, develop and deliver relevant solutions – all with a sense of urgency. This approach has enabled the compression of time to deliver technology and knowledge at scale. Emphasis on Spatial Data Integration (SDI) using cloud computing will facilitate the delivery system along the value chain, including the agri-entrepreneurs.

As the NAREE4D system must synergistically integrate social, economic, and environmental dimensions of agriculture as a whole, multidisciplinary approach is called both for science of discovery and science of delivery. Against this backdrop, it is unfortunate to see that our NARES, one of the largest in the world, is undergoing unmindful splitting, attempting to create ivory towers and undermining multidisciplinarity. This negative trend should be reversed.

2.16 Investing in Agri-Food Systems, Especially in Agricultural Research, Education and Extension

Public sector investment has been instrumental in creating infrastructure and support services to promote agriculture-led development. During the Green Revolution, public sector investment, being 33 per cent of the investment in agriculture sector in 1985, was the main driver of the Revolution, but now it has reduced to only 17 per cent. In absolute terms, the real agricultural investment during the year 2016-17 was 2.6 lakh crores accounting to about 2.2 per cent of GDP. The remaining 83 per cent of the investment has come from the private sector, primarily by farmers. The contribution of the corporate sector is hardly 2 per cent. The investment capacity of the majority smallholder marginal farmers being low, public sector investment in the regions crowded by such smallholder viz. eastern and north-eastern regions, should be substantially enhanced. The level and scale of public investment has direct impact on overall GDP growth. Hence, the public sector investment should steadily be enhanced to accelerate the overall GDP growth rate, which will directly help in increasing farmers' income. The corporate sector must be boosted to strengthen R&D, inputs supplies like quality seeds, agrochemicals, machinery, processing, and value addition. The recent initiatives of the Government related to Make-in-India, even upto 100 per cent FDI, tax reliefs for small scale enterprises have huge scope in the agricultural sector.

Technology being the main driver of productivity and income enhancement, investment in agricultural research education and extension must match with that potential, opportunities, and prospects. The total R&D budget of the nation, covering all sectors, in 2014-15 was Rs. 35034 crore. Of this, 11.37 per cent i.e. Rs. 3983 crore was allocated to the ICAR. Despite increasing allocation to agricultural sciences and technology in recent years, being Rs. 13,786 crore in TE 2017-18, India's agricultural research intensity is only 0.37 per cent, as compared to 0.62 per cent in China, 1.82 per cent in Brazil, 2.0 per cent in South Africa 3.2 per cent in USA, and 3.3 per cent in Australia. Both Centre and States have contributed almost equally to R&D funding, despite agriculture being a state subject. The financial status of most SAU's is deplorable. Further, there is large inter-state variation, in 2014, the research and education funding intensity being as low as 0.07 per cent in UP, the largest agricultural and food producing state with more than 85 per cent of its farmers being small and marginal. West Bengal (0.09%) and Madhy Pradesh and Rajasthan (each with 0.11%) were the other poor investors. Encouragingly, Himanchal Pradesh, Jammu and Kashmir, Bihar and Kerala, Karnataka and Assam, Gujarat and Tamil Nadu, and Punjab had funding intensity of 1.28, 0.88, 0.60, 0.58, 0.55, and 0.50 per cent, respectively (Suresh Pal, 2017). For the last two decades, NAAS, as several other concerned organizations, have been pleading for doubling the national research intensity, taking it to about 1 per cent.

Extension expenditure intensity is still far lower, less than half of that of research (table 10) Given the high transferable yield gaps, judicious efforts are needed to increase the extension intensity.

Table 10. Expenditure Intensity in R&D in India

Expenditure Intensity in India (per cent)		
	Research	**Extension**
1983	0.25	0.10
1993	0.31	0.15
2003	0.39	0.14
2014	0.40	0.18
2018	0.39	

Source: NIAP, 2017-18

In line with the Prime Minsiter's call for Doubling Farmers Income, the then Finance Minister while announcing the Union Budget 2018-19 in the Parliament had said "Our emphasis is on generating higher incomes for farmers. We consider agriculture as an enterprise and want to help farmers produce more from the same land parcel at lesser cost and simultaneously realise higher prices for their produce", the Minister added while announcing a slew of the following new initiatives for the farm sector in the Budget, as reported by Mohd Mustaquim, Rural Marketing Website, Feb 2018.

The Government has decided to keep Minimum Support Price (MSP) for all hitherto unannounced crops of Kharif at least at one and half times of their production cost. "This historic decision would prove an important step towards doubling the income of our farmers. NITI Ayog in consultation with Central and State governments will put in place a foolproof mechanism so that farmers will get adequate price for their produce".

Institutional credit for agriculture sector was raised to Rs.11 lakh crore for the year 2018-19 from Rs.10 lakh crore in 2017-18. 'Operation Greens' was launched to address price volatility of perishable commodities like potatoes, tomatoes and onions, at an outlay of Rs. 500 crore. 'Operation Greens', on the lines of 'Operation Flood', shall promote Farmer

Producers Organizations (FPOs), agri-logistics, processing facilities and professional management in the sector.

100 per cent deduction was announced in respect of profits to Farmer Producer Companies (FPCs), having turnover up to Rs. 100 crore, for a period of 5 years from FY 2018-19, in order to encourage professionalism in post harvest value addition in agriculture. A sum of Rs.200 crore was allocated to support organized cultivation of highly specialized medicinal and aromatic plants and aid small and cottage industries that manufacture perfumes, essential oils and other associated products.

The existing 22,000 rural haats were upgraded into Gramin Agricultural Markets (GrAMs). In these GrAMs, physical infrastructure will be strengthened using MGNREGA (National Rural Employment Guarantee Act) and other Government schemes and would be electronically linked to e-NAM and exempted from regulations of APMCs, which would provide farmers facility to make direct sale to consumers and bulk purchasers.

Out of 585, 470 APMCs have been connected to e-NAM network and rest will be connected by March, 2018. Further, an Agri-Market Infrastructure Fund with a corpus of Rs. 2,000 crore will be set up for developing and upgrading agricultural marketing infrastructure in the 22,000 GrAMs and 585 APMCs.

Allocation for Ministry of Food Processing was doubled from Rs. 715 crore in RE 2017-18 to Rs.1,400 crore in BE 2018-19. The Prime Minister Krishi Sampada Yojana (PMKSY) a flagship programme for boosting investment in food processing, is growing at an average rate of 8 per cent per annum. With the increased allocation for the sector, the Government will promote establishment of specialised agro-processing financial institutions in this sector and to set up state-of-the-art testing facilities in all the forty two Mega Food Parks.

To help small and marginal farmers in fisheries and animal husbandry sector to meet their working capital needs, the facility of Kisan Credit Cards (KCC) was extended to the sector. This would give benefit of crop loan and interest subvention, so far available to agriculture sector only under KCC, for rearing of cattle, buffalo, goat, sheep, poultry and fisheries.

Setting up of a Fisheries and Aquaculture Infrastructure Development Fund (FAIDF) for fisheries sector and an Animal Husbandry Infrastructure Development Fund (AHIDF) for financing infrastructure requirement of animal husbandry sector was announced. Total corpus of these two new Funds would be Rs.10,000 crore.

Re-structured National Bamboo Mission was launched allocating Rs. 1290 crore, which is based on a cluster based approach to address the complete bamboo value chain and promote bamboo sector in a holistic manner. With a focus on linking bamboo growers with consumers; creation of facilities for collection, aggregation, processing, marketing, MSMEs, skill building and brand building, this announcement would contribute in generating additional income for farmers, employment opportunities for skilled and unskilled youth especially in the rural areas.

As a measure to tackle the challenge of air pollution in the Delhi-NCR region, a special scheme will be implemented to support the efforts of the governments of Haryana, Punjab, Uttar Pradesh and the NCT of Delhi to address air pollution and to subsidise machinery required for in-situ management of crop residue.

2.18 Science Culture

A sound science culture in the National Agricultural Research, Education, Technology Development and Innovations System is a must to achieve the Sustainable Development Goals. The three key attributes of science culture - research, integrity, scientific creativity, and scientific integrity are mutually reinforcing and should be the most possessed treasure of all stakeholders from individuals to institutions, policy makers, and political leaders for transparently informing policy based only on scientific evidence, free from all influences (NAAS, 2019). Even the loan waiver drive and the hazards associated with it, and commercialization of GMOs and nanotechnologies should be scientifically analyzed to provide balance opinion/advice to the political parties, the Central and State Governments, and the people at large. Chapter 16 elucidates the NAAS points for commercialization of genetically engineered organisms and products.

The evolution of the science culture over the years should be analyzed to assess our situation and to make need-based changes. As learnt recently (Times of India, June 27, 2019), farmers want GM Crops. It is a revolt to a decade of policy paralysis which must end. A herbicide tolerant (HT) BT cotton has been taken up by farmers in Maharashtra occupying 15 per cent of the state's cotton area. In Haryana, Bt brinjal is being grown by farmers. The materials cleared by the GEAC should be allowed to be commercialized, including the GM mustard. These initiatives of farmers should be scrutinized from the biosafety and legality point of views.

India's ranking in the world as per various social, economic, science and technology indicators for 2018 is given below (Table 11). Enigmatically, despite the country's fast economic growth during the past decade, India lags behind in several vital areas. Viewing, the rankings it appears that we have not been able to judiciously humanize science. The academia and the scientific community need to examine the issue comprehensively and suggest the way forward to strengthen science of delivery and adoption so that our rankings improve.

Table 11. India's rank in the world as per various Global Indicators, 2018

Global Indicator	India's Rank	Out of number of countries
Human Development Index	130	189
Inclusive Development Index	62	74
Child Development Index	112	141
Innovation Index	57	126
Youth Development Index	134	183
Happiness Index	133	153
Gender Inequality Index	76	188

Hunger Index	103	119
ICT Development Index	138	175
Education Index	145	191
Human Capital Index	103	130
Social Progress Index	53	138
GDP growth rate	15	225
Per Capita GDP	139	187
Imports	12	222
Exports	21	222
Unemployment Rate	43	217
Financial Development Index	51	183

Source: Various UN and NITI Aayog publications / reports

Towards enriching our science culture, we must ask ourselves the following questions and resolve them:

- Do we have science leaders who could creatively and accumulatively build and sustain universally accepted science culture?
- Are our universities and scientific institutions, including Academies, duly insulated, equipped, and incentivized to produce the desired science leaders and ambience?
- Do we have the necessary political will to nurture the science culture of inter and multi-disciplinary integrated, and holistic approach to synergistically build the knowledge base to transform our agriculture – food system to converge excellence and relevance for a wholesome outcome and impact, rather than promoting dis-integration and fragmentation?

Recently, our Hon'ble Prime Minister has been seeking congruence and convergence of Jai Jawan, Jai Kisan, Jai Vigyan, and Jai Anusandhan to harness science and innovation to serve the humanity towards building a New India. The NAAS must pursue this approach to transform agriculture–food system to reshape India.

2.18 International Collaboration

In this changing world, the local and global are no longer far apart. As a matter of fact, their interdependence is increasing fast, thus the increasing importance of international cooperation. This has implications for convergence of food demand, food production, agricultural research, and agricultural policies and trade. Climate change, urbanization, migration, modern technologies and automation, increased inequality, fluctuating inward-looking policies of some of the most developed countries, such as Brexit in Europe, increasing protectionism and tariff wars, anti-globalization sentiments and disagreement with Paris Agreement of USA are bound to adversely impact multilateral collaboration and agreements. Glaringly increasing inequality will further enhance the vulnerability of women, youth and smallholder farmers. Artificial intelligence, automation and digitization are bound to take away routine jobs generally outsourced to labour-abundant economies. The pervading and persisting inequality will greatly suppress the overall development process. In this unequal world, we have to nurture "share and grow" concept and strive for a World Grant System in a world without borders to serve the entire humanity.

India has been a leader in international cooperation in the field of agriculture. Besides having liberally shared its rich genetic resources, trained human resources and formal and non-formal training programmes, India is a substantial bilateral and multilateral donor in AREE4D. It has strong linkages with the CGIAR Centres, houses regional offices/programmes of most of them, is a major donor to some of them, besides hosting ICRISAT and BISA Headquarters. It has participated in several of the UN TCDC/ECDC South-South and South-North-South (Trilateral) collaborations. Recently, the NAAS has prepared a comprehensive project for collaboration with Africa.

2.19 Epilogue

The major trends of the Agriculture and Food Systems, especially related with food, nutrition, livelihood, income and environmental security, population dynamics, inequality, diversification, science, research, technology and innovation reveal tremendous progress made during the past decades. The analysis has also revealed several persisting and new and emerging challenges and opportunities, as discussed in the next chapter, which are embedded in several of the sustainable development goals. These include high incidences of hunger, undernutrition and poverty, mounting pressure on natural resources, and volatilities in climate change and market. Fortunately, India, and other developing and developed countries and the international system is paying greater attention to meet the challenges. Besides Agenda 2030 for Sustainable Development, the Addis Ababa Action Agenda, the Paris Agreement on Climate Change, the World Humanitarian Summit and UN Secretary General Agenda for Humanity, and analogous commitments at country levels provide platforms to help mobilize concrete and concerted actions by veritable stakeholders to realize the goals.

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Chapter 3

Challenges facing India's Agriculture and Food Systems & Their Possible Resolutions

3.1 Introduction

From the national aspiration of building a New India and the trends in agriculture-food systems described in the previous chapters, several major challenges have been identified which must be resolved to meet our vision of a sustainably healthy, happy, prosperous and vibrant India. The NAAS, as per its Vision and Mission has been analyzing and discussing the national status of agriculture-food systems from day one of its establishment. For each set of challenges, through veritable analyses and brainstorming meetings, also keeping in view the regional and global situation, it has come up with scientific solutions/suggestions with complementary policy options and strategic action plans, contained in nearly 150 NAAS policy papers and other publications, to attain our Mission.

3.2 Challenges and Corresponding NAAS Publications suggesting Their Resolutions

This chapter lists below the various challenges and gives serial number and title of each Policy / Strategy Paper and Brief specifically brought out to meet the challenges.

Challenges	***NAAS Policy Paper*/Policy Brief[#]/Strategy Paper[@] with their serial numbers***
Ending hunger and all forms of malnutrition, diversification of agri-food systems towards comprehensive nutritional security; almost one-fifth of the world's hungry and about 35 per cent of the world's undernourished, stunted and wasted children have their homes in India.	***7.*** *Diversification of Agriculture for Human Nutrition, 2001* ***8.*** *Sustainable Fisheries and Aquaculture for Nutritional Security, 2001* ***20.*** *Dichotomy Between Grain Surplus and Widespread Endemic Hunger, 2003* ***54.*** *Integration of Millets in Fortified Foods, 2012* ***55.*** *Fighting Child Malnutrition, 2012* ***66.*** *Role of Millets in Nutritional Security of India, 2014* ***78.*** *Reservoir Fisheries Development in India: Management and Policy Options, 2016* ***S2.*** *Towards Pulses Self-sufficiency in India, 2016* ***S7.*** *Vegetable Oil Economy and Production Problems in India, 2017* ***S12.*** *Harnessing Full Potential of A1 and A2 Milk in India: An Update, 2019* ***PB1.*** *Policy Brief to Accelerate Utilization of GE Technology for Food & Nutrition Security and Improving Farmers' Income, 2016*
Eradicating extreme poverty,	***5.*** *Sustainable Agricultural Export, 1999*

ending poverty in all its forms everywhere, enhancing productivity, increasing inclusiveness, reducing inequality, and doubling farmers income; over 200 million people, mostly smallholder farmers, are below poverty line; farmers' income is one-fourth to one-sixth of that of non-farmers.	***23.*** *Export Potential of Dairy Products, 2003* ***26.*** *Peri-Urban Vegetable Cultivation in the NCR Delhi, 2004* ***39.*** *Innovations in Rural Institutions: Driver for Agricultural Prosperity, 2007* ***47.*** *Protected Agriculture in North-West Himalayas, 2010* ***75.*** *Linking Farmers with Markets for Inclusive Growth in Indian Agriculture, 2015* ***S3.*** *Strategy for Transformation of Indian Agriculture and Improving Farmers Welfare, 2016* ***PB1.*** *Policy Brief to Accelerate Utilization of GE Technology for Food & Nutrition Security and Improving Farmers' Income, 2016* ***S9.*** *Accelerating Seed Delivery Systems for Priming Indian Farm Productivity Enhancement: A Strategic View Point, 2018*
Promoting policy options to converge social, economic, and environmental perspectives of agri-food system transformation; population growth/pressure, demographic pattern, gender, rural youth, urbanization, fast increasing middle class and changing food habits/preferences, demand supply balance, changing mindset to think in a system mode and abandoning the ivory tower approach in this fast changing world; production by masses and not just mass production.	***S1.*** *Role of Social Scientists in National Agricultural Research System (NARS), 2015* ***80.*** *Augmenting Forage Resources in Rural India: Policy Issues and Strategies, 2016* ***82.*** *Breeding Policy for Cattle and Buffalo in India, 2016* ***83.*** *Issues and Challenges in Shifting Cultivation and its Relevance in the Present Context, 2016* ***PB1.*** *Policy Brief to Accelerate Utilization of GE Technology for Food & Nutrition Security and Improving Farmers' Income, 2016* ***86.*** *Mismatch between Policies and Development Priorities in Agriculture, 2017* ***S10.*** *Renewable Energy: A New Paradigm for Growth in Agriculture, 2018*
Ensuring a sustainable natural resource base (land, water, biodiversity); our soils are both hungry and thirsty, deficiency of micro, essential and even macro-nutrients ever-growing; water availability has already entered critical zone, improving water use efficiency; per drop more crop; fast eroding agro-biodiversity.	***1.*** *Agricultural Scientist's Perceptions on National Water Policy, 1995* ***2.*** *Fertilizer Policy Issues (2000-2025), 1997* ***3.*** *Harnessing and Management of Water Resources for Enhancing Agricultural Production in the Eastern Region, 1998* ***4.*** *Conservation, Management and use of Agro-biodiversity, 1998* ***5.*** *Sustainable Agricultural Export, 1999* ***14.*** *Conservation and Management of Genetic Resources of Livestock, 2001* ***28.*** *Impact of Inter River Basin Linkages on Fisheries, 2004*

	32. *Emerging Issues in Water Management – The Question of Ownership, 2005* ***33.*** *Policy Options for Efficient Nitrogen Use, 2005* ***35.*** *Low and Declining Crop Response to Fertilizers, 2006* ***36.*** *Belowground Biodiversity in Relation to Cropping Systems, 2006* ***42.*** *Crop Response and Nutrient Ratio, 2009* ***43.*** *Antibiotics in Manure and Soil – A Grave Threat to Human and Animal Health, 2010* ***48.*** *Exploring Untapped Potential of Acid Soils of India, 2010* ***49.*** *Agricultural Waste Management, 2010* ***51.*** *Carrying Capacity of Indian Agriculture, 2011* ***56.*** *Sustaining Agricultural Productivity through Integrated Soil Management, 2012* ***57.*** *Value Added Fertilizers and Site Specific Nutrient Management (SSNM), 2012* ***68.*** *Efficient Utilization of Phosphorus, 2014* ***74.*** *Biodrainage: An Eco-friendly Tool for Combating Water logging, 2015* ***88.*** *Mitigation Land Degradation due to Water Erosion, 2017* ***S6.*** *Strategy on Utilization of Glauconite Mineral as Source of Potassium, 2017* ***S8.*** *Conservation Policies for Hilsa and Mahseer, 2018* ***PB3.*** *Soil Health: New Policy Initiatives for Farmers Welfare, 2018* ***S13.*** *Development and Adoption of Novel Fertilizer Materials, 2019*
Addressing climate change and intensification of natural hazards and increasing incidences of pests and diseases; India is facing highest intensities of climate change volatilities and uncertainties, frequent droughts, floods and temperature fluctuations; emphasizing productivity and sustainability of rainfed areas, establishing a climate smart agriculture to achieve the triple wins of enhanced productivity, resilience,	***27.*** *Disaster Management in Agriculture, 2004* ***50.*** *Drought Preparedness and Mitigation, 2011* ***58.*** *Management of Crop Residues in the Context of Conservation Agriculture, 2012* ***60.*** *Water Use Potential of Flood-affected and Drought-prone Areas of Eastern India, 2013* ***65.*** *Climate Resilient Agriculture in India, 2014* ***69.*** *Carbon Economy in Indian Agriculture, 2014* ***81.*** *Climate Resilient Livestock Production, 2016* ***87.*** *Abiotic Stress Management with Focus on Drought, Food and Hailstorm, 2017* ***PB2.*** *Innovative Viable Solution to Rice Residue Burning in Rice-Wheat Cropping System through Concurrent Use of Super Straw Management System-*

and mitigation.	*fitted Combines and Turbo Happy Seeder, 2017* ***S11.** Rumen Microbiome and Amelioration of Methane Production, 2019*
Ensuring quality education, human resource capital, skill development, demographic dividend, **employability of graduates and employment security**; India houses largest number of unemployed/underemployed youth, promoting job-creating economic growth.	***6.** Reorienting Land Grant System of Agricultural Education in India, 1999* ***21.** Priorities of Research and Human Resource Development in Fisheries Biotechnology, 2003* ***25.** Stakeholders' Perceptions On Employment Oriented Agricultural Education, 2004* ***31.** Redefining Agricultural Education and Extension System in Changed Scenario, 2005* ***S5.** Strengthening Agricultural Extension Research and Education, 2017*
Improving sustainability, productivity and agricultural growth rate, input use efficiency, TFP; TFP growth rate 50 per cent of that of China; yield of several commodities at farmers fields are low and unstable; promoting high-yield seeds and related technologies; diversification; renewable energy; organic farming; zero budget natural farming.	***22.** Seaweed Cultivation and Utilization, 2003* ***30.**Organic Farming: Approaches and Possibilities in the Context of Indian Agriculture, 2005* ***35.** Low and Declining Crop Response to Fertilizers, 2006* ***41.** Sustainable Energy for Rural India, 2008* ***45.** Agrochemicals Management: Issues and Strategies, 2010* ***59.** Livestock Infertility and its Management, 2013* ***64.** Improving Productivity of Rice Fallows, 2014* ***71.** Role of Root Endophytes in Agricultural Productivity, 2014* ***76.** Bio-fuels to Power Indian Agriculture, 2015* ***S4.** Sustaining Soybean Productivity and Production in India, 2017* ***S9.** Accelerating Seed Delivery Systems for Priming Indian Farm Productivity Enhancement: A Strategic View Point, 2018* ***S10.** Renewable Energy: A New Paradigm for Growth in Agriculture, 2018*
Establishing a vibrant highly responsive and effective science, research, technology and innovation system coupled with effective holistic system-based extension, communication and technology transfer, adoption, adaptation and regulatory mechanism, promoting disruptive innovations; marrying corporate social responsibility with scientific social responsibility.	***9.** Strategies for Agricultural Research in the North-East, 2001* ***10.** Globalization of Agriculture: R & D in India, 2001* ***13.** Hi-Tech Horticulture in India, 2001* ***15.** Prioritization of Agricultural Research, 2001* ***18.** Agricultural Policy: Redesigning R & D to Achieve Its Objectives, 2002* ***21.** Priorities of Research and Human Resource Development in Fisheries Biotechnology, 2003* ***46.** Veterinary Vaccines and Diagnostics, 2010* ***61.** Mastitis Management in Dairy Animals, 2013*

	84. *Practical and Affordable Approaches for Precision in Farm Equipment and Machinery, 2016* ***PB1.*** *Policy Brief to Accelerate Utilization of GE Technology for Food & Nutrition Security and Improving Farmers' Income, 2016* ***85.*** *Hydroponic Fodder Production in India, 2017* ***S5.*** *Strengthening Agricultural Extension Research and Education - The Way Forward, 2017*
Linking farmers with markets, ensuring realization of remunerative prices, MSP equal to CII+50 per cent of CII; access to markets, production resources, and technology especially by smallholder farmers, addressing the price slippage issues and adequate coverage of Minimum Support Price and insulation from market volatilities and trade distortions and disputes, market reforms, improving terms of trade of agriculture and its backward linkages; reducing spoilage and improving labour productivity in agriculture.	***5.*** *Sustainable Agricultural Export, 1999* ***11.*** *Agriculture-Industry Interface: Value Added Farm Products, 2002* ***16.*** *Export Potential of Dairy Products, 2003* ***23.*** *Linking Farmers with Markets for Inclusive Growth in Indian Agriculture, 2015* ***75.*** *Empowerment of Women in Agriculture, 2001* ***78.*** *Reservoir Fisheries Development in India: Management and Policy Options, 2016* ***79.*** *Integration of Medicinal and Aromatic Crop Cultivation and Value Chain Management for Small Farmers, 2016*
Adopting a value chain approach from plough to plate, preventing post-harvest losses and wastes, adding value through on-farm processing, warehousing, storages, cold chains, assuring high products quality and zero waste.	***37.*** *Employment Opportunities in Farm and Non-Farm Sectors through Technological Interventions with Emphasis on Primary Value Addition, 2006* ***40.*** *High Value Agriculture in India: Prospects and Policies, 2008* ***62.*** *Biopesticides – Quality Assurance, 2014* ***67.*** *Urban and Peri-urban Agriculture, 2014* ***89.*** *Vertical Farming, 2019*
Enhancing budgetary allocation to the agriculture sector, including water resources, related infrastructure and institutions, especially in research, education, and extension for agrarian development; streamlining the centre-state linkages in AREE4D through NITI Aayog's cooperative federalism initiative.	***S3.*** *Strengthening Agricultural Extension Research and Education, 2017*
Enhancing generation and use	***19.*** *Intellectual Property Rights in Agriculture, 2003*

of new innovations and technologies, such as genetic engineering, synthetic biology, nano-technology, bioinformatics, and space technology; Ensuring data-led governance and policy making for achieving growth, equality and sustainability of agri-food system; establishing and streamlining collection, sharing, processing and integration of quality data from all levels along the entire value-chain using the Big Data approach for developing sound methodologies for creating indicators for implementation, outcome and pathways analyses towards planning and evidence-based policy formulation; new and emerging technologies, regulatory measures, and intellectual property.	***24.*** *Biosafety of Transgenic Rice, 2003* ***29.*** *Transgenic Crops and Biosafety Issues Related to Their Commercialization In India, 2004* ***44.*** *Plant Quarantine including Internal Quarantine Strategies in View of Onslaught of Diseases and Insect Pests, 2010* ***52.*** *Biosafety Assurance for GM food Crops in India, 2011* ***53.*** *Ecolabelling and Certification in Capture Fisheries and Aquaculture, 2012* ***63.*** *Nanotechnology in Agriculture: Scope and Current Relevance, 2014* ***72.*** *Bioinformatics in Agriculture: Way Forward, 2014* ***77.*** *Aquaculture Certification in India: Criteria and Implementation Plan, 2015* ***PB1.*** *To Accelerate Utilization of GE Technology for Food & Nutrition Security and Improving Farmers' Income, 2016*
Ensuring comprehensive international collaboration; As local and global are increasingly becoming interdependent, and despite the tariff wars, protectionism and antiglobalization moves, the world has adopted some global commitments such as the sustainable development goals (SDGs) – Agenda 2030 and Compact 2025, which seek global convergence in agricultural transformation to enhance economy and social security consistent with environmental sustainability. In this context, India must ensure comprehensive international collaboration, especially through South-South and Trilateral cooperation to share modern and emerging technologies and innovations.	***12.*** *Sanitary and Phytosanitary Agreement of the World Trade Organization – Advantage India, 2001* ***38.*** *WTO and Indian Agriculture: Implications for Policy and R&D, 2006* ***44.*** *Plant Quarantine including Internal Quarantine Strategies in View of Onslaught of Diseases and Insect Pests, 2010*

Creating effective transparent governance and implementation pathways encompassing monitoring, evaluation, outcome and impact assessment through deploying result frameworks, differentiated responsibility and accountability of various stakeholders and partners (public-private-producer partnership).	***17.*** *Scientists' Views on Good Governance of an Agricultural Research Organization, 2002* ***34.*** *Guidelines for Improving the Quality of Indian Journals & Professional Societies in Agriculture and Allied Sciences, 2006* ***73.*** *Monitoring and Evaluation of Agricultural Research, Education and Extension for Development [AREE4D], 2015*

**Policy paper (serial number); #Policy Brief (PB) serial number; @ Strategy Paper (S) serial number*

Several of the above challenges and their possible solutions and associated policy options and actions were elucidated in the various addresses of the Presidents of the Academy, especially at the Annual General Meetings of the Academy. Several other substantive publications of the Academy, Annexure 1, contained elaborate analysis on specific themes and science-informed policy options and strategies.

The above publications have been widely used by the National Agricultural Research, Education and Extension Systems and other stakeholders, and internalized in national policies and action plans.

3.3 Aligning Agenda 2030 – the SDGs with the Challenges Facing Indian Agriculture–Food System as identified by NAAS

The 2030 Agenda for Sustainable Development calls for bold transformational changes to achieve a world that is more inclusive, fair, sustainable, and resilient, a world free of hunger and extreme poverty, a world that protects and promotes sustainable use of biodiversity and all natural resources for development, a world that is more just, and a world of peace. The 14 groups of challenges identified and their resolutions identified by NAAS above are akin to the 17 SDGs.

NAAS's vision is an India free from hunger, undernutrition and abject poverty, where agricultural and food systems are pivotal to improving livelihood security consistent with social, economic and environmental security. As the country strives to realize the vision, understanding of the trends and challenges will greatly help in finding solutions, strategies and policies for meeting the challenges and achieving the national goal under the SDG umbrella. As mentioned earlier, NAAS policy perspectives evolved during the past nearly 30 years on many of the most important issues facing food and agriculture today seek to promote multi-stakeholder partnerships to mobilize technical, policy, and financial resources required by the country for achieving the SDGs. The foremost challenges identified by NAAS are almost the same as the foremost Goals under Agenda 2030.

It must be reiterated that NAAS prepares and promotes evidence-based policy through structured dialogue by the Fellows, other scientists and stakeholders at the national level. Often in its conferences/congresses it involves leading experts from all over the world, including the UN, CGIAR, and World Bank. Most of the policy options and actions suggested by NAAS are internalized in the National Policy, but the Academy has little say in implementation of recommendations and in monitoring their effectiveness. Consequently the Academy had given little attention to the preparation of strategic results framework and results matrix with clearly defined responsibility and accountability. However we should be proactive in monitoring and outcome assessment and suggest a matrix framework for the implementation agencies. India will do well to focus on the following frameworks which may assist in meeting the SDGs, as suggested by FAO (2018), and recommended and reiterated in various NAAS publications.

a) Strengthening the linkage between Agriculture and Social Protection initiatives:

This is successful only when integrated into broader livelihood promotion and rural development strategies. Hence we must promote coherence between social protection, food security and nutrition, and agricultural interventions – "Cash Plus" approach. Greater attention is needed for improving:

- Inadequate physical and social infrastructure
- Isolation and territorial distances
- Limited institutional capacity
- Community-based and traditional approaches, and
- Adapting to ageing of the rural population.

b) Congrueing the agricultural sectors in nationally determined contributions with priority areas for international support through:

- Compliance with enhanced transparency framework of the Paris Agreement
- Coherent policy frameworks for climate action in the agriculture sectors
- Research, analysis and tools to connect the local and global
- Capacity development for implementation and action in agriculture sectors
- Investment for the development of Agriculture sectors
- Developed & Developing countries to commit needed financial resources
- Global community committed support to the above initiative.

c) **Sustainable agriculture development for food & nutrition security by ensuring following actions:**

- Foster policy coherence for food security and nutrition
- Address nutrition, food safety, working conditions & services
- Foster empowerment of youth
- Protect the environment and promote sustainable management and efficient use of natural resources
- Enhance resilience against risks and variability
- Promote cooperation and collaboration in innovation, research and development, and address data needs
- Improve animal health and welfare
- Recognize, protect and support pastoral systems for livelihoods and sustainable resource management
- Promote and support sustainable grazing systems
- Promote and support mixed systems
- Promote the sustainability of intensive systems.

d) Connecting smallholders to markets:

Smallholders account for 70 per cent of world's food supply, yet majority of the hungry are smallholders. With full understanding of the role of smallholder in a changing context, linkages among local, national, and regional markets and food systems, gender equity and empowerment, youth aspirations and expectations, international markets, need for comprehensive nutritional security, and institutional procurement, the following recent FAO recommendations for linking smallholders with markets should be adopted in total:

- Collect comprehensive data on markets linked to local, national, and regional food systems
- Promote a more enabling market environment for smallholders
- Support affordable mechanisms for smallholders' access to useful timely and transparent market and price information to enable informed decision making.
- Promote and expand opportunities, including procurements, food assistance and school feeding
- Improve procurement procedures
- Establish policy and institutional arrangement along the value chains and for contractual arrangements

- Promote institutional innovation and improve agriculture production systems and integrate smallholders in the value chain
- Promote inclusive participation in local food systems, especially women and youth
- Invest in the improved processing facilities and tools and equipment, access to smallholder, emphasize quality, safety, and reduce seasonality of food insecurity
- Improve access to inclusive financial assistance, micro-financing, special terms of credit, start-up capital, insurance
- Develop or improve smallholder targeted infrastructure, *viz* irrigation, small-scale processing, packaging, feeder roads, energy, market places for direct sale.
- Recognize the environmental, social and economic value of food produced in context of smallholders
- Promote integrated and balanced approaches between policies and national strategies, including gender-targeted interventions, market linkages etc.
- Promote smallholder products with specific qualities responding to consumers demand while preserving traditions and biodiversity
- Facilitate production diversification towards CSA, and diversified food consumption for nutrition, reduce seasonal fluctuation
- Invest in capacity building and smallholder innovation, technology building to enhance value addition, employment, income
- Encourage production of nutritious and healthy foods that may produce new market opportunity
- Promote short food supply chains to obtain better return
- Ensure ownership of assets by smallholders, land rights, employment opportunities, access to financial services, and simplified administrative procedures
- Promote rigorous protection of food safety and provide necessary training, information and capacity building
- Target education & training, particularly to youth, entrepreneurship development, agribusiness
- Support development of production, entrepreneurial capacities, their enterprises, with special attention to women and youth
- Promote South-South and Triangular and North-South cooperation as per Addis Ababa Action Agenda
- Increase their bargaining capacity and control over their economic environment, forming cooperatives associations & networks, equal participatory decision making powers.

The Govt. of India is giving high priority to transforming agriculture to make it more efficient, competitive, sustainable and resilient and has launched several new inititatives viz. Doubling Farmers' Income, The Prime Minister Irrigation Yojana, the Prime Minister Agricultural Insurance Scheme, the National Mission on Sustainable Agriculture, and e-NAM (One Nation, One Market) geared towards accomplishing the SDGs. Keeping in view the fast growing urbanization, links between rural and urban areas should be improved to ensure desired outcomes (Paroda, 2018).

3.4 Internalization of NAAS Policy Papers and Recommendations in the National Agricultural Development Process

Towards formulating science-informed policy options, most of the policy papers had analyzed the technological, socio-economic, ecological, and institutional challenges and opportunities, as highlighted in the Introductory Chapter.

To illustrate the usual structure and scope of the Policy Papers and efficacy of implementation of such policy papers, salient points of the Policy Paper 35, 2006, entitled "Low and Declining Crop Response to Fertilizers", as an example, are enumerated here. The paper emerged from a brainstorming session convened by an eminent ICAR National Professor and NAAS Fellow, involving nearly 50 selected stakeholder experts. It had made recommendations under four heads, namely: (i) cause for low and declining crop response to fertilizers, (ii) agenda for research, (iii) rejuvenation of agricultural extension, and (iv) policy decisions.

Further, congrueing the above four aspects, the following overall policy recommendations were made to formulate a long term pragmatic policy for all fertilizer nutrients including secondary nutrients and micronutrients to achieve balanced nutrition to overcome soil fertility and health degradation, and to improve crop productivity on a sustainable basis:

- Adequate number of well equipped soil-testing laboratories manned by well trained personnel to take care of secondary and micronutrient analysis
- Soil health cards for all the categories of the farmers throughout the country for the purpose of periodical monitoring of soil fertility status and as one of the sources for obtaining agricultural credit
- Quality control for fertilizers including micronutrient fertilizers
- Standardization of organic manures
- Providing price incentives to the fertilizers manufacturers opting for the manufacture of value-added fertilizers such as neem-coated urea and balanced customized fertilizers
- Strengthening collaboration between the fertilizer industry and national institutes engaged in developing soil test-based and site-specific nutrient recommendations to develop soil- and crop-specific quality fertilizers

- Provision of a transparent regulatory framework for ensuring supply of tailor-made crop-and soil-specific quality fertilizers to the farmers and corresponding provision in the Fertilizer (Control) Order, GoI
- More proactive State Fertilizer Review Committees having wider representation of the scientists and the industry and empowered with quality control for blended and value-added fertilizers
- Ensuring credit to the farmers at low interest rates for the purchase of fertilizers, seed, pesticides, and agricultural equipment
- Providing subsidies to promote cultivation of legume crops for green manuring/grain to build-up soil fertility and to meet the shortage of pulses requirements in the country
- Establishment of a national network on Integrated Fertilizers Development for Sustainable Agriculture by the ICAR/Ministry of Agriculture
- Establishment of Coordination Cell for coordinating the activities of different ministries of Government of India related to efficient use of fertilizers such as Ministry of Agriculture, Ministry of Fertilizers and Chemicals, Ministry of Irrigation, ICAR and National Commission for Farmers.

The scientific, environmental, economic (productivity), sustainability, partnership (cooperative federalism), and institutional contextuality of the above suggested policy actions are more than obvious. It is encouraging that some of the recommendations have been implemented with certain outcomes, including the adoption of neem-coated urea, championed in recent years by none other than our Prime Minister Shri Narendra Modi. Science-informed wholesome action plans are needed for effective holistic implementation of the recommendations. For instance, the recommendation made at the above serial no. 2 regarding Soil Health Card has now become a national movement, but the preceding recommendation at no.1 on soil testing laboratories (and adequately trained human resources) which underpins the quality and efficacy of the Cards, remains poorly implemented. As a result, despite huge investment and claimed wide coverage of the project as judged by the targeted issuance of 140 million Soil Health Cards within the stipulated five-year periods – 2015 to 2019, there is little evidence of soil health improvement reflected in enhanced input use efficiency, total factor productivity, output productivity, and farmers' income. Such dichotomies in implementation should be eliminated soonest, and should not arise to begin with.

Several of the recommendations contained in the NAAS Policy Papers were internalized in the National Plans, especially the XIth and XIIth Plans, and got reflected in agricultural universities curricula and research and extension priorities of the National Agricultural Research System (NARS). Most importantly, the recommendations were prominently reflected in the National Policy for Farmers (NPF), 2007, drafted by the National Commission on Farmers (NCF) in its Final Report, 2006, as given below:

- To increase focus on the economic well-being of the farmer rather than only on production; measure the agricultural progress by farmers' net income growth; rename the Agriculture Ministry as Ministry of Agriculture and Farmers Welfare
- To develop support services including provision for seeds, irrigation, power, machinery and implements, fertilizers, and credit at affordable prices and in adequate quantities
- To conserve and improve land, water, and biodiversity resources, and to strengthen the bio-security of crops, farm animals, fish and forest trees for safeguarding livelihood and providing income security to farmers and national health and trade security
- To strengthen farmer-market-consumer linkage and value chain management and to provide appropriate price and trade policy mechanisms to enhance farmers' income
- To complete the unfinished agenda in land reforms, and to undertake asset reforms to empower farmers and to promote inclusive agricultural growth
- To provide appropriate opportunities for non-farm and off-farm employment to farmer households, and to strengthen rural livelihoods
- To provide suitable risk management measures for adequate, timely compensation to farmers
- To develop and introduce a social security system for farmers, and to foster community-based food, water and energy security system to ensure nutrition security at the level of every child, woman and man
- To introduce measures to help attract and retain youth in farming, and to restructure university curricula to strengthen their entrepreneurship and employability and
- To make India a global outsourcing hub in the production and supply of agriculture products and related inputs, and promoting use of modern technologies such as biotechnology, nanotechnology and ICT.

It is gratifying that some of the initiatives of the government during 2006-13, such as the National Rainfed Area Authority, National Food Security Mission, Rashtriya Krishi Vikas Yojana, and National Food Bill, were in consonance with the intent, direction and measures suggested in the National Policy for Farmers (NPF), and echoed in the NAAS Policy Papers. Several of the recommendations were further analysed, refined, and sharpened and it is doubly gratifying that these have been streamlined in the current development thrust of the present Government since 2014, and the Prime Minister's call for Doubling Farmers Income, Empowering the Farmer, renaming the Ministry of Agriculture as the Ministry of Agriculture and Farmers Welfare, fixing the MSP at CII+50 per cent of CII, and Reaching the Unreached are being implemented.

During the past couple of decades several significant agriculture-related events/trends were witnessed. The food price spike and financial crises during 2008 had globally pushed over 100 million more people into poverty. Most affected were the majority rural poor, mostly involved in farming in developing countries. It also emerged that those agriculturally dependent and agriculturally important countries which had managed their agriculture adequately, generally escaped and absorbed the shocks rather satisfactorily and recovered soon. Overall GDP growth originating in agriculture had proven to be, on an average, two to four times as effective in raising income of the poor as growth generated in non-agriculture sector.

The World Development Report 2008: Agriculture for Development had underpinned the centrality of agriculture in the 21st century for poverty reduction, economic growth, and environmental sustainability. It had highlighted that efficacy of the system will depend upon the ability of concerned institutions, policies and investments to respond to accelerated demand for food, globalization of markets and associated risks, rising urbanization, growing land and water scarcity, and climate change. For operationalization of the policy options and programs, the World Bank (2010-12) had suggested five key areas for action, namely:

- Raise agricultural productivity growth
- Link farmers to markets and strengthen value chains
- Reduce risk and vulnerability
- Facilitate agricultural entry and exit, and rural non-farm income
- Enhance environmental services and sustainability, including climate change management.

The bang of the 2008 global crisis was heard by most national and concerned international programmes and a renewed commitment to agriculture emerged globally. Efforts were accordingly geared to harness the power of agriculture to promote poverty alleviation with focus on farm and non-farm rural incomes, inclusive economic growth, nutritional security, zero hunger, and sustainable development.

The NAAS took full cognizance of the crisis and adjusted its priorities/programmes of work. Its brainstorming sessions met more frequently and discussed the prevailing and foreseen problems and their possible scientific, policy and institutional solutions. The sub-challenges within a set of challenges, and the 14 sets of challenges among themselves are interrelated and often interdependent. The foremost two challenges, hunger and poverty, identified by NAAS are analogous to the topmost two challenges of the Agenda 2030 (SDGs 1 and 2). Meeting the 14 sets of NAAS challenges could be seen as 14 Goals of the Academy (NAASG 14). For each Goal, the listed policy/theme/strategy papers have identified specific activities, but have not set the target. As done for the SDGs (see the box below for SDG1 – Ending Poverty), NAAS should, as elaborated in Chapter 17 fix targets and prepare an implementation pathway to reach the targets.

The Global Targets for Sustainable Development Goal 1 to be achieved by 2030

1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day

1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions

1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable

1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance

1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters

1.a Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programs and policies to end poverty in all its dimensions

1.b Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions.

As mentioned earlier, India, and most other countries, have adopted the SDGs and set targets and strategies as per their needs, possibilities and perspectives. For instance, India is implementing a comprehensive development strategy to end poverty in all its forms. As elucidated by NITI Aayog (2018), the strategy encompasses focusing on economic growth, poverty alleviation programs, ensuring gainful employment, and improving access to basic services particularly to the vulnerable. Necessary institutional platforms, technology support and financial services are also geared to meet the goal. Analogous to the global targets, based on national indicators, India's SDG1 indices were fixed by NITI Aayog as below.

Indicators Selected for SDG - 1 India Index	National Target Value for 2030
(1) Percentage of population living below National Poverty line	10.95
(2) Percentage of households with any usual member covered by any health scheme or health insurance	100
(3) Persons provided employment as a Percentage of persons who demanded employment under MGNREGA	100
(4) Proportion of the population (out of total eligible population) receiving social protection benefits under Maternity Benefit	100
(5) Number of homeless households per 10,000 households	0

A number of outcome-based specific programs and schemes have been launched at national, regional and state levels, such as Mahatma Gandhi National Rural Employment Gurantee Act

(MGNREGA), Pradhan Mantri Jan-Dhan Yojana (PMJDY) and Deendayal Antyodaya Yojana of Pradhan Mantri National Rural and Urban Livelihood Mission, National Social Assistance Programs (NSAP), Pradhan Mantri Jeevan Jyoti Bima Yojana, Pradhan Mantri Jeevan Suraksha Bima Yojana, Ayushman Bharat, National Food Security Mission, Poshan Abhiyan, Swachh Bharat Mission, Pradhan Mantri Awas Yojana, Pradhan Mantri Ujjwala Yojana etc.

SDG 2- Ending all forms of hunger and malnutrition by 2030, one of the foremost global goals is the highest priority of India. The targets to be achieved by 2030, as listed below, are reflected in the 14 challenges identified by NAAS, and are linked with SDGs 1,3,4,5,6,7,8,10,12, and 13.

The Global Targets to be achieved for SDG 2 (end hunger) by 2030 are as follows:

2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round

2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under five years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women, and older persons

2.3 By 2030, double the agricultural productivity and the incomes of small-scale food producers, particularly women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets, and opportunities for value addition and non-farm employment.

2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters, and that progressively improve land and soil quality

2.5 By 2020, maintain genetic diversity of seeds, cultivated plants, farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at national, regional and international levels, and ensure access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed

2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development, and plant and livestock gene banks to enhance agricultural productive capacity in developing countries, in particular least developed countries

2.b Correct and prevent trade restrictions and distortions in world agricultural markets, including by the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round

2.c Adopt measures to ensure the proper functioning of food commodity markets and their derivatives, and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility

The NITI Aayog, has, however, identified only four national targets as listed below:

Indicator Selected for SDG India Index	National Target Value For 2030
(1) Ratio of rural households covered under public distribution system to rural households where monthly income of highest earning member is less than Rs.5,000	1.29
(2) Percentage of children under age 5 years who are stunted	21.03
(3) Percentage of pregnant women aged 15-49 years who are anaemic (11.0g/dl)(per cent)	23.57
(4) Rice, wheat and coarse cereals produced annually per unit area (Kg/Ha)	5018.44

As mentioned earlier, the NAAS papers have suggested specific as well as general actions towards meeting the goals/challenges, but have not set targets. Considering that India and rest of the Asia-Pacific is not making satisfactory progress towards achieving the targets set for some of the important goals viz. SDG1 and SDG 2, analogous to NAAS G1 and NAAS G2, this compilation includes chapters which fill the gaps in the policy/strategy options and implementation pathways. Some of the papers support additional new points to develop relevant policy options/actions/strategies as for realizing Farmers' Rights. A couple of the papers are simply abridged reproduction of earlier policy papers for underpinning and reemphasizing some of the important aspects awaiting redressal *viz.* genetical engineering, accelerated oilseeds production, and renewable energy.

Notwithstanding the various ongoing programs and the above suggested overall framework for implementing the SDGs in general, specific Roadmap Framework should be formulated and judiciously implemented for specific SDGs to achieve targeted outcomes and impacts. In this context, the joint efforts of RIS (Research and Information System for Developing Countries) and WFP (World Food Programme of the United Nations) in preparing a Roadmap Framework for SDG2 (Zero Hunger) is laudable. NITI Aayog which is responsible for overall coordination of SDGs and the Ministry of Statistics and Programme Implementation (MoPSI) which is responsible for evolving indicators, alongwith other concerned ministries and agencies, are already preparing Roadmap Frameworks for all the SDGs. NAAS should join hands with such ongoing efforts and ultimately come up with robust Result Framework for effective implementation of new policy options.

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Chapter 4
Nutrition-Sensitive Agriculture and Food System to Build Zero Hunger New India

4.1 Ending Malnutrition by 2030: the Foremost Priority of India

Hon'ble Prime Minister Narendra Modi, respecting the wishes, aspirations, hopes, and desires of 1.3 billion Indians, pledged on 15 August 2017, the 71st Independence Day, to build a New India by 2022. He envisioned an innovation-driven, vibrant, healthy India free from corruption, communalism, casteism, terrorism, and illiteracy. He further envisioned a clean (*swachh*) India characterized by peace, prosperity, unity, plurality, transparency, inclusiveness, and compassion. To be prosperous, inclusive, and at peace, **New India must also be free from abject poverty, hunger, and under-nutrition** – the foremost priority of the Sustainable Development Goals (SDGs) – Agenda 2030.

India, through the Green Revolution process ushered in the 1960s, and followed by White, Yellow and Blue Revolutions, had witnessed unprecedented gains in agricultural and food production, registering record productions of nearly 300 million tonnes of foodgrains, 315 million tonnes of fruits and vegetables, 175 million tonnes of milk (highest in the world), and 12 million tonnes of fish, rendering India the second largest agrarian economy of the world. Importantly, the Rainbow Revolution had halved the incidences of poverty and hunger in the country and transformed the nation from the state of ship-to-mouth to the state of Right-to-Food based on home-grown food. And, India emerged as a major exporter of foodgrains and other agricultural products. The revolution was largely due to the synergy of technologies, informed policies, services, farmers' enthusiasm and strong political will.

Despite the Rainbow Revolution and high overall economic growth rate of about 8 per cent during the past decade or so, nearly one-fourth of world's hungry and 40 per cent of the world's undernourished, stunted, and, wasted children have their homes in India. It is estimated that the high under-nutrition in the country may annually cost about 6-10 per cent of the national GDP, let alone the unethically entrenched human deprivation. Moreover, the epigenetic effect of hunger has aggravated the intergenerational injustice. Obviously, the "Pot of gold", meaning eternal justice, inclusiveness, prosperity, peace, happiness, and vibrancy, at the end of the Rainbow (Revolution) has remained elusive. A big question is: how a 'tall' vibrant New India could be built on the shoulders of stunted and wasted children?

Globally, studies have shown that in agriculturally important countries, like India, growth in Agriculture and Food System (AFS) is almost three times more effective in alleviating hunger, poverty and undernutrition than analogous growth in other sectors. Being the second largest agriculture economy in the world, India must harness its AFS effectively to break the enigmatic co-existence of high economic growth and the deprivations (an infamous Indian Enigma). The food and agriculture system must be transformed so that the related development should not mean only enhanced production, instead it should mean production plus plus, with equal emphasis on remunerative net income of the farmer, physical and economic access to adequate quality food, safe drinking water, sanitation and hygiene, ecological efficiency, environmental health, nutritional adequacy, inclusiveness, and sustainability, seeking a wholesome and integral approach.

State of Malnutrition in India

Of the 821 million undernourished people in the world, 196 million are in India, the largest number in any country in the world. Worst, of the world's 51 million wasted children below the age of five; 26 million are our own children (Table 1). As regards prevalence of undernutrtion, over 15 per cent of Indians are undernourished against the corresponding world average of 10.8 and China's average of 9.6 per cent (Table 2). In the 0 to 5 age group, over 38 per cent of Indian children are stunted against only 9 per cent in China.

Table 1. Number of undernourished people, 2017 (millions)

Geographic entity	Number of undernourished people	Number of children under 5 wasted	Number of children under 5 stunted
World	821	51	151
India	196	26	47
China	125	1.6	6.9
Asia	515	35	84
Africa	257	14	59

Source: FAO, The State of Food Security and Nutrition in the World, 2018

Table 2. Prevalence of undernutrition (per cent)

Geographic entity	Prevalence of undernourishment in total population		Prevalence of stunting under 5 years age		Prevalence of wasting under 5 years age	Prevalence of Anaemia among women of reproductive age (15 to 49 years)	
	2004-06	2015-17	2012	2017	2017	2005	2016
World	14.3	10.8	24.9	22.2	7.5	30.6	32.8
China	15.3	9.6	11.7	9.4	2.3	18.4	26.4
India	20.5	15.1	47.9	38.4	21.0	53.2	51.21
Brazil	4.5	<2.5	7.1	-	-	27.5	27.2

Source: FAO, SOFI, 2017

Stunting in children below 5 is widespread among developing countries being highest in South Asia (36 per cent) and Africa (34 per cent) (Figure 1). India, despite some progress made in the past decade or so, continues to have the largest number of stunted, wasted, underweight children – seriously eroding the human resource base. Worst, the number of wasted children has been increasing (Figure 2). Hidden hunger, deficiency of iron, zinc, calcium, vitamin A, B-complex vitamins, particularly vitamin B2 (riboflavin) and folic acid is rampant. Sixty per cent children below five are deficient in Vitamin A and 70 per cent of children are anaemic. Deficiencies of vitamin D and B-12 which were not considered to be of public health importance are emerging as new areas of concern. What is particularly worrisome is reduction in the extent of undernutrition over many decades has been highly sluggish.

While undernutrition is entrenched and declining very slowly, the burden of obesity has started enhancing rather steadily. The prevalence of obesity in adult > 18 almost doubled between 2012 and 2017, increasing from 3 per cent to 5.8 per cent. (Table 3).

Table 3. Prevalence of overweight and obesity (per cent)

Geographic Entity	**Prevalence of overweight in children, <5**		**Prevalence of obesity in adult, >18**	
	2012	**2017**	**2012**	**2017**
World	5.4	5.6	11.7	13.2
India	1.9	2.1	3.0	5.8
China	6.6	na	5.1	6.6
Asia	4.5	4.8	6.0	7.3
Africa	5.0	5.0	10.4	11.8

Source: FAO, the State of Food Security and Nutrition in the World, 2018

Figure 1. World Stunting Map

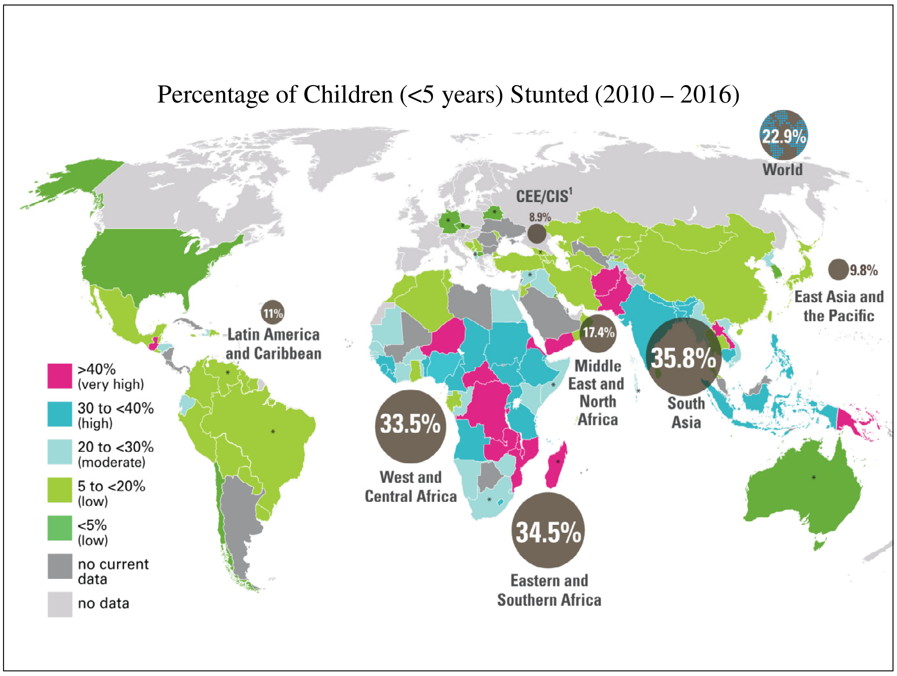
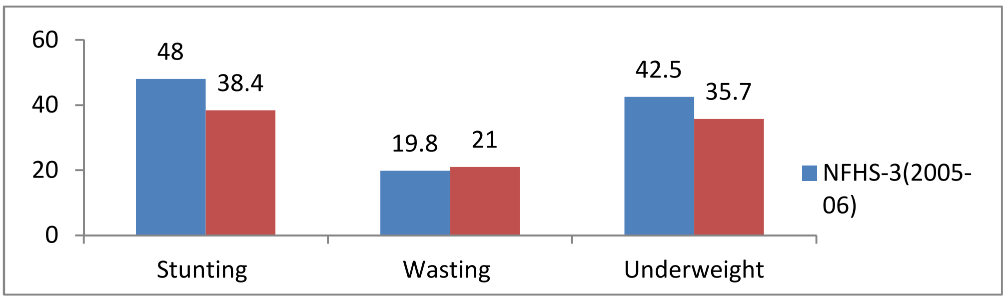


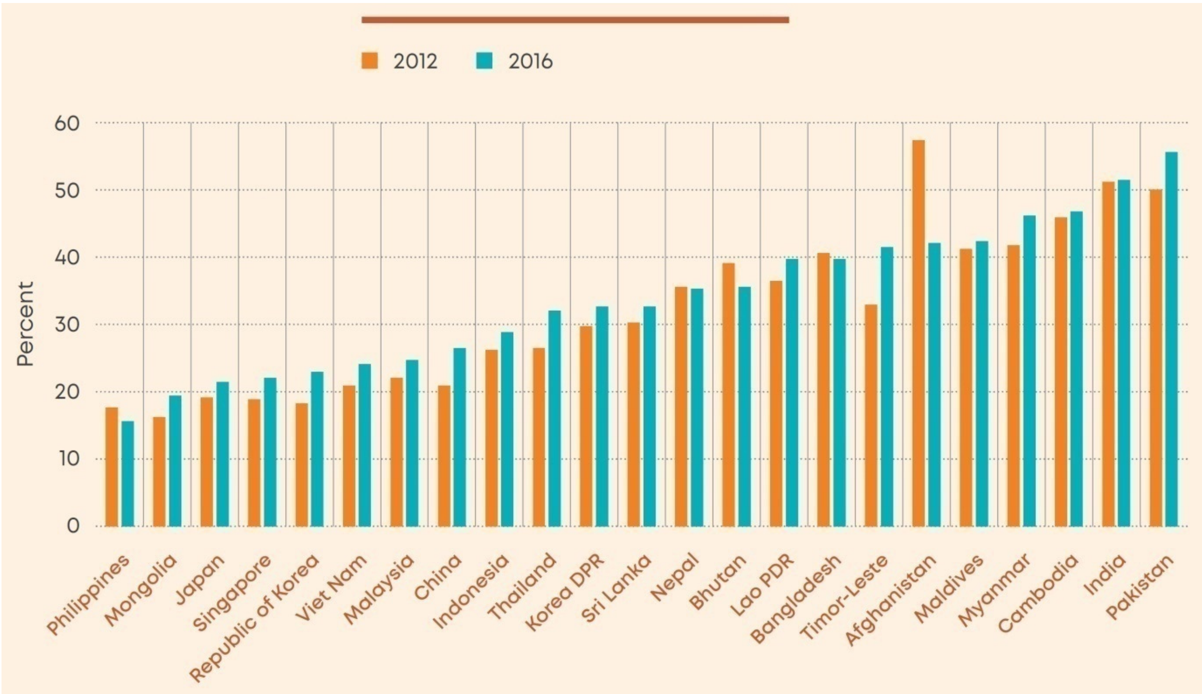
Figure 2. Incidence of child undernutrition (per cent) in India



Source: NITI Aayog, Nourishing India, 2018

Figure 3 gives the prevalence of anaemia in women of reproductive age in Asia. More than of 50 per cent of Indian women are anaemia. Almost a quarter of men working force suffer from anaemia, and they are about 10 per cent less productive than they could be. About 24 million primary school children in our country attend classes hungry. Studies have shown that cognitive ability of malnourished children is two to three times worse than their adequately nourished peers. Unfortunately, the hidden hunger is seen as "normal", seriously undermining its prominence as a development issue.

Figure 3. Prevalence of Anaemia in Women of Reproductive Age in Asia



Source: FAO. 2018. Asia and the Pacific Regional Overview of Food Security and Nutrition 2018

While in the poorer regions and areas deeply stressed by climate change, there is stagnating higher concentration of stunted and wasted children, the richer regions have increasing incidence of obesity in both men and women increasing respectively by 60 to 100 per cent during the last 10 years.

Undernutrition takes a heavy toll of human health and consequent suffering and adverse impact on national productivity and overall development. Some of the important consequences are: (1) over one-third child deaths are due to undernutrition, due to greater severity of diseases, (ii) undernutrition between conception and age 2 yrs (1000 days) has lesser physical and mental development affecting productivity and national development, (iii) Economic cost of undernutrition: Direct-increased burden on health care, Indirect-lost productivity, is high (iv) According to the World Bank (2012) report, annually India loses more than $12 billion in GDP to vitamin and mineral deficiencies. Childhood anaemia alone is associated with a 2.5 per cent drop in adult wages, (v) Malnourished children are at risk of losing more than 10 per cent of their lifetime earnings potential, and (vi) Malnutrition may increase the risks of HIV infection, while reducing the numbers of children and mothers who survive malaria.

Thus, today elimination and prevention of undernutrition and the overall malnutrition in India is most critical for development in space and time. In the life cycle approach it must be prevented as early as possible to avert irreversible deficits in development of individuals, societies, and the nation as a whole. Intergenerational continuity of high incidences of undernutrition is fraught with the epigenetic fixation of the malady. And, this inhuman development must be averted soon (Singh, 2015).

The Global Nutrition Report 2016 had highlighted that malnutrition annually costs about 11 per cent of the GDP in Asia, and preventing malnutrition delivers $ 16 to 40 in return on investment for every $ 1 spent. Given the high prevalence of undernutrition, India carries high health, humanitarian, economic, and social burdens - the foremost challenge facing the country. Needless to assert, without effective concurrent investment in nutrition, health, and human capital, India would not have the thriving workforce to benefit from the structural transformations and to trigger accelerated, inclusive, and sustained economic growth to build New India.

Developing nations should reposition nutrition as central to development. According to a group of economists, including three Nobel laureates, investment in nutrition is one of the 'best buys' that developing countries can make for economic growth. The following statement from Policies without Politics: Analyzing Nutrition Governance, sums up the need for holistic governance to address the problem of malnutrition in India, "It is widely believed that India's limited success in dealing with undernutrition is linked to poor governance, including lack of a strong national agenda against malnutrition within the highest executive offices; lack of consistent monitoring of the situation based on reliable data; and an inability to comprehend malnutrition as a holistic issue, unsatisfactory quality of interventions across a number of sectors, including water and sanitation, education, agriculture, and others. Malnutrition is viewed primarily as a problem of hunger and food distribution, requiring supplementary feeding and subsidized distribution systems".

The poor spends 60 to 70 per cent of his income to meet his daily food needs. Any increase in food prices and uncertainties in supply caused due to climate change and other reason, are bound to further depress the food and nutritional security of poor. And, unfortunately one-fourth of the world's poor have their homes in India. Therefore, India must be most vigilant in not allowing the situation to worsen by ensuring secured, sustained need based investment in developing appropriate technologies, effectively adopting them at the farmers' field and at ground level, and consistent increase in their net incomes by linking the farmers to remunerative markets. Only such efforts can defy Malthus and Paddock Brothers who had predicted mass starvation deaths in India.

4.2 Global Commitment for Ending all Forms of Malnutrition

Ever since the UNICEF globally in 1990 formulated the Policy Framework and gave holistic approach for multi-sectoral multilevel response to malnutrition, several major global initiatives have emerged. UNICEF had identified key drivers of malnutrition and emphasized stakeholders responsibility and accountability. In recent years, momentum around nutrition has intensified. In 2012 the UN Zero Hunger Challenge Program was announced at the Rio+20 UN Conference on Sustainable Development. In the same year, the World Health Assembly adopted the 2025 Global Target for Maternal, Infant and Young Child Nutrition. In 2013, it adopted targets for non-communicable diseases (NCDs). Also in 2013, at the first Nutrition for Growth (N4G) Summit, donors committed US $ 23 billion to actions to improve nutrition. The 2014, Second International Conference on Nutrition (ICN2), recent renaming of 2016-2025 as the UN Decade of Action on Nutrition, and milestones such as Scaling-Up Nutrition (SUN) Movement have evoked global awareness to addressing malnutrition in all its forms. These initiatives are directly and highly relevant to India and should be duly internalized in India's policies and actions on comprehensive nutritional security.

The UN Sustainable Development Goals announced in 2015 - Agenda 2030 (SDGs, 2016 to 2030), especially SDG2, calling for Zero Hunger by 2030, has the objective of "ending all forms of malnutrition", for all people, by 2030, with targets for doubling agricultural productivity and income of small-scale food producers (SDG 2.3).

Target 2.2 of SDG 2 calling for ending all forms of malnutrition, adopted the targets agreed by the World Health Assembly, 2025, as given in the Box below: Other sub-goals of SDG2 are ensuring sustainable food systems (SDG 2.4), and maintaining genetic diversity (SDG 2.5). The SDGS were built on the Millennium Development Goals (MDGs, 2000 to 2015), the foremost goals of these two global initiatives are synonymous – end poverty and hunger, achieve food security and improved nutrition, and promote sustainable development. And, in India, a vibrant and dynamic agriculture is central to meeting most of the SDGs.

Table 4. World Health Assembly Six Global Nutrition Targets for 2025 for Material, Infant and Young Child Nutrition and One NCD Target

		WHA targets
	Stunting	40 per cent reduction in the number of children under five who are stunted
	Anaemia	50 per cent reduction of anaemia in women of reproductive age
	Low birth weight	30 per cent reduction in low birth weight
	Childhood overweight	No increase in childhood overweight
	Breastfeeding	Increase the rate of exclusive breastfeeding in the first six months up to at least 50 per cent
	Wasting	Reduce and maintain childhood wasting to less than 5 per cent
		NCD Targets
	Adult obesity	Halt the rise in obesity

Source: WHO, 2014a; FAO, 2018a

4.2.1 FAO Leading the Global Zero Hunger Challenge Program

The United Nations' Secretary General while announcing the Global Zero Hunger Challenge Programme had called for building a future in which all people enjoy their fundamental right to food, and in which their livelihoods and food systems are resilient and able to withstand the pressures induced by climate change and other resource and environmental challenges. The Global ZHC programme is based on five pillars (Figure 4). The Secretary General had hoped that we can achieve Zero Hunger during our lifetimes, say by 2030.

Figure 4. Five Strategies of the Global Zero Hunger Challenge Program

Each of the above strategic pillars had their defined outcomes (Table 5).

Table 5. Expected outcomes of the five strategies of ZHC program

Strategy	Outcome
1. Zero stunted children less than two years	Access to the needed food through sustainable agriculture and food systems, employment security and social protection, fair and well-functioning market, universal access to nutritious food in the 1000- day window, sustainable nutrition-sensitive health care, and specific nutrition interventions empowering women
2. 100 per cent access to adequate food all year round	All people will have assured access to food all time through transparent and effective public distribution and other social protection floors, direct cash transfer to farmers, assured minimum income of farmers, and comprehensive agricultural insurance
3. All food systems are sustainable	Climate-resilient agricultural practices, coherent policies for sustainable use of land, water, energy, and biodiversity, climate smart villages
4. 100 per cent increase in smallholder productivity and income	Technologies appropriate for smallholders, especially women farmers, appropriate mechanization, diversification, custom hire services, training and market linkage and price support resulting in reduced rural poverty and improved equity
5. Zero loss or waste of food	"Save and Grow" mindset, minimum losses along the value chain, various sizes of warehouses within rural areas build by private and public sectors, producer companies

The Second International Conference on Nutrition (ICN2), organized by FAO, Rome 2014, had underpinned that despite remarkable rates of economic growth in several developing countries, the negative health consequences of micronutrient deficiencies continue to affect around 2 billion people. More than 100 million children under the age of 5 are underweight and unable to realize their full socio-economic and human potential. Among other things, the Conference had recognized that poverty and the lack of access at all times of sufficient food are major contributors to malnutrition. And, undernutrition was the main underlying cause of death in children under five, causing 45 per cent of all child deaths in the world in 2013.

The Conference pledged to "improve nutrition by strengthening human and institutional capacities to address all forms of malnutrition through, inter alia, relevant scientific and socio-economic research and development, innovation and transfer of appropriate technologies on mutually agreed terms and conditions". It lent a strong support to the Global Zero Hunger Challenge Programme.

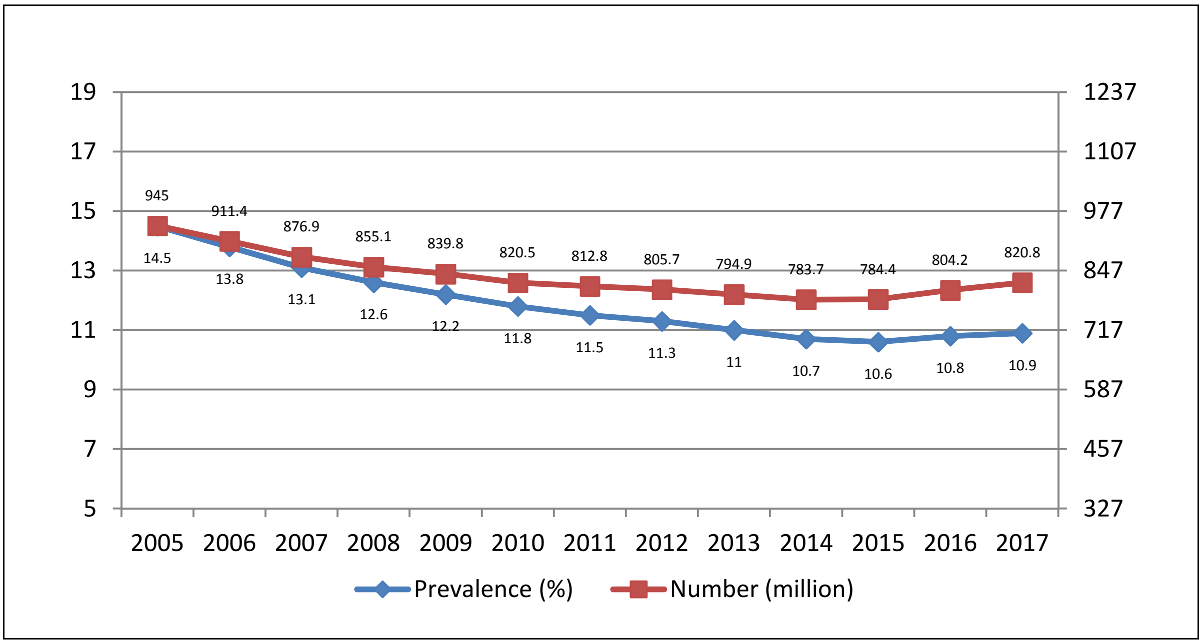
The Conference had recognized that world population is projected to increase to over 9 billion in 2050. By then, share of the world's people living in urban areas will increase from 54 per cent to 65 per cent and the proportion of middle class will swell from 50 per cent to 70 per cent. The economic and demographic changes will fuel demand for quality, protein-rich high value food, particularly livestock and horticultural products. Overall, global agricultural output will have to double by 2050 to meet the expected demand of food, feed, fibre and fuel. In order to realize the additional production, the use of extracted water in agriculture will increase from 70 per cent in 2013 to 89 per cent in 2050.

FAO had echoed accelerated, substantial, and sustainable hunger reduction is possible with the requisite political commitment. This has to be well informed by sound understanding of national challenges, relevant policy options creating enabling mechanisms and environment for security and nutrition, broad participation, and lessons from other experiences. It was emphasised that hunger reduction requires an integrated approach, which would include: public and private investments to raise agricultural productivity; better access to inputs, land, services, technologies, and markets; measures to promote rural development; social protection for the most vulnerable, including strengthening their resilience to conflicts and natural disasters; and specific nutrition programmes, especially to address micronutrient deficiencies in mothers and in children under five.

FAO prepared frameworks to guide and facilitate country level actions to implement ZHC with concrete outcomes under the leadership of each Government. Member Countries were encouraged to prepare National Action Plans for the National Zero Hunger Challenge through multi-stakeholders consultation and support from UN Country Teams (UNCTs). India had actively participated in these initiatives.

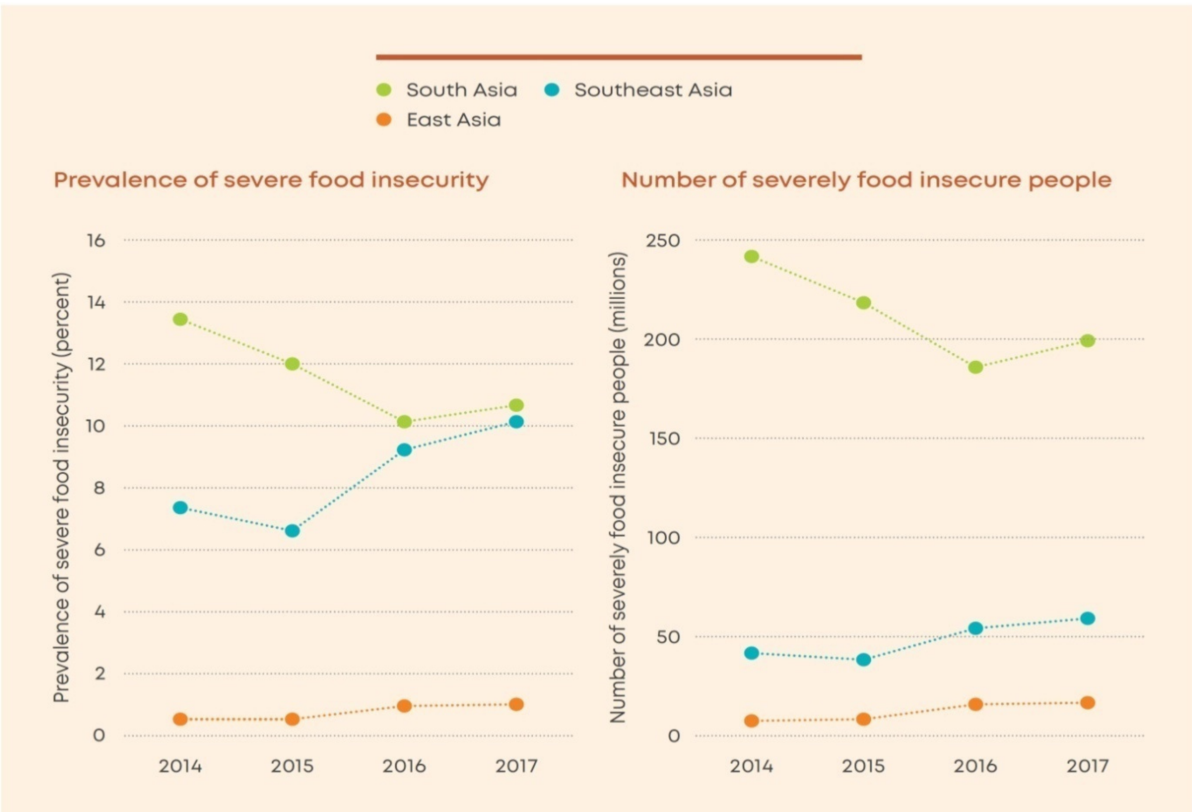
In this effort, FAO, alongwith IFAC, UNICEF, WFP, and WHO, in its latest (2018) Report on the State of Food Security and Nutrition in the World, has highlighted the increase in number of undernourished in the world since 2014 (Figure 5). And, this is partly attributed to climate variability. As judged also by food insecurity as experienced by people (FIES), the incidence and number of severely food insecure had also increased during 2014 to 2017 (Figure 6; FAO, 2018)

Figure 5. Number (million) and prevalence (Percentage) of undernourished in world during 2005-17



Source: FAO, 2017

Figure 6. Prevalence and Number of Severely Food Insecure Based on FIES, 2014-2017



Source: FAO. 2018. Asia and the Pacific Regional Overview of Food Security and Nutrition 2018

In the above context, FAO (2018) highlighted the following key messages:

- "Climate variability and exposure to more complex, frequent and intense climate extremes are threatening to erode and even reverse the gains made in ending hunger and malnutrition
- Climate variability and extremes are a key driver behind the recent rise in global hunger and one of the leading causes of severe food crises
- Severe droughts linked to the strong El Niño of 2015–2016 affected many countries, contributing to the recent uptick in undernourishment at the global level
- Hunger is significantly worse in countries with agricultural systems that are highly sensitive to rainfall and temperature variability and severe drought, and where the livelihood of a high proportion of the population depends on agriculture."

To address these messages, FAO in this Report has highlighted the way forward to meet the SDG 13 – Combat Climate Change and its impact, which will be directly impacting SDG 2 – Eliminate Hunger and Malnutrition by 2030.

4.2.2 Global Inter-Academy Partnership for a Food-Nutrition-Health Secure World

The Inter-Academy Partnership (IAP), global network of the world's science academies, has recently formed a new global collaboration by interconnecting established regional networks of academies to ensure that the voice of science is heard in creating a food-nutrition-health secure world. The four regional groups (Asian, African, European and American) of academies examined the science opportunities associated with the following:

- Ensuring sustainable food production (land and sea), sustainable diets and sustainable communities, including issues for agricultural transformation in the face of increasing competition for land use
- Promoting healthy food systems and increasing the focus on nutrition, with multiple implications for diet quality, vulnerable groups and informed choice
- Identifying the means to promote resilience, including resilience in ecosystems and in international markets
- Responding to, and preparing for, climate change and other environmental and social changes.

Each regional group had the responsibility to decide the relative proportion of effort to be committed to the different themes based on local needs with due consideration of the integrative food systems approach. The Association of Academies and Societies of Science in Asia (AASSA), which had organized one of its meetings at NAAS as well, has recently (March 2018) brought out its report on "Opportunities and Challenges for Research on Food and Nutrition Security and Agriculture in Asia".

The report highlights that population and income growths will be the main drivers of food needs. The projected population in Asia in 2050 will be 5.3 billion, an increase of 1 billion (about half of the projected world growth). The projected growth across Asia is not even. While India's population will swell from 1.31 b in 2015 to 1.71 b in 2050, China's population will decrease from 1.38 billion to 1.35 billion during the same period. Almost half of the projected population growth for Asia is in India. Other South Asian neighbors will also record sizeable increase whereas Japan and Thailand, like China, will show population decrease and no growth is projected in South Korean population (Table 6).

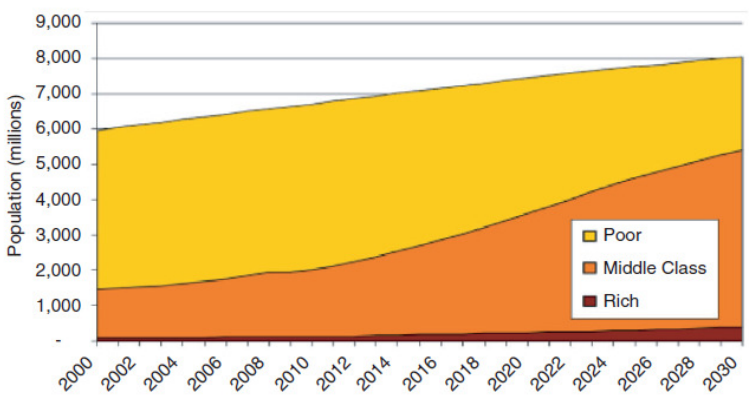
Table 6. Projections of total population size (millions) based on United Nations medium variants for Asia, Oceania and selected countries

Countries	**2015**	**2050 (projected)**
Asia	4593	5267
Oceania	39	57
Australia	24	34
China	1377	1348
India	1311	1705
Indonesia	258	322
Israel	8.1	12.6
Japan	127	107
South Korea (Republic of Korea)	50	50
Thailand	68	63

Source: United Nations Department of Economic and Social Affairs, Population Division (2015). Also refer to Lutz and Samir (2010)

As regards income growth, the world is changing from being mostly poor to being mostly middle class. By 2022, more people in the world will be middle class rather than poor (Figure 6). In India, the middle class is growing annually by11-13 per cent. These changes coupled with free flow of information and commerce will increase demand for higher value food such as meat, milk, eggs, fish, nut and fruits.

Figure 6. The projected increase in the global middle-class



Source: Kharas and Gertz (2010)

The high points emerging from the report are:

- A system analytical approach is needed to identify impediments and to provide workable holistic solutions, with "all-hands-on deck" approach where all stakeholders – public, private, corporate, academia, NGO and civil society will be a part of the solution
- The application of current scientific knowledge through improved education and extension practices, the development of new scientific knowledge in targeted areas and related technology developments will all be essential in terms of meeting the global food challenge
- Emphasis should not be placed on calorie provision alone; rather, the focus should be on diverse diets supplying a balance of food types and dietary nutrients and non-nutrients that are known to influence health and FNS should address malnutrition in all its forms
- Use 'systems analysis' to identify key impediments to FNS in these areas and to use such analysis to priorities extension, education and research for development (R4D) activities
- The territorial approach to investigating FNS implies a shift from a sectoral (usually agricultural production), top-down, 'one-size-fits-all' approach to one that is multi-sectoral, bottom up and context specific. India being a large and agro-ecologically highly diverse country, the territorial approach will promote inclusive and sustainable agricultural growth
- Obesity is sprawling fast also in Asia and Oceania, and any food and nutritional security programme/strategy must not ignore this aspect and should emphasize on healthy, variety of food types and to educate people about healthy eating and lifestyle to minimize non-communicable diseases
- Greater emphasis is needed on agri-food R&D, extension and education, emphasizing cross-disciplinary and system-oriented approaches, and to promote more diversified food system that enhances availability and affordability of nutritionally balanced foods for the poor.

Highlighting the role of science and technology in fighting undernutrition, a regional cooperative forum was suggested to focus on key opportunities areas, recognizing the following as key science, technology and research areas:

1. genomics-based approaches to plant and animal breeding
2. 'big-data' capture and analysis, precision agriculture and robotics
3. food technology innovations in harvest, processing and storage to reduce food wastage
4. sustainable farming practices for land and water use that address wider issues such as biodiversity and climate
5. aquaculture production and integrated farm production systems.

The overall recommendations of AASSA, which are highly pertinent to India, were as below:

1. Priority in relation to R&D and educational efforts should be given to countries and regions that have been identified as being at 'high risk' concerning current and future FNS. Particular focus should be afforded to India, Bangladesh, Pakistan, Afghanistan, Nepal, Myanmar (countries having elements in common) and the Philippines, Iraq, Tajikistan and Yemen

2. A strategy moving forward would be to undertake systems analysis to identify key impediments to raising food yields or supplying an adequate balance of food types. The systems analysis would prioritize extension, education and R&D needs, region by region and/or group by group, and would provide guidance on means of sustainably increasing food production and diversity. There will undoubtedly be some R&D/extension/education focus areas that are of global relevance and universally applicable (see above)

3. The AASSA should work with its constituent societies to develop a trans-national funding mechanism that puts *basic research* connected to FNS at the forefront. Such a framework, if properly funded, can have far-reaching consequences for both S&T and FNS in the Asia/Pacific region, similar to the effect of the European Research Council (ERC) integration grants on science in Europe

4. Investment in inter-disciplinary R&D relevant to FNS in Asia/Oceania needs to be increased significantly. Consideration should be given to forming cross-nation, cross-disciplinary consortia (centres of research excellence), to focus on defined pressing issues related to FNS

5. Regional cross-nation initiatives should be implemented to greatly increase the quantum of education and training of the next generations of scientists, technologists, extension officers and leaders in agriculture, nutrition and food. Training should have a trans-disciplinary basis.

4.2.3 Tata Cornell Institute for Agriculture and Nutrition (TCI)

Founded in 2013, TCI has a long-term research initiative focused on solving problems of poverty, malnutrition, and rural development in India. Its applied and field-based research is designed to:

- "Solve real-world problems through cutting-edge research
- Cultivate the future generation of researchers, thought-leaders, problem implementers and policy influencers by incorporating intensive fieldwork and project management experience into the rigorous graduate training provided at one of the world's best universities
- Inform policymakers and development practitioners to make better, evidence-based policy decisions, and

- Meet the needs of the rural poor through strong collaboration with our NGO partners."

Adopting an "all-hands-on-deck" approach, TCI's research and project areas aim to:

- "Influence agriculture policies to create a nutrition-sensitive food system, which includes
    - Meeting the rising demand for food quality, quantity and diversity
    - Improving access to markets for smallholder farmers, and
    - Retooling social safety net programs to meet not only the caloric, but also the nutrient needs of society's most vulnerable members.
- Promote biofortified crops, such as zinc-fortified wheat and orange-fleshed sweet potatoes
- Test strategies for mitigating mycotoxin risks in rural food systems
- Provide clean, in-house, piped water, which not only improves community health but also saves women time and opens opportunities for them to participate in other productive activities
- Use social marketing to distribute and sell affordable micronutrient supplement powders
- Develop a novel & sustainable fortified food product with microalgae to address iron deficiency
- Ignite change in sanitation practices through community-led communication campaigns, in accompaniment to the mass-construction of toilets."

With grant from Bill & Melinda Gates Foundation, TCI has established a flagship project Technical Assistance and Research for India Nutrition and Agriculture (TARINA) in New Delhi with field operations in several states. Led by TCI, TARINA, in collaborations with several leading international and national institutes and NGOs, including IFPRI, aims to promote a more diversified food system that enhances the access to nutrient-rich foods for India's rural poor.

Through these programs, Pingali and Sunder (2017) have given a succinct account of Transition Toward Nutrition-Sensitive Food System in Developing Countries. They have defined a nutrition sensitive food system as one that goes beyond staple grains productivity and places emphasis on the consumption of micronutrient-rich non-staples through a variety of market and non-market interventions. The nutrition sensitive approach, congruently considers the macro level availability, and household- and individual level determinants of improved nutrition. In addition to agriculture, intra-household equity, behaviour changes, food safety, and access to clean water and sanitation are integral components of the food systems. Thus, food systems encompass all activities involved in the production, distribution and consumption of food - the entire value chain. The policies on nutrition thus must address all the components of the food system in a holistic policy framework aiming to enhance the diversity, quality and safety of the food system and make it more accessible and inclusive to all people at all times.

Diverse diets are balanced in calorie, protein, and micro-nutrient intakes. In India in the midst of high, about 8 per cent, annual growth rate of GDP, the country has adequate production or availability of different food commodities, yet there is persisting high incidence of undernutrition and food insecurity. Apparently, the distribution system is not aligned with the stage of structural transformation. It should be kept in mind that income and health are bidirectionally related and are important drivers of economic and social change. During the Green Revolution era policies favoured staple grains at the cost of diverse food items - pulses, oilseeds, vegetables and fruits. But, soon the White, Yellow and Blue Revolutions followed which have greatly helped in diversifying diets and reducing intake of rice and wheat and increasing intake of other items. But, the poor still greatly depend on the narrow cereal diet, perpetuating undernutrition. Appropriate policy interventions are needed to enhance the dietary diversity of the poor.

Various models have been suggested providing framework for connecting various aspects of agriculture with nutrition. UNICEF (2013) proposed a framework that looks at the linkages between the food availability and access at the micro level that feeds into the household livelihood strategies which in turn determine food consumption at individual level. Pingali and Rickets (2014) added an economic policy lens to the UNICEF framework. Their framework has four components: (i) Household income primarily from agricultural productivity and off-farm employment, (ii) Food access and its impact on micronutrient intake, and the year-round availability of diverse food at an affordable price, (iii) Factors impacting intra household food distributions, and (iv) improving the ability of people to translate food intake into absorbed nutrients through providing clean drinking water and sanitation. The first two consist of the household-level factors and the last two comprise individual level factors. This multi-lateral framework calls for multi-sectoral policies, which should be aligned to the changing economic climate, promote food system and dietary diversity to ensure famer-market linkage, and create a food system that is balanced between staple grains and other nutrient-dense foods.

The TCI-TARINA consortium has taken a series of nutrition studies at district level in Bihar, Madhya Pradesh, Odisha, and Uttar Pradesh. They had studied the status of dietary diversity and nutritional outcomes and found that dietary diversity score was 3.8 (on a 0-10 scale) in Bihar and Uttar Pradesh and 4.8 in Odisha, suggesting that a greater proportion of women in Odisha consume meat/fish/poultry-eggs, and vitamin A-rich green leafy vegetables, and other fruits as compared to those in Bihar and UP. Based on the disaggregated food-group data, they showed that across districts 80 per cent of the women predominately consequence cereals and pulses, while less than 30 per cent consume micronutrient- rich food, like green leafy vegetables, vitamin-A rich fruits and vegetables, and eggs/meat/fish. These ground level findings reiterate the necessity of implementation of the policy options and actions, as listed below:

- Diversify and intensify through a spatially and temporally differentiated approach, and look beyond calories
- Adopt life cycle approach to nutrition and congruently strengthen value chains, and
- Develop consumer welfare objectives from producer protection point of view, including direct cash transfer.

4.2.4 International Food Policy Research Institute (IFPRI)

IFPRI has played a leading role in the developing world, especially the food-insecure developing world, to transform their agriculture and food systems for attaining comprehensive nutritional security. Its forthcoming publication "Agriculture for Improved Nutrition: Seizing the Moment", narrates program and policy experiences from countries around the world which are developing nutrition-sensitive agriculture, will inspire those who must reshape agriculture to improve the nutrition of billions of people. Its 2016 publication Nourishing Millions : Stories of change in Nutrition, highlighting that undernutrition reduces global GDP by US$ 1.4 to 2.1 trillion a year, and coinciding with the onset of the SDGs era, is a rich compilation providing insight into what works, what does not, and the factors that contribute to success (Gillespie *et.al.* 2016).

Recently, highlighting that progress in eliminating hunger and malnutrition is too slow, IFPRI has cautioned that "if the world is to end hunger and malnutrition by 2030 – the target year to achieve the Sustainable Development Goals – it is time to pick up the pace". While individual countries must develop and implement their need-based strategies, IFPRI has identified the following "accelerators" under policies, programs, and institutions:

- Making nutrition a key goal of agriculture
- Reforming agricultural subsidies and food taxes for nutrition
- Promoting behaviour change communication
- Tapping the power of women to improve nutrition
- Engineering social protection programs for nutrition
- Focusing on water, sanitation, and hygiene
- Reorienting food industries for better nutrition.

Likewise, the suggested technology "accelerators" are:

- Fortification, bio-fortification, and alternative proteins
- Big data and information and communication technologies
- Energy and technology for value chain
- Converting yield-enhancing technology to multiple-win innovations.

As regards India, particularly through its South Asia Regional Office in New Delhi, IFPRI and India have been working together for the last over 40 years to build a Zero Hunger India. During the past one-decade or so, the collaboration has emphasized nutrition, public investment, climate change, value chains, capacity strengthening, and bio-fortification to help provide solutions to the "Indian Enigma".

Among the various nutrition-related programs, Partnerships and Opportunities to Strengthen and Harmonize Actions for Nutrition in India (POSHAN) serves as IFPRI's primary platform for research and policy engagement on nutrition in India. Poshan is supporting the use of data and evidence by policy makers and field partners to improve nutrition decisions and actions. For instance, it helped the Govt. of Odisha to rollout the Nutrition Action Plan, which has helped improve nutrition in the State. It is helping other lagging states like Bihar, Uttar Pradesh, and Madhya Pradesh to improve their nutrition plans and actions. IFPRI's analysis and district nutrition projects have also been internalized in the National Nutrition Mission.

Outcomes of IFPRI's LANSA (Leveraging Agriculture for Nutrition in South Asia) research consortium have helped India and other partner countries in advancing nutrition sensitive agriculture agenda. Likewise, IFPRI's leadership to CGIAR's consortium transform nutrition has augmented the evidence base for nutrition–sensitive actions at ground as well as political levels.

IFPRI has been an active partner in several other consortia partnered by selected CGIAR institutes, and donors, such as Bill & Malinda Gates Foundation and DFID. Among such arrangements, the HarvestPlus in India is working with several institutions and Ministries *viz* the ICAR institutes of the MoAFW, Health, and Education Ministries. The effort has resulted in development of bio-fortified staples, especially Zn-fortified wheat and Fe-fortified pearl millet, being consumed by over a million people. The ICAR has already issued directives to breed and popularise only those pearl millet and wheat varieties which have been duly fortified with Fe and Zinc, respectively. Such fortified grains should be included in the PDS and Mid Day Meal schemes of the Government.

IFPRI's research on agricultural production, pricing and subsidies is informing the government in its efforts to alleviate hunger, undernutrition, and poverty. Under the Cereal Systems Initiative for South Asia (CSISA) project, IFPRI research outcomes have informed discussions on subsidy targeting and effectiveness and encourage machine use and the balanced application of fertilizers and micro-nutrients. Its researches have also been helpful in shaping our soil health cards, crop insurance system, liberalization of foreign direct investment and promoting public-private partnership in creating rural business hubs. Its India food security portal provides latest country-level information on commodity prices and other indicators, which are valuable for policy-makers. IFPRI's study of pulse value chain has helped in removing barriers to enhance pulses production, including pulses minimum support prices. Its recent book "Pulses for Nutrition in India: Changing Pattern from Farm to Fork" will greatly aid policy makers to prepare and implement sound action plans to make India self-sufficient in pulses. Further, IFPRI's work has enhanced the efficacy of women self-help groups, Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), and the Women Improving Nutrition through Group-based Strategies (WINGS). The Refreshed IFPRI Strategy 2018-20, responding to the ongoing and emerging challenges, provides invaluable framework based on topical research and informed policies to meet the SDG 2 and other related goals. NITI Aayog should internalise the refreshed strategies in its national policy and action geared to build a Zero Hunger nutritionally secured New India.

The forthcoming February 2019 IFPRI's book by Fan, Yosef and Pandya-Lorch titled "Agriculture for Improved Nutrition : Seizing the Momentum" reviews the latest ground level experiences and related policies from countries around the world which are congrueing agriculture and nutrition and making nutrition a key goal of agriculture. The book will strengthen the evidence base and broaden vision of all stakeholders as to how agriculture can contribute to nutrition. The book "seeks to inspire those who want to scale up successes that can transform food systems and improve the nutrition of billions of people."

4.3 Nourishing India: NITI Aayog Programs and Policies

4.3.1 Ongoing efforts and new Initiatives

In line with the global developments, declarations, and commitments, India had launched its national Integrated Child Development Service (ICDS) scheme - the world's largest nutrition programme as early as in 1975 to address the health and nutrition needs of children under the age of six years. Other initiatives such as the Public Distribution System (PDS), the Mid Day Meal Scheme, and the Food Bill, Food a Legal Right, 2013 etc were launched to fortify the national movement. However, these initiatives have been pursued as business-as-usual and the country is off track to reach the targets. An unintended consequence of these interrelated schemes is that the focus is primarily on basic calorie sufficiency and staple grains at the cost of comprehensive nutritional balance. Policies related to minimum support price, procurement, and diversification must be guided by the fundamental need of assuring comprehensive nutritional security to all for all times. As happening in several developing countries, concerted broad based efforts have put many countries on course to meet the global targets of nutrition, and India should adopt similar approach.

Some of the Indian states have, however, done well and their experiences should be adopted by other states. For instance, the Tamil Nadu Integrated Nutrition Project (TINP), launched in 1980 and developed alongside ICDS, and the ICDS programs in the recent decade in Maharashtra and Odisha have made significant impact. The elements of success were high-level political support, fiscal and policy space to operate, and collaborations with development partners, especially committed and knowledgeable bureaucrats. The lessons learnt are: (i) setting goals, (ii) ensuring bureaucratic stability, and (iii) creating an enabling environment with no political interference, adequate financing, and technical support.

India is designing its policies and programs to achieve the Sustainable Development Goals which are comprehensively linked with nutrition, *viz.* those related to nutrition and food security, health, education, employment, female empowerment, poverty alleviation, climate change management and inequality reduction. These, alongwith the UN Decade of Action on

Nutrition provide the national programs important framework for priority setting, planning, and actions for alleviating malnutrition. For this, it is crucial that timely data on trends in different forms of malnutrition and on outcomes of actions and programs become available and accessible in the public domain. More data that are actionable at the sub-national level are also needed. More and better evaluations are required which are not just assessments of whether a program works or not, but based on critical analysis and process evaluations that highlight impact pathways to help understand why, how, and where programs work or don't work.

NITI Aayog is rightly emphasizing that investing in nutrition is the most critical development imperative for fulfilling human rights. Most importantly, nutrition is the most effective entry point for human development. The time is ripe for a major long-term investment in strengthening capacity for nutrition. Capacity is needed at different levels - individual, community, organizational, and systemic - and for different purposes. In particular, within the new generation of nutrition professionals, we need individuals with stronger strategic and operational capacities to go along with their technical skill sets. And we need to strengthen the capacity of individuals in other sectors, to empower and motivate them to apply a nutrition lens in their work and to contribute to nutrition-relevant change through their programming and investments. We need to develop the next generation of nutrition leaders and to strengthen existing initiatives, including university curricula that aim to build leadership capacity.

As mentioned earlier, Zero Hunger Challenge in India is most formidable initiative as India has 18 per cent of world population but its 25 per cent people go hungry. Prime Minister Modi, as also NITI Aayog, have given high priority to remedy this malady. The POSHAN Abhiyaan of the Prime Minister had decided to undertake annual survey on nutrition across the country and release reports on the same every year (March TOI, 2018). This is towards implementation of the PM's Overarching Scheme for Holistic Nourishment (POSHAN) Schemes. Successful experiences within of the country in reducing stunting, anaemia and malnutrition will be judiciously replicated at the national level. Some of the Govt of India's Initiatives for Nutrition Security include: Increased Production, Food Bill, Doubling Farmers Income, National Food Security Mission, RKVY, Integrated Schemes on Oilseeds, Pulses, Palm Oil & Maize (ISOPOM), PM Fasal Bima Yojana, e-Markets, PM Sinchayi Yojana and Water Harvesting, and Soil Health Card.

4.3.2 Main Interventions of NITI Aayog

Towards nourishing India, NITI Aayog has prioritized the following interventions:

i. Integrated Child Development Services
ii. National Health Mission
iii. Janani Suraksha Yojana
iv. Swachh Bharat including Sanitation
v. National Rural Drinking Water Program
vi. Mahila Sahyog Yojana
vii. SABLA for Adolescent Girls

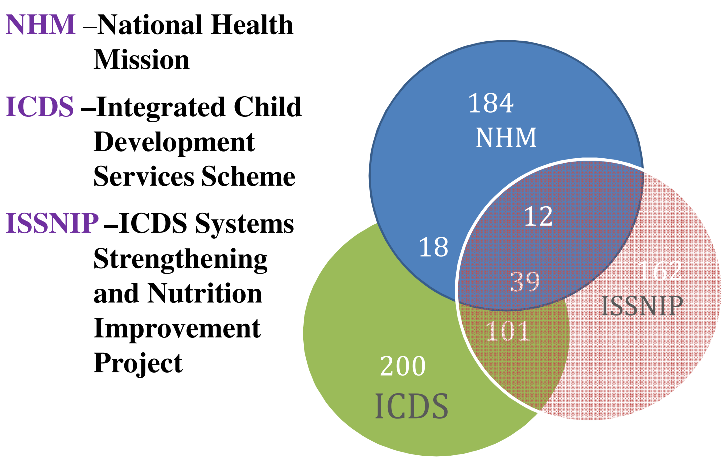
viii. Mid Day Meal Scheme
ix. Targeted Public Distribution System
x. Nutritional Food Security Mission
xi. Mahatma Gandhi Rural Employment Schemes, and
xii. The National Rural Livelihood Mission.

It may be pointed out that 2014-15 National Budget has stated “A National Program in Mission Mode is urgently required to halt the deteriorating malnutrition situation in India, as present interventions are not adequate”. The impact of these missions and initiatives are yet to be seen. The main drawback has been a fragmented approach and lack of accountability with responsibility.

Despite the National Nutrition Policy 1993, little explicitly was assigned to nutrition *per se* before the XI Five Year Plan. The National Food Security Act 2013 and National Policy for Children, 2013 provided framework for comprehensive nutrition–specific interventions. The XII Five Year Plan reinforced the commitment and articulated monitorable targets and seeks inter-sectoral and inter-state and even international collaboration.

The concerned different Ministries had identified priority districts for concentrating their work. The National Health Mission of the Ministry of the Health and Family Welfare had identified 184 districts, and the Integrated Child Services Scheme (ICDS) and the ICDS System Strengthening and Nutrition Improvement Project (ISSNIP) of the Ministry of the Women and Child Development, had identified respectively 200 and 162 priority districts. As seen from (Figure 7), only 39 districts are common among the two Ministries and the three programs. Generally there is lack of coordination among the Ministries is addressing the nutrition problems even in the common districts. Recalling that nutrition is a multi-disciplinary concern, judicious and result-oriented coordination is called for among various stakeholders and partners to achieve desired outcomes.

Figure 7. High Burden/Priority Districts of ICDS, NHM & ISSNIP



Source: NITI Aayog, Nourishing India, 2018

The National Nutrition Mission and the NITI Aayog based on the recent National Family Health Survey 4 (NFHS4) data have identified 100 worst performing districts with respect to stunting. A coordinated approach enrolling all concerned stakeholders will be adopted in the identified districts to attain holistic outcome. The topmost distressed districts were concentrated in UP (30), Bihar (25) and Madhya Pradesh (13).

The NITI Aayog has come up with Mission 2022 to meet its commitment to ensuring that "every child, adolescent girl and women attains optimal nutritional, status", especially preventing undernutrition in the first three years of life. The Vision "Kuposhan Mukt Bharat" - free from malnutrition across the life cycle envisages "healthy, optimally nourished children, realizing their growth and development potential, active learning capacity and adult productivity; Healthy, optimally nourished women realizing their social and economic development potential; In protective, nurturing, gender sensitive and inclusive community environments - That enhance human and national development in the present - and in the future."

The above efforts will be in line with the 2012 World Health Resolution 65.6, which had specified a set of six global nutrition targets for 2025, which were revised for 2030, as given in Table 7.

Table 7. Global Nutrition Targets for 2025 and the revised targets for 2030 (From a 2012 baseline)

	2025 Target	**2030 Target**
Stunting	40 per cent reduction in the number of children under five who are stunted.	50 per cent reduction in the number of children under five who are stunted.
Anaemia	50 per cent reduction in anaemia in women of reproductive age.	50 per cent reduction in anaemia in women of reproductive age.
Low birthweight	30 per cent reduction in low birthweight	30 per cent reduction in low birthweight
Childhood overweight	No increase in childhood overweight	Reduce and maintain childhood overweight to less than 3 per cent
Breastfeeding	Increase the rate of exclusive breastfeeding in the first six months up to at least 50 per cent	Increase the rate of exclusive breastfeeding in the first six months up to at least 70 per cent
Wasting	Reduce and maintain childhood wasting to less than 5 per cent	Reduce and maintain childhood wasting to less than 3 per cent

Source: WHO and UNICEF. 2018. The extension of the 2025 maternal, infant and young child nutrition targets to 2030 - Discussion paper

As most of the 17 SDGs contain indicators that are nutrition-related, realization of the set targets will help meet the SDGs. The critical point is to judiciously monitor the deliverables/outcomes. Towards achieving the goals, NITI Aayog has set out ten Guiding Principles (Ten Commandments) as reproduced below:

A Life Cycle Approach

Recognizing that there is an intergenerational cycle of undernutrition, a life cycle approach will be adopted, with a focus on critical periods of nutritional vulnerability and opportunity for enhancing human development potential.

Early Preventive Action

Recognizing that growth and development deficits that compromise child health and survival and achievement of optimal learning outcomes are cumulative and largely irreversible – there will be emphasis on preventing under nutrition, as early as possible, across the life cycle.

Inclusive and Gender Sensitive

It will be rooted in a rights based framework that seeks to promote the rights of women and children to survival, development, protection and participation – without discrimination. In this, strategies for ensuring social inclusion of marginalized community groups will be pursued- recognizing that nutritional vulnerability is compounded by multiple deprivations - based on socio economic status, high burden of disease, natural factors such as floods/droughts and/or other conditions such as lack of access to services. Efforts will focus on reaching the most vulnerable and deprived.

Community Empowerment and Ownership

Families and communities will be enabled for improved care behaviors and nutrition of children and women, to demand quality services, to contribute to increased service utilization and to participate in community based monitoring.

Valuing, Recognizing and Enhancing the Contribution of Anganwadi Workers, Helpers and Ashas

The approach will be to improve the working conditions, skills, development pathways and motivation of Anganwadi workers, helpers and also ASHAs - a frontline team of over 33 lakh women from the local community covering 13.42 lakh habitations across the country– recognizing that they are prime movers of social change.

Decentralization and Flexibility

Contextually relevant, decentralized approaches will be promoted, with greater flexibility at State, district and local levels for greater and sustained programme effectiveness and impact, in harmony with the approach of cooperative federalism. This will also enable utilization of opportunities provided by the recommendations of the Fourteenth Finance Commission with greater devolution of resources to States- mobilizing and catalyzing state resources and action for Nutrition.

Ownership of Panchayati Raj Institutions and Urban Local Bodies

Strengthening the ownership of Panchayati Raj Institutions and urban local bodies is a key principle – to ensure that local self governments own, promote, monitor and sustain nutrition initiatives – effecting convergence of action at the grass roots. This is essential as the subjects allocated in the 73rd Amendment include those addressing the immediate and underlying determinants of undernutrition such as Health and Sanitation, Family Welfare, Drinking Water, Women and Child Development, Public Distribution Systems, Agriculture, Education, Poverty Alleviation and Social Welfare, among others. This is even more relevant in the light of the Fourteenth Finance Commission Recommendations.

Foster Innovation

Innovation will be encouraged and recognized - including through quality circles, which encourage a cluster of frontline teams to identify best practices and replicate the same – with a ripple effect, and widening of the innovation. Best practices will be identified and local adaptation and replication or scaling up encouraged.

Informed by Science and Evidence

Programme strategies will be evidence based, informed by the state of the science (as well as by the state of the practice) and updated, as new evidence emerges related to nutrition, health and development.

Ensure That There Is No Conflict of Interest

An underlying principle of action is that policy development and programme implementation must be transparent, open to public scrutiny and kept free from conflict of interest, with requisite safeguards. (This includes ensuring that representation on policy, technical advisory groups and various management committees at different levels is free from conflict of interest.)"

4.4 NAAS Initiatives in Augmenting the National Policies and Actions to Sustainably Enhance the National Nutritional Security

Since its early years NAAS has paid high attention to analyze the nutritional status in the country and suggested implementable policy options and actions on several fronts. Fortunately, several of the NAAS's recommendations have been internalized in concerned national policy, plans, and programs. Listed below are the NAAS Policy and Strategy Papers and Policy Briefs on India's nutritional security:

- 2001 Policy Paper 7 Diversification of Agriculture for Human Nutrition
- 2001 Policy Paper 8 Sustainable Fisheries and Aquaculture for Nutritional Security
- 2002 Policy Paper 16 Agriculture-Industry Interface: Value Added Farm Products
- 2003 Policy Paper 20 Dichotomy Between Grain Surplus and Widespread Endemic Hunger

- 2010 Policy Paper 43 Antibiotics in Manure and Soil – A Grave threat to Human and Animal Health
- 2012 Policy Paper 54 Integration of Millets in Fortified Foods.
- 2012 Policy Paper 55 Fighting Child Malnutrition
- 2012 Policy Paper 66 Role of Millets in Nutritional Security of India
- 2019 Policy Brief 5 Saving the Harvest : Reducing the Food Loss and Waste
- 2019 Strategy Paper 12 Harnessing Full Potential of A1 and A2 Milk in India: An Update

Of the above, Policy Papers nos. 7, 20, 55, and 66, and Policy Brief no. 5 are most pertinent. Salient points and recommendations of these papers are reproduced below in condensed forms:

4.4.1 Diversification of Agriculture for Human Nutrition (Policy Paper 7, 2001)

Shifting agricultural resources to higher-valued options is the new strategy for agricultural development. Buoyancy in domestic demand for such commodities has generated congenial incentive environment for such transition and the process has begun. Good export prospects reinforce this trend. Non-conventional crops like aromatic and medicinal plants, floriculture, etc., figure importantly in this strategy but the major impetus comes from horticulture, livestock, dairy poultry, fisheries, etc., which have traditionally been minor constituents of Indian diets. The nutritional implications are obvious. Growth in incomes has spurred demand for these commodities even as foodgrain consumption stabilizes, and producers have responded to such market signals.

General inadequacy of Indian diets in terms of micronutrients and vitamins is well established. For the poor, access to even macronutrients is constrained. As overall well-being improves with future growth in incomes, special attention will have to be paid to nutritional aspects. Salient recommendations relating to diversification and nutrition emanating from the symposium are summarized below.

4.4.1.1 Policy Imperatives

- Thrust on raising productivity of foodgrains must remain a central feature of agricultural policy. Only through this route can the twin objectives of self-reliance and rapid rural income growth be realized. It will enable unlocking of resources which would otherwise remain tied to less remunerative enterprises.

- Diversification of production base of Indian agriculture requires massive investments in rural and other infrastructure. Apart from roads, electricity, irrigation, greater emphasis on storage, specialized handling and transport, assembling, wholesale and retail markets, effective market intelligence, etc. will be needed.

- The emerging economic regime requires dismantling all distortions in input-output pricing. These impart incorrect price signals and farmers are distracted from efficient production patterns. Massive irrigation subsidy and its effect on cropping patterns is an illustration. The structure of tariffs is also a case in point.

- A reorientation of the institutional support for agriculture will be necessary for exploitation of new opportunities by small producers who constitute more than 80 per cent of the farming households. Input-output marketing, value addition and processing, credit, insurance, R&D, extension, etc. need to shift from foodgrain and large-farm-based approaches to a more holistic paradigm. Leasing and tenancy reforms will be necessary.

- Agro-processing investments must move to the countryside where production is concentrated. While technology and quality considerations may necessitate foreign investments in this sector, mechanisms will have to be developed to ensure effective small farm participation.

- A task of this magnitude and complexity will necessitate a dominant role for the private sector. The public sector will need to withdraw from some areas and strengthen others, like R&D, information, natural resource management, regulatory processes and so on. A set of policies to provide incentives to the private sector will be necessary.

- A large population will continue to be economically and nutritionally deprived. People below the poverty line, women and children, particularly in rural areas, and urban slums, will need strong safety nets. Weaknesses in existing programmes have been well identified and are being addressed. These need to be pursued more vigorously.

- These challenges are beyond the competence and resources of governments. It will be necessary to involve people in planning and executing decentralized initiatives. Nongovernmental organisations, self-help groups, cooperatives, *panchayats* will need to play a greater role and these must be strengthened.

4.4.1.2 Nutrition

- Nutrition education must be made part of regular curricula in schools. Sustained drives using mass media, particularly in rural areas and urban slums are necessary to create greater awareness.

- Programmes like homestead gardening, urban gardening, household preservation and enrichment of food, etc. must be actively supported. Health and hygiene, sanitation, etc. make significant contributions to nutritional well-being and should be accorded greater priority.

- Food enrichment, fortification strategies need to be supported. Assessment and incorporation of indigenous ingredients offer considerable opportunities and should be exploited.

- National nutrition monitoring effort must be further strengthened and focused on target themes and populations.

4.4.1.3 R&D

- Continuous increase in productivity of agricultural enterprises—crops, animals, fish, is essential. This would ease the subsistence pressure on natural resources, relating them to commercial enterprises. The research system must continue to accord high priority to food crops, particularly those which are of importance to the rural poor and tribal farmers.

- Advances in modern sciences, particularly biotechnology, offer exciting opportunities for incorporation of marketable and nutritional qualities in food crops of various kinds. Even as research on genetically modified organisms is accelerated, proper testing and safeguard procedures need to be put in place. The point to note is that this area of research can tackle several constraints inhibiting yield, quality, and nutrition.

- More resources should be allocated for nutrition research. There are basic as well as applied research issues relating to indigenous food, nutraceuticals, formulations, food safety, standards, etc. which need to investigated. There is enormous variability in food habits, tastes and preference products etc. across the country and these must be captured and analysed.

- Unmindful pursuit of market opportunities often exacerbates pressure on natural resources and ecology. Safeguarding future production potential and ecological balance should be high priority for research.

- Wide diversity in growing conditions implies a wide range of options for diversification and income growth. This is a big strength for Indian agriculture, but this necessitates decentralized research approaches which maximize comparative advantage of different regions. A careful regional prioritization of research is called for.

- Preventing post-harvest losses has emerged as a critical element, and so has value addition and processing. Known technological options in these areas are highly capital intensive and not really appropriate for small scale operations which are characteristic of the Indian rural scene. The research system faces this unique challenge of developing efficient small scale technologies which will benefit small scale rural producers and entrepreneurs.

- Finally, success of the diversification strategy would demand research on a number of socioeconomic parameters like, market structure, conduct and performance, input-output demand, comparative cost and returns, price analysis, organizing producers' and entrepreneurs' private sector role, etc. While the research system is gearing up to meet production research challenges, this area must also receive attention.

4.4.2 Dichotomy Between Grain Surplus and Widespread Endemic Hunger (Policy Paper 20, 2003)

The dichotomy was deliberated at a one-day workshop under the convenorship of Dr M.S. Swaminathan in 2002, resulting in this policy paper. Highlighting the Indian Dilemma : Grain Mountains (about 60 million tonnes of foodgrain bufferstocked) and Hungry Millions (more than 200 million hungry women, children and men – nearly one-fourth of the worlds hungry), the workshop noted the profound words of the then Hon'ble Prime

Minister Sri Atal Bihari Vajpayee who had said “We have sufficient stock of foodgrains. No one need go hungry in this country. Nevertheless, it is true that many millions of our countrymen still go hungry to bed every night. Malnourishment, especially among women and children, is widespread. We are determined to change this situation” on the occasion of release of the Food Insecurity Atlas of Rural India.

The following five sets of recommendation were made by the Workshop:

- Food for sustainable development initiative
- Adopting a whole life cycle approach to nutrition security
- Developing and spreading a Holistic Action Plan to achieve sustainable nutrition security at the level of each individual
- Institutional structures for extending the extrapolation domain of successful experiences and efforts
- National Alliance Against Hunger: Launching a National Food Guarantee Scheme

4.4.2.1 Food for Sustainable Development Initiative

The programme could accord priority to the:

- Restoration of hydrological and biodiversity ‘hot spots’, particularly in mountain ecosystems.
- Coastal agro-aqua farms (planting of Salicornia, mangroves, Casuarina, palms, etc. along with coastal agriculture and aquaculture).
- Water harvesting, watershed development, wasteland reclamation, and anti-desertification measures.
- Recycling of solid and liquid wastes, and composting.
- Agroforestry and other sustainable land use systems in the fields of resource poor farmers.

The Food for Sustainable Development Initiative could be managed at the local level by Community Food Banks (CFB) operated by women’s self-help groups having a unique opportunity to foster a community centered and controlled nutrition security system endowed with several advantages.

The CFBs may be organized with the following four major streams of responsibilities.

- *Entitlements:* The benefits of all government and bilateral and multilateral projects intended for overcoming under- and malnutrition can be delivered in a coordinated and interactive manner (as for example those intended for overcoming the deficiencies of macro- and micro-nutrients).
- *Ecology:* Food for sustainable development with particular reference to the establishment of water banks, land care, control of desertification and promotion of afforestation. Thus, grains can be used to strengthen local level water security

- *Ethics:* This group of activities will relate to nutritional support to old and infirm persons, pregnant and nursing mothers and infants and preschool children.

- *Emergencies:* This activity will relate to the immediate relief operations following major natural catastrophes like droughts, floods, cyclones and earthquakes, as well as to meet the challenge of seasonal slides in livelihood opportunities due to, natural causes as well as human conflicts/and mini-wars.

4.4.2.2 Adopting a Whole Life Cycle Approach to Nutrition Security

Nutrition programs specifically suited to Pregnant Mothers, Nursing Mothers, Infants (0-2 years), Preschool Children (2-6 years), Youth (6 to 18 years), Adults (18 to 60 years), Old and Infirm Persons should be judiciously designated and implemented.

4.4.2.3 Developing and Spreading a Holistic Action Plan to Achieve Sustainable Nutrition Security at the Level of Each Individual

The major components of such an integrated action plan are the following:

- Identification of nutritionally insecure

- Education and Information Empowerment, making people aware of their entitlements about the nutritional safety nets available to them and also undertake nutrition education. An entitlements database can be developed for each area and household entitlement cards can be issued, indicating how to access nutritional, health care and educational programmes

- Overcome Protein-calorie Undernutrition

- Eliminate Hidden Hunger Caused by the Deficiency of Micronutrients in the Diet

- Drinking Water, Hygiene and Primary Health Care

- Sustainable Livelihoods: Improve economic access to food through market-linked micro-enterprises supported by microcredit. Also, create an economic stake in the conservation of natural and common property resources. Encourage production by masses and not mass production. Promote job-led economic growth and not jobless growth

- Pay Special Attention to Pregnant and Nursing Mothers and Preschool Children

4.4.2.4 Institutional Structures for Extending the Extrapolation Domain of Successful Experiences and Efforts

Without appropriate institutional structures, isolated success stories will remain just talking points. Based on local cultural traditions and socioeconomic conditions, institutional structures should be fostered which can take new technologies to the unreached and which can give the power of scale to small producers at the production, post-harvest and marketing phases of farming.

Without socially compatible and socially owned institutional structures, the extrapolation domain of successful experiences and development efforts will remain limited. Community involvement will ensure low transaction costs and a high percentage of success and help to convert unique examples into more universal ones.

4.4.2.5 National Alliance against Hunger: Launching a National Food Guarantee Scheme

The huge stock of foodgrains provides a unique opportunity for launching a national alliance against hunger, with the alliance partners reaching the remotest village and hamlet based on Mahatma Gandhi's principle - "To the hungry, God is bread; this God should be present in every house and hut of the country." The strategy of a hunger-free nation could consist of the following three inter-related groups of activities:

- Ensuring a whole life-cycle approach to nutrition security at the level of each individual by providing the needed horizontal linkages among ongoing vertically structured programmes (often operated by different national, bilateral and UN agencies).
- Organization of a Food Guarantee Scheme on the model of the Employment Guarantee Scheme (EGS) of Maharashtra. This will essentially be a 'Food for Work' programme having the following features-highest priority in this project, which should cover both rural and urban areas, needs to be given to water harvesting, watershed and wasteland development, eco-restoration of hydrologic and biodiversity 'hot spots' and waste recycling (composting) and bioenvironmental management of mosquitoes.
- Promoting the establishment of Community Food Banks at the local level, to serve as the focal point for according concurrent attention to ending poverty induced endemic hunger, micronutrient deficiency induced hidden hunger and transient hunger caused by human conflicts and natural calamities.

The national alliance against hunger can provide policy guidance and undertake resource mobilisation (financial, technical and managerial) for achieving the goal of 'food for all'. While the above approach would help to alleviate hunger today, we can avoid hunger tomorrow only by sustaining advances in agricultural production through an evergreen revolution approach using environment-friendly eco-technologies.

4.4.2.6 Immediate Action Points

Although, the Food Corporation of India has huge foodgrain stocks, the country still has the largest number of undernourished in the world. This calls for serious introspection of both our strategies for fighting hunger as well as of our ethical commitment to the cause of hunger-free India.

- This paradoxical situation can be effectively addressed by introducing the social security systems for the able-bodied poor in the form of a National Food Guarantee Scheme on the model of Maharashtra's employment guarantee scheme. The public distribution system should be strengthened and should be designed to reach the unreached. On the basis of ICMR norms, about 158 million persons, belonging to about

32 million households, fall under the category of ultra-poor and need immediate assistance to help them to lead a healthy and productive life. They are best identified by *Gram Sabhas* and local bodies. They can be issued with Food Entitlement Coupons, which should entitle them to be provided with work under the Food Guarantee Scheme. The total requirement for such an open-ended employment-cum-food security project may need at the maximum about 10 million tonnes of foodgrains per year. Meeting this need is well within our national capacity.

- Consumption inequality decreases as income increases. Diversification of diets also happens with increased purchasing power. Unfortunately, inequality of income distribution is growing. A job-led economic growth strategy will help to reduce protein-energy malnutrition, and at the same time, stimulate farming systems' diversification.

- A whole life-cycle approach should be introduced by providing a horizontal dimension to the numerous on-going vertically structured programmes supported by the central and state governments as well as by bilateral and multilateral agencies. At the local level, the management of a life-cycle based nutrition security system, beginning with pregnant women and extending up to old and infirm persons, is best left to the one million elected women members of the *Panchayats*.

- Proactive approach to implementation of recommendations submitted by the Committee on Long Term Grain Policy, with regard to MSP, universal PDS.

- Decentralized procurement and decentralized storage will help to minimize transport and transaction costs. Uttar Pradesh, Madhya Pradesh, West Bengal and Tamil Nadu have accepted the principle of a decentralized procurement system. The storage can be done through a national grid of Community Food Banks (CFBs) managed by self-help groups. The construction of CFBs can be done at the local level under the 'Food for Work' programme.

- We must strive to produce more in a manner that high yields can be obtained in perpetuity without associated ecological or social harm. Farming systems' intensification, diversification and value addition are extremely important to generate the needed on-farm and non-farm employment. Productivity improvement in both irrigated and rain-fed areas will help to increase marketable surplus at the household level and thereby the cash income. Livestock husbandry and livelihood security tend to be closely correlated in the case of poorer households. There is greater equity in livestock ownership as compared to land. Hence, support services should be organized for small scale livestock farming families in the form of fodder and feed banks and healthcare and insurance facilities.

- There is an urgent need for spreading quality literacy including Codex Alimentarius standards and sanitary and phytosanitary measures. In addition, there is need for greater research in the field of breeding crop varieties having the quality characteristics needed for food processing and exports. If productivity and quality are improved, farm income will go up substantially.

- Sustainability of food security measures should be ensured. PDS at the local level should provide reasonable income to those operating the ration shops. Community Food Banks may receive their initial food supply from government but subsequent replenishment should come from local communities.

- There is a need for Organization of a National Consortium for Sustainable Food Security. NAAS can act as a catalyst to promote the organization of a National Consortium for Sustainable Food Security consisting of representatives of FCI, CII, FICCI, ASSOCHAM, NHDB, NDDB, APEDA, TISCO, Hindustan Lever and appropriate agricultural universities and ICAR institutes for fostering sustainable food security both in the hunger 'hot spots' of India as well as in other countries in Asia and Africa.

A universal and user-sensitive Public Distribution System, Food Guarantee Scheme, Community Food Banks and various other food entitlement projects need to be implemented in an integrated manner, so that the goal of hunger-free India can be achieved. Nutrition status will, however, continue to fall, unless the purchasing power of the poor is increased. Hence, livelihoods for all should be the bottom line of all national development and import and export policies.

Several of the above policy options have been implemented by the Government *viz* the National Food Bill, Whole Life Cycle Approach to Nutrition Security and others.

4.4.3 Fighting Child Malnutrition (Policy Paper 55, 2012)

4.4.3.1 The Problem of Malnutrition – A National Shame

The Prime Minister, Dr Manmohan Singh, on January 10, 2012, while releasing the HUNGaMA (Hunger and Malnutrition) Report prepared jointly by Nandi Foundation, the Citizen's Alliance and other partners observed that the surveyors in preparing the Report had reached more than 73,000 households in 112 districts across 9 States and had measured the nutrition status of more than one lakh children and had heard the voices of 74,000 mothers. The Prime Minister reiterated that "the health of our economy and society lies in the health of our children" (particularly referring to health of those below the age of six years) and underpinned that "We cannot hope for a healthy future for our country with a large number of malnourished children. The problem of malnutrition is a matter of national shame. Despite impressive growth in our GDP, the level of undernutrition in the country is unacceptably high. We have also not succeeded in reducing this rate fast enough." Emphasizing the need for clearly understanding malnutrition, the PM observed that despite a 20% decline in malnourishment in the last 7 years, it is a matter of great concern that 42% of our children are still underweight, an unacceptably high occurrence.

The Prime Minister emphasized that "though the ICDS continues to be our most important tool to fight malnutrition, we can no longer rely solely on it. We need to focus on districts where malnutrition levels are high and where conditions causing malnutrition prevail. Policy makers and programme implementers need to clearly understand many linkages – between education and health, between sanitation and hygiene, between drinking water and nutrition – and then shape their responses accordingly. These sectors can no longer work in isolation of each other." He referred to the following four functions of the National Council on India's Nutrition Challenges: "To launch a strengthened and restructured ICDS; to start a multi-sectoral programme for 200 high-burden districts; to initiate a nationwide communication campaign against malnutrition; and to bring nutrition focus to key programmes of agricultural development, research and development in agriculture, the Public Distribution System, the mid-day meals programme, drinking water, sanitation, health and the latest on the horizon is the Food Security Bill etc." The Prime Minister assured that the ministries concerned are taking necessary action to implement these four decisions, and hoped that all stakeholders would effectively work together to bring malnutrition below unacceptable levels.

Highly concerned with the perpetuating high intensity of child undernutrition in the country, the NAAS in association with the National Institute of Nutrition, under the convenorship of noted scientist experts, namely, Prof. V. Prakash, Prof. Mahtab Bamji and Prof. M. Nair, involving leading human nutritionist organized the Brainstorming Session at NIN, November 2011.

The session reiterated that the Article 47 of Constitution of India states that "State shall regard the raising of the nutrition and the standard of living of its people and the improvement of public health as its primary duties". It noted that since then several programmes, Missions and Acts like the National Nutrition Policy (1993), National Nutrition Plan of Action (1995), and National Nutrition Mission (2001) have been mooted with no follow-up action. The Coalition for Sustainable Nutrition Security under the leadership of Professor M.S. Swaminathan, 2009 had recommended agenda for action23. The Indian National Science Academy (INSA) had released two papers: 1) Nutrition Security for India: Issues and the Way Forward, A Position Paper, (2009) and 2) Micronutrient Security for India – Priorities for Research and Action (2011) based on extensive scientific consultation. Prime Minster of India, Dr Manmohan Singh had called malnutrition a curse and constituted the National Council on India's Nutrition Challenges.

The Brainstorming Session had recommended that nutrition should be stated as an explicit goal with measurable parameters for monitoring of missions such as National Food Security Mission, National Horticulture Mission whose emphasis is only on production, income and export and National Rural Health Mission whose emphasis is only on communicable and non-communicable diseases. As mentioned earlier, Food Security Bill – a diluted version of The National Advisory Committee's recommendation for Food Security only includes cereals and millets. Inclusion of millets is to be appreciated but food security needs a basket of foods including pulses, vegetables, fruits, foods of animal origin and oil. Money released from purchase of cereals can be diverted to these foods, provided there is awareness in the public. India is not lacking in policies and programmes beamed at improving nutrition security but lacks in their implementation. With proper leadership, convergence between the efforts of various departments and administrative efficiency, India too can become hunger-free. The economic, health and social cost of malnutrition is too heavy, had underpinned the session, and had suggested the following priority action points for improving nutrition security.

4.4.3.2 Maternal and Child health and Nutrition

1. Female health and nutrition should receive high priority to address the issue of LBW babies-where the problem of child malnutrition begins. Apart from science and technology, behavioural change through social engineering to eliminate gender prejudice and administrative efficiency to improve the working of existing safety net programmes are needed.

2. Promotion of the WHO guidelines for infant feeding. Exclusive breast feeding for the first 6 months and age-appropriate complementary feeding after that. Media help to be taken for creating awareness.

4.4.3.3 Increase Access to Food

3. Adopt nutritionally and environmentally promotive agriculture. For this, the component of human nutrition should be strengthened in agriculture (and medical) education and not left only to food and nutrition departments in agricultural universities.

4. Promote homestead production of vegetables, fruits, poultry (high egg-yielding breeds), milk, fish and even pulses and millets. It improves access to these income-elastic nutritious foods. Urban agriculture needs to be taken up in right earnest.

5. Reduce wastage of farm produce by building storage facilities/cold chain etc. Identify traditional methods for decentralized storage. Nation cannot feed over a billion people by allowing wastage of 30-40% farm produce.

6. Make agriculture remunerative with appropriate support systems and pricing policies and not populist schemes like Rs 1/- kg rice which impact adversely.

7. Use all scientific and technological approaches to augment food production, food protection and biofortification. Fight prejudice and opposition against GM crops with adequate research and monitoring to ensure their safety to health, environment and biodiversity.

8. Develop affordable, nutritious, ready-to-cook/eat processed foods with appropriate forward/backward linkages to benefit the farmers and resource-poor consumers.

9. Ensure food safety from farm to plate with proper legislation, awareness and monitoring.

10. Conduct operation research to find out lacunae in existing feeding and MN supplementation programmes where a lot of money is being spent without adequate impact on child nutrition.

11. Promote nutrition literacy among politicians, administrators and professionals from health, agriculture, education, media, and other categories (besides the public at large) through special short-duration sensitisation/awareness programmes and involvement of multi-media channels, including use of icons.

12. Pass the Food Security Act at the earliest by making it universal rather than targeted. Creamy layer can be eliminated.

4.4.3.4 Policy Issues

13. Leadership at all levels and governance to ensure convergence between the efforts of different departments/programmes.

14. Make nutrition an important input and output parameter for all Government programmes that can directly or indirectly impact nutrition.

15. Streamline targeting, monitoring and impact assessment. Women and children should be the priority

16. National Nutrition Monitoring Bureau which conducts surveys on food and nutrition should be a permanent institution and cover all the States of India. Suitable nutrition surveillance system should be put in place.

17. Nutrition should be the focus of national development, and not treated as trickle down beneficiary of economic development.

18. An integrated and holistic life-cycle approach from paediatric to geriatric is very important in all the programmes interlinking and networking with each other. Otherwise with fragmented programmes, the desired nutrition will not reach the target population.

19. Inter-Ministerial integration in all of the programmes and the idea of Nodal Agency in each Ministry with an identified person and then a Committee with a common charter inclusive of scientists, engineers and technologists in this Committee can mean a lot in the implementation. (Example has been the success of milk and dairy products because of the integrated approach).

4.4.4 Role of Millets in Nutritional Security in India (Policy Paper 66, 2013)

Convened by Prof. Bamji, the Brainstorming Session elucidated that the challenge is to accelerate demand for millets for human consumption and ensure supply through scientific, technological and behavioural engineering.

4.4.4.1 Strategies for creating demand

1. The production and consumption of millets must be augmented with appropriate policy initiatives.
2. Consortium-mode research may be pursued for validating the advantages of millets as health and functional foods.
3. Traditional and non-traditional, ready to use, convenience foods and foods that can be used for complementary feeding programmes may be developed with proven nutrient content and bioavailability mapping.
4. Millet-based complementary foods such as *khichdi*, *upama, roti* etc. in feeding should be introduced in feeding programmes such as MDM, ICDS etc.
5. R&D on millets as fodder and forage for livestock feed security may be strengthened.
6. Commercialize and promote millet-based processed Ready to eat snacks and convenience foods through public private partnership.
7. Awareness regarding nutritional, health and environmental advantages may be created thorough known communication strategies.

4.4.4.2 Strategies for enhancing supply

1. Development of varieties/hybrids of SAM with better recovery capacity on reversal of dry spell for harsh environment/drought prone areas
2. Exploration of zero tillage for millets under rice fallows particularly for southern States.

3. Development of hybrids/varieties resistant/tolerant to salt/high temperature. Strengthening breeding programmes through conventional breeding, marker-assisted breeding as well as biotechnology for biofortification and other traits such as varieties with better root architecture.
4. Validation of high productive technology under real farming situations.
5. Effective deployment of trait-specific germ plasm available in gene banks for genetic enhancement.
6. Evolving strategies for better seed production with public, private, NGO partnership and establishment of seed villages.
7. Research for better post-harvest management for enhancing the shelf life of millets and prevention of wastage.
8. R&D for integrated toolkit for farm mechanization. CIAE Bhopal has developed a millet mill suitable for small millets. This should be tested in millet catchment area. Retro fitting of machinery used for rice/wheat/maize for millet foods processing.
9. Markets and entrepreneurship development through modern and innovative approaches.
10. Generation of scientific data to substantiate the claim of conservation of biological resources, low water consumption, agro-climatic limitations and high nutritious value of millets and their derivatives.
11. Promote production and consumption of millets through mixed/ relay cropping with legumes and vegetables in homestead gardens
12. R&D work to generate evidence-based information on the phytochemicals with nutraceutical characteristics and authenticate their health potential including anti-diabetes, anti-inflammatory and hypo-cholesterolemic properties, through clinical trials and nutritional studies. Functional foods for diabetes and obese populations based on SAM will have good market. Measurements of glycemic index should be done using specified WHO-FAO protocol. Such studies must be extended to the best preparations/recipes from millets with functional properties, through proper clinical trials.
13. Studies to examine the bioavailability of micronutrients from different preparations of millets.
14. Breeding to improve the levels of lysine and tryptophan and also screening the germplasms for specific end uses such as milling, popping, malting and vermicelli noodles etc.
15. Setting up of a training-cum-demonstration centre for integrated processing of sorghum and millets
16. Undertaking surveys of sorghum and millets foods and allied industries, for bringing out a directory and share knowledge base for modernization of the SAM processing industries

4.4.4.3 Concluding Remarks

Nutrition security implies awareness and access at affordable cost to balanced diet, safe environment and drinking water and health care outreach. In this context, Millets contribute towards balanced diet as well as safe environment. They are nature’s gift to humankind. Millets are a treasure-trove of micronutrients like B-complex vitamins and minerals whose deficiencies in India are rampant. They also contain fibre and health promoting phytochemicals which function as antioxidants, immune stimulants etc., and thus have potential to mitigate degenerative diseases such as diabetes, CVD, cancer etc. whose incidence is rising in India. This makes millets important candidates as functional foods. Unfortunately some of these phytochemicals like fibre, phytates and tannins interfere with the bioavailability of micronutrients particularly minerals. Processing can improve the bioavailability of nutrients as well as functionality. Limited studies show that bioavailability as well as functionality differs with the type of processing and preparation. More work is needed to optimize both of these.

Millets are drought, temperature and pest tolerant and hence are grains for the future in an environment of climate change and global warming. Despite these attributes, millets are losing their pride of place both in terms of production and consumption, for a variety of reasons, including policy initiatives which favour cereals. Though they have not enjoyed technological breakthroughs like the green revolution for cereals, their productivity has increased. Confined to poor lands, productivity is further affected and there is a wide gap between potential productivity and productivity in farmers' fields.

Unlike cereals, primary processing of millets poses some problems for want of proper machinery, particularly for small and medium scale enterprises. In recent years, a variety of traditional and non-traditional, millet-based processed foods and complementary foods have been developed. These can become income generation activity for women in household industry. Even while commercialization is needed, primary effort should be to see that millets are consumed by the poor and they are cultivated as mixed/relay cropping with legumes and vegetables in homestead gardens for home consumption to ensure household food and nutrition security.

Scientific, technological and behavioural engineering involving convergence of efforts of agriculture scientists, food technologists, home scientists, policy makers, and media is needed to revalorise millets. Some recent initiatives to rejuvenate millets from production to Consumption, include: "Initiative for Nutritional Security through Intensive Millets Promotion" (INSIMP), under the Rashtriya Krishi Vikas Yojana of Government of India, "Revalorising Small Millets in the Rain-fed regions of South Asia (RESMISA) funded by International Development Research Centre (IDRC) and CIDA (Canadian funds), and DSR-led value chain development approach for commercialisation of millets. Millets are an important component of the National Agriculture Innovation Projects of ICAR, and All India Coordinated Project in Home Science, Other policy initiatives include: price and procurement support for millets, inclusion of millets in the Mid day meal programme and, promotion of Nutrifarms.

4.4.5 Saving the Harvest : Reducing the Food Loss and Waste (Policy Brief 5, 2019)

The challenge is to accelerate demand for millets for human consumption and ensure supply through scientific, technological and behavioural engineering. The following research and policy priorities and strategy were suggested:

4.4.5.1 Strategies for creating demand

1. The production and consumption of millets must be augmented with appropriate policy initiatives.
2. Consortium-mode research may be pursued for validating the advantages of millets as health and functional foods.

3. Traditional and non-traditional, ready to use, convenience foods and foods that can be used for complementary feeding programmes may be developed with proven nutrient content and bioavailability mapping.
4. Millet-based complementary foods such as khichdi, upama, roti etc. in feeding should
5. be introduced in feeding programmes such as MDM, ICDS etc.
6. R&D on millets as fodder and forage for livestock feed security may be strengthened.
7. Commercialise and promote millet-based processed Ready to eat snacks and convenience foods through public private partnership.
8. Awareness regarding nutritional, health and environmental advantages may be created thorough known communication strategies.

4.4.5.2 Strategies for enhancing supply

1. Development of varieties/hybrids of SAM with better recovery capacity on reversal of dry spell for harsh environment/drought prone areas.

2. Exploration of zero tillage for millets under rice fallows particularly for southern States.

3. Development of hybrids/varieties resistant/tolerant to salt/high temperature. Strengthening breeding programmes through conventional breeding, marker-assisted breeding as well as biotechnology for biofortification and other traits such as varieties with better root architecture.

4. Validation of high productive technology under real farming situations.

5. Effective deployment of trait-specific germ plasm available in gene banks for genetic enhancement.

6. Evolving strategies for better seed production with public, private, NGO partnership and establishment of seed villages.

7. Research for better post-harvest management for enhancing the shelf life of millets and prevention of wastage.

8. R&D for integrated toolkit for farm mechanisation. CIAE Bhopal has developed a millet mill suitable for small millets. This should be tested in millet catchment area. Retro fitting of machinery used for rice/wheat/maize for millet foods processing.

9. Markets and entrepreneurship development through modern and innovative approaches.

10. Generation of scientific data to substantiate the claim of conservation of biological resources, low water consumption, agro-climatic limitations and high nutritious value of millets and their derivatives.

11. Promote production and consumption of millets through mixed/ relay cropping with legumes and vegetables in homestead gardens.

12. R&D work to generate evidence-based information on the phytochemicals with nutraceutical characteristics and authenticate their health potential including anti-diabetes, anti-inflammatory and hypo-cholesterolemic properties, through clinical trials and nutritional studies. Functional foods for diabetes and obese populations based on SAM will have good market. Measurements of glycemic index should be done using specified

WHO-FAO protocol. Such studies must be extended to the best preparations/recipes from millets with functional properties, through proper clinical trials.

13. Studies to examine the bioavailability of micronutrients from different preparations of millets.

14. Breeding to improve the levels of lysine and tryptophan and also screening the germplasms for specific end uses such as milling, popping, malting and vermicelli noodles etc.

15. Setting up of a training-cum-demonstration centre for integrated processing of sorghum and millets.

16. Undertaking surveys of sorghum and millets foods and allied industries, for bringing out a directory and share knowledge base for modernization of the SAM processing industries.

4.4.5.3 Issues and Challenges

India is the second largest food and agriculture producer in the world – annually producing nearly 300 mt of foodgrains, 320 mt of horticultural products, 180 mt of milk and 12 mt of fish. Various estimates reveal that about 25% of these produces is annually lost or wasted.

The major issues and challenges faced by the Indian farmers in saving their harvests include postharvest handling and storage in the open, lack of cemented structures for post-harvest farm operations (sometimes forcing the farmers to even use road surfaces for drying their produce), lack of suitable and adequate storage infrastructure, lack of packing houses, cold chain, on-farm processing facilities, fragmented supply chain, uncertain returns leading to either not harvesting or abandoning the produce on streets, besides spillage during harvesting and threshing. In a larger perspective, the country faces the problem of plenty due to insufficient storage capacity for rice and wheat stocks and other food items important for food security.

4.4.5.4 Policy Solutions and Actions

Solutions to saving the harvest depend upon integrated efforts for providing adequate infrastructure, technical support and creating public awareness for the critical loss points along the food chain from harvest to consumption. These include, harvesting/field drying, threshing/shelling, winnowing, farm storage, packaging, cold chain, transportation to market, market storage, avoiding wastage at the retailer and checking wastage in consumption. The following ten specific policy actions were recommended:

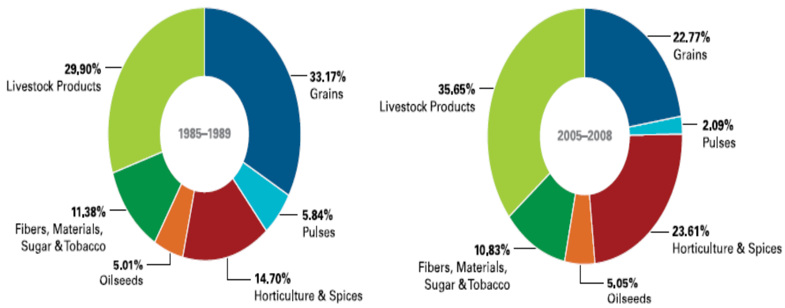
1. Need for greater investments and policy support
2. Research for the assessment of FLW in the supply chain from production to consumption
3. Improvements in on-farm operations through technological interventions
4. Storage and conservation solutions
5. Improvement in transportation
6. Modernization of the domestic slaughter houses

7. Need to increase food processing capacity
8. Establishment of efficient communication environment
9. Food banks for reducing food waste
10. Need to create public awareness

4.5 Diversified Agriculture and Food Systems for Dietary Diversity

Needless to assert, the first and foremost responsibility of all agriculture and food systems is to ensure sustainable, comprehensive, and resilient food and nutrition security. Towards this goal, The Indian agriculture is diversifying fast. Between 1985 and 2008, the proportions of contributions of livestock and horticulture to India's agricultural production had increased by 6 and 9 Percentage points, respectively, while those of grains and pulses declined considerably (Figure 8). The fast expanding middle class and urbanization have pushed up the demand for livestock, including poultry and fish, and horticultural products. Despite the expanding human population per caput consumption of milk and horticultural products has increased considerably, and still growing. The stagnation in pulses production and decline in per capita consumption has recently been corrected and tend should be sustained.

Figure 8. Composition of India's Production Growth by Commodity Group, 1985-1989 and 2005-06



Source: GAP Report 2014

Dietary diversification (food fortification) is the safest and best approach to improve nutritional security. Farming community can be educated to make cropping patterns nutritionally relevant through local planning. While commercial agriculture has to go on for economic security, village/block-level planning to ensure production of all food groups-cereals, millets, pulses, vegetables and fruits for self sufficiency in food is an approach which needs to be tested. Often, nutrition gardens and backyard poultry with high egg-yielding strains have yielded promising outcomes. Urban agriculture can also supplement the efforts. While total dependence on organic methods is not advocated for India, there has to be active research on plant and microbial fertilizers and pesticides since availability of chemical fertilizers has limitations.

4.5.1 Livestock

As the demand for livestock products increases, the production needs to be accommodated in context of finite natural resources, contribution to livelihood and food security and the impact on climate change. Under the declining natural resources and the climate change, as source of high-quality protein and regular income to producers, a positive balance sheet should be created in livestock's contribution to national food, livelihood, and income security. Livestock thus must be an engine of growth equipped with food safety and environmental regulations.

In India, livestock ownership, an effective instrument for livelihood and socio-economic transformation, is fortunately highly egalitarian. It provides employment to 18 million people. It is the base of sustenance to almost 70 per cent of milk producers who are landless livestock keepers or small marginal farmers. Livestock is the main source of quality protein and a pillar of food and nutritional security, employment, gender empowerment, and serves as a source of regular income, a sort of live bank for the day to day needs of the family. On an average, one livestock unit is there for every two humans.

The strengths in India's livestock sector are: (i) although from a low base, despite limited investment from public and private sector, a constant and sustainable growth has been maintained; (ii) highest milk production in the world with sustained high growth rate; (iii) almost a world's monopoly in buffalo production, holding largest buffalo germplasm, and mega bovine biodiversity and population; (iv) differentiated production systems (zero input – low input – moderate output, intensive input – high output); and (v) increasing and sustained demand for animal products.

However, we have a few weaknesses as well, *viz.* (i) low productivity (one third of the world average) with high population and regional imbalances in production; (ii) little control over quality in production system; (iii) low level of technology adoption, low processing; (iv) poor animal health and biosecurity; (v) poor animal nutrition, shortage of feed and fodder and continuous shrinking of fodder area; and (vi) wide gap between availability and requirement of proven dairy bulls.

Unfortunately, our treasure of livestock, especially cattle, germplasm has been eroding fast, particularly due to our misplaced and *ad hoc* cattle breading programmes. If any, our policy on this aspect is divorced from scientific evidences. The damage done must be halted and we must formulate scientifically sound policy of livestock germplasm conservation and utilization. Indigenous populations should be identified, characterized and recognized as "breeds". These should be conserved and improved through selective breeding. Open Nucleus Breeding System (ONBS) programme should be adopted for the best indigenous cattle and buffalo breeds. A differentiated approach is called for crossbred cattle so that defined crossbreds with desired Percentage of exotic blood level could be developed for defined locations. Most importantly, no recognized indigenous breed should be used for crossbreeding.

It is gratifying that the Government of India has taken decision to promote conservation and propagation of indigenous milch breed of cattle under National Livestock Mission and Rashtriya Gokul Mission to promote conservation of native breeds of cattle. The Gokul Mission must help save *Kamdhenus* (*Sahiwal*, Red-*Sindhi*, *Tharparkar*, *Kankrej, Hariana, Gangatiri etc.*) not only for higher productivity but also for high biotic and abiotic resistance and climate resilience. The indigenous breeds are also source of the veritable mega-antibodies for multiple deliveries of vaccines. Such endogenous resources could become the global hub for vaccine production, an uncommon opportunity for strengthening the "Make-in-India" drive.

Man and animals have co-evolved. Causal organisms and cures of several zoonotic and epizoonotic diseases are shared. The recent deadliest outbreak of Ebola Virus, most likely transmitted from fruit bats, in West Africa underpins the biosecurity concerns under the fast changing land use patterns and habitats sharing. The outbreak, and of course the increasing occurrences and spread of swine flu in our own country, point to a deeper interconnect of socio-economic, environmental and human health problems.

It is now well known that almost 80 per cent of viruses and 50 per cent of the bacteria that infect humans are of zoonotic origin. The emergence of new and re-emergence of known infectious diseases is often anthropogenic, and its management is a huge challenge to the entire scientific and development partners and the humanity as a whole. Proactive research and information sharing based on judiciously generated accurate data to allow dynamic decision making must be a high priority. The Veterinarians should partner with human doctors, medical scientists, virologists, microbiologists, bioinformatics experts, biotechnologists, nanotechnologists etc. and create detailed Human Immunophenotype Survey data (immunomics) and an associated map for Indian populations towards building a biosecure India. Biosecurity is a pre-requisite for food security.

As livestock sector impacts climate change and gets impacted by it, the enterprise is increasingly obliged to mitigate its own GHG emissions. Under the fast changing climate, livestock reproductive capacity, feed and fodder are jeopardized and their energy requirement and vectorborne diseases are increasing. Appropriate breeding and mitigation policies are needed to meet the challenges. Climate smart livestock based integrated farming systems hold great promise. There is an urgent need to reorient livestock research and assess the genetic potential of indigenous breeds. Intensive research work needs to be undertaken for genetic identification of traits of excellence in indigenous Indian breeds, and to identify the functional genomics associated with such traits.

4.5.2 Horticulture

Alongwith the Green and White Revolutions, a silent Golden Revolution - horticultural revolution, has been taking place in fruits and vegetables in India. Between 1951-52 and 2016-17, area, production and yield of fruits increased 2.3, 5.6, and 2.5 times, respectively (Table 8). Fruit production increased from 16.5 million tonnes in 1951-52 to 93 million tonnes in 2016-17. The vegetables story is still brighter, area increasing from about 0.5 mha to 10.3 mha and the production swelled from 1.7 million tonnes to 175 million tonnes. The average yield of fruits thus increased from 5.8 to 14.3 t/ha and that of vegetables from 3.4 to 17.0 t/ha.

Table 8. Area, production and yield of fruits and vegetables

Year	Fruits			Vegetables		
	Area (th.ha)	Production (thousand tonnes)	Yield (t/ha)	Area (th.ha)	Production (thousand tonnes)	Yield (t/ha)
1951-52	2840	16500	5.81	490	1660	3.39
1991-92	2874	28632	9.96	5590	58532	10.47
2001-02	**4010**	**43001**	**10.72**	**6156**	**88622**	**14.40**
2010-11	6383	74878	11.73	8496	146554	17.25
2016-17	6479	92846	14.33	10289	175008	17.01

Source: Department of Agriculture, Cooperation & Farmers Welfare, 2018

Horticultural research, science, technology and innovations have paid handsomely:

- There has been increase in the per person availability of fresh fruits in India at 200 g which is better over 190 g/ person/ day as recommended by the ICMR in 2008. Availability duration of fruits like banana, papaya, apple, citrus fruits, grape, guava etc. has expanded
- There has been substantial area expansion under fruit cultivation in Tamil Nadu, Maharashtra, Andhra Pradesh, Gujarat, Karnataka, Uttar Pradesh, Bihar and Madhya Pradesh. India presently ranks second in fruit production after China
- Amongst fruits, the country ranks first in the world in production of banana (27.85 per cent), papaya (35.31 per cent), and mango (39.04 per cent)
- The vast production base offers India tremendous opportunities for export. In recent years, India had exported fruits and vegetables worth ` over 10,000 crore. Mango, walnut, grape, banana and pomegranate account for larger proportion of fruits exported from the country. Freedom from fruit fly infestation has boosted the export. The horticultural value chains of new employment opportunities.

Despite outstanding progress made in overall horticultural production, the following aspects deserve further focused attention: development of high yielding varieties, especially hybrids, combining resistance to biotic and abiotic stresses; designer varieties; molecular breeding; adequate production and distribution of quality planting material; suitable rootstocks; prevention of post-harvest losses; conservation of genetic resources; mechanization; protected cultivation; and eco-friendly plant health management. Horticultural produces suffer the most from postharvest losses and wastes, the losses averaging around 30 per cent. Thus, horticultural research and technology development should give priority attention to refining maturity standards, ripening techniques, storage, cold-chains, transport to distant markets, value addition and diversified products, including functional foods and nutraceuticals.

Likewise, in vegetables, several breakthroughs have taken place. Through varietal developments, growing seasons and availability of several major vegetables have expanded considerably. With the development of tomato varieties “Pusa Sheetal” and “Pusa Sadabahar”, it is now possible to grow tomatoes under extreme weather conditions. With appropriate choice of suitable varieties for specific seasons we can now grow radish, brinjal, cabbage, carrot and cauliflower round the year. Until 1978, *kharif* onion cultivation was common only in the states of Maharashtra, Gujarat, Andhra Pradesh and Tamil Nadu which has now extended to Northern Indian states as a result of development of variety N53.

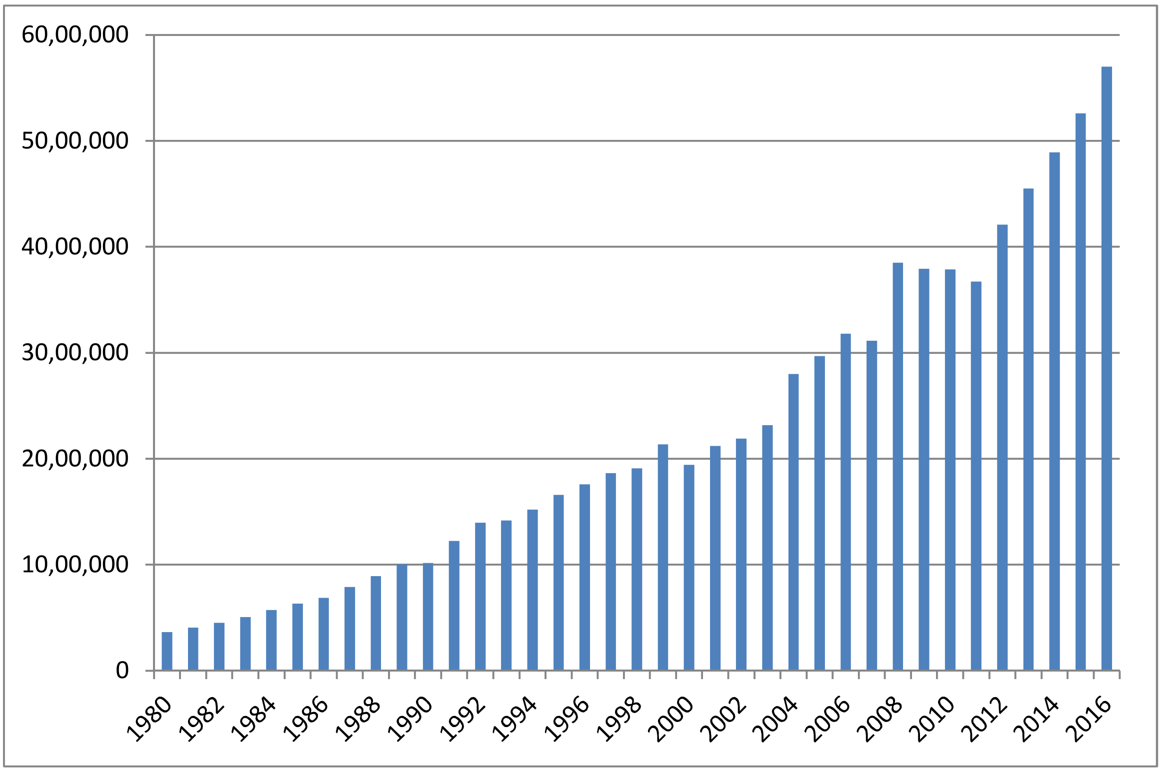
The vast production base offers India tremendous opportunities for export. Vegetable exports have increased from 1,547.00 crore during 2007 to nearly 5,000 crores in recent years. Vegetables like onions, okra, bitter gourd, green chillies, bean, sweet corn, baby corn, mushrooms and potatoes contribute largely to the vegetable export basket.

With current level of vegetable production in the country (over 175 million tonnes), population (1.32 billion) and considering 25 per cent post-harvest losses and 5 per cent requirements for export and processing industry, per capita availability of vegetables in our country is around 290 g as against 300 g recommended dietary allowance (RDA). In order to meet out the requirement of ever increasing population, India needs to produce around 250 million tonnes of vegetables by 2030 and around 350 million tonnes by 2050. With increasing trends in processing and export, the production targets are likely to further increase and productivity per hectare of vegetable crops has to be increased beyond the current level.

4.5.3 Fish

Fish demand will be more than doubled by 2030. As the level of capture fish production has stagnated over the past decades, the dependence on aquaculture will further increase. For the first time in history, in 2012, aquaculture produced as much or more fish as compared to capture fish for human consumption. Aquaculture is practiced generally by small and medium size entrepreneurs, thus their role in increasing nutritional security has increased significantly. In India, aquaculture production multiplied six-fold between 1990 and 2016 (Figure 9). The additional demand for fish toward 2030 is to be entirely met by aquaculture production. The current growth rate would have to be maintained to meet the demand, but extra effort will be needed to produce required feed and to effectively manage fish diseases.

Figure 9. Aquaculture Production in India



Source: FAO, FishStat, 2017

Improving and spread of culture-based fisheries in large number of suitable water bodies provide ample opportunity for fisheries enhancement and will bring in more equity among landless fishers. Further researches need to focus on yield enhancement in small and medium reservoirs and wetlands with due importance on environmental upkeep; large-scale cage and pen culture in reservoirs; formulation of appropriate management norms; development of ecosystem-based models; scientific estimation of environmental flows for the riverine systems for sustenance of fisheries is essential. The research thrust on upland coldwater fisheries in the country should be to focus on promotion of trout and mahseer farming through scientific management for enhancing production, including mass-scale seed production; fish stock enhancement in upland reservoirs; need-based modification of carp farming in mid-altitude waters to other hilly regions.

Considering the availability of technologies and proposed plan to enhance the mean pond productivity to 4 tonnes/ha/yr in the next decade, it is necessary that the research should focus on diversification of species and systems; selective breeding in important fish/shellfish species for useful traits; programmes on transgenics for disease resistance; stem cell development, genomics, proteomics and nanotechnology; quality seed production of potential finfish and shellfish species including ornamental fishes; farm-made feeds and commercial feeds to suit different levels of farming. Stock characterization of commercially important species; milt cryopreservation as a tool for stock up-gradation and *ex-situ* conservation; impact of exotics; and development of molecular markers and their use in molecular taxonomy would need greater attention towards effective biodiversity management and stock up-gradation. As capture fisheries is still an important component of Indian fisheries, due importance needs to be given to habitat restoration and fish conservation in different ecosystems.

4.5.4 Pulses

In India, most people, by choice depend on vegetarian diet. Pulses (grain legumes), besides being on important source of complex carbohydrates, are protein rich, hence the main source of non-cereal dietary protein in the country. But, the pulses production has stagnated around 12 million tonnes during the past decades (Table 9), until 2011-12 when it reached 17 million tonnes. The Green Revolution varieties of wheat and rice had pushed pulses to still marginal areas. Yet, there were ample opportunities for increasing domestic production of pulses and becoming self-sufficient. Several niche areas, such as rice fallows and the "diara" lands, remain under-exploited. There are huge gaps in the demonstrated and actual average yields of pulses. The annual import of 3 to 5 million tonnes of pulses to meet the consumer demand should have been avoided.

Table 9. Pulses and Oilseed production in India since 1951 to 2016

	Pulses			**Oilseeds**		
Year	Area *(million hectares)*	Production *(million tonnes)*	Yield *(kg/hectare)*	Area *(million hectares)*	Production *(million tonnes)*	Yield *(kg/hectare)*
1951-52	18.78	8.42	448	11.69	5.03	430
1961-62	24.24	11.76	485	14.77	7.28	493
1971-72	22.15	11.09	501	17.27	9.08	526
1981-82	23.84	11.51	483	18.91	12.08	639
1991-92	22.54	12.02	533	25.89	18.6	719
2001-02	22.01	13.37	607	22.64	20.66	913
2011-12	24.46	17.09	699	26.31	29.8	1133
2016-17	29.46	22.95	779	26.2	32.1	1225

Source: Department of Agriculture, Cooperation & Farmers Welfare, 2018

Further, pulse prices have in recent years been high and rising, resulting in reduced consumption of pulses particularly by the majority poor people. Since the international market of pulses is very thin, India being the foremost producer, consumer and importer of pulses, must increase its domestic production to meet the ever-increasing demand for pulses. As a matter of fact, given the price incentive, the country had already achieved the targeted production of 23-25 million tonnes during the past two years.

Given the huge gaps in potential area and productivity of pulses, the production gap should be filled forever. Question is often raised as to why India can't meet its pulses demand through home-grown pulses. A mission mode project on pulses productivity and production with defined and differentiated targets should be launched. As suggested by the National Commission on Farmers, clusters of pulses villages with convergent support of technologies, inputs and markets should be created. Public-Private collaboration should be strengthened to produce and distribute adequate quantity and quality of seeds of improved varieties. In at least 5 million ha of the rice-wheat area and other fallows, a mungbean crop is a distinct possibility. Fortunately, 60-day mungbean varieties capable of yielding about 1 t/ha on an average are available. Using conservation agriculture techniques, depending on soil moisture and water availability, a catch crop of mungbean between wheat and rice should be promoted for augmenting the nitrogen and carbon economy, income growth and, above all, protein nutrition.

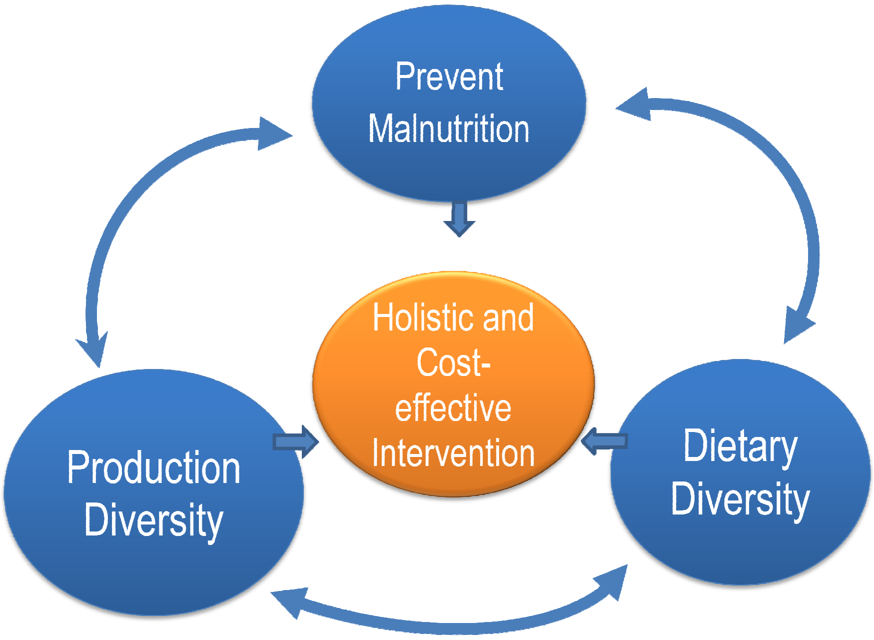
There are strong regional and sub-regional preferences for specific pulses, even though they all may be similar nutritionally. Because of the low substitution among pulses, overall availability is not enough, we need research and development support to increase the production and availability of all the main pulses – chickpeas, pigeonpeas, peas, mungbeans, black gram and lentils.

The rice-wheat system has often been hard particularly on underground0 water resources. Crop diversification out of the system to save water without sacrificing farmers' income should be a viable option. Short duration (120-125 days) pigeonpea genotypes now available can fit in a pigeonpea-wheat cropping pattern with economic returns analogous to those from the prevalent rice-wheat system, plus a huge bonus in terms of soil fertility, reduced water consumption and enhanced human nutrition. The system could be still more productive and sustainable with drip irrigation for the pigeonpea crop. Notwithstanding the bright prospect, the high vulnerability of determinate pigeonpeas to pod borers should be overcome. While other options must be developed as per location-specific settings, GM/GE pigeonpea and other GM crops, as Bt cotton, should prove a boon.

4.5.5 Neglected and Underutilized Species

In context of attaining freedom from undernutrition, FAO (2018) emphasized that concerted effort will be needed to overcome two major existing or emerging gaps. Firstly, the production gap arising due to population increase will require almost doubling in food production by 2050. And, this will have to be achieved with shrinking land, water, and biodiversity resources of the main staples while the increasing heat and drought due to climate change is expected to reduce their yield by 25 per cent. Therefore, relying on these crops alone will not bridge the demand supply gap. Secondly, although staple crops may generally meet calories requirements, they lack several of the essential nutrients, resulting in undernutrition due to unbalanced diets. These production and nutrition gaps may be filled by adopting diversified, holistic agriculture and food systems especially by including proven/potential neglected and underutilized species (NUS) which are nutrition sensitive and climate smart, as depicted below (Figure 10).

Figure 10. Features of Agriculture and Food System for Nutritional Security



While strongly advocating science-led need-based diversification, FAO has recently commended use of neglected and underutilized species (NUS), often called as orphan species, as Future Smart Food (FSF) to fight hunger, malnutrition and poverty. These crops enrich dietary diversification, and micro-nutrient intake, are generally climate resilient, and agro-eco-friendly. Of the several NUS, based on soil, water, and ecological compatibility, the most potential species, complementing the existing staple crops, should be identified for each zone and the AFS should be evolved along the value chain – production, processing, marketing, and consumption of FSF for judiciously harnessing the bio-treasure.

The ICN2 emphasized the importance of NUS through its recommendation 10: "Promote the diversification of crops including underutilized traditional crops, more production of fruits and vegetables, and appropriate production of animal-source products as needed, applying sustainable food production and natural resource management practices". The FAO Regional Office for Asia and the Pacific, under the Zero Hunger Initiative, reiterating that "Agriculture diversification and sustainable intensification is indispensable to address hunger and malnutrition in a changing climate" (Kadiresan, 2018), has established the following criteria for prioritizing NUS in different countries focused on cereals, horticultural species, nuts and spices, pulses, and roots and tubers: (i) Nutritional, food and health values, (ii) Production, productivity and compatibility with the local assets, (iii) Agro-ecological adaptability, and (iv) Socio-economic potential and acceptability.

Under this programme, the national scoping studies in Bangladesh, Bhutan, Cambodia, Lao PDR, Myanmar, Nepal, Vietnam and West Bengal in India had identified the following potential future smart foods (Table 10).

Table 10. Smart Foods in eight countries in South and Southeast Asia

Cereals	Roots and tubers	Pulses	Fruits and vegetables	Nuts, seeds and spices
Amaranth	Elephant foot yam	Black gram	Chayote	Linseed
Buckwheat	Fancy yam	Cow pea	Drumstick	Nepali butter tree
Finger millet	Purple yam	Faba bean	Fenugreek	Nepali pepper
Foxtail Millet	Swamp taro	Grass pea	Indian gooseberry	Perilla
Ragi	Sweet potato	Horse gram	Jackfruit	Walnut
Grain Amaranth	Taro	Lentil	Pumpkin	
Proso millet		Mung bean	Roselle	
Quinoa		Rice bean	Snake gourd	
Sorghum		Soybean	Wood apple	
Specialty Rice				
Tartary Buckwheat				

Source: FAO, 2018

The FAO RAP study has developed the following ten key recommendations related to the NUS and FSF to be adopted at various levels:

1. "Urgent call for decision makers to raise awareness of the nutrition-sensitive and climate-resilient benefits of NUS to address hunger, malnutrition and climate change
2. Recognize, identify and promote complementarities of NUS with existing staple crops for nutrition enhancement, climate-change resilience and diversification of cropping systems, and reliable NUS as Future Smart Food (FSF) to popularize these species
3. Establish a National Coordinating Committee on FSF involving concerned ministries and appoint a Strategic Coordinator at the inter-ministerial level
4. Create an enabling environment by strengthening national institutional support for mainstreaming FSF into national policies and programmes, using appropriate incentives, procurement of FSF for food programmes (e.g. mid-day meal/school-meal scheme) to enhance national consumption, local production and facilitate marketing, as extensively pursued in Brazil during its Zero Hunger Campaign
5. Establish nationally coordinated research for development programmes targeting FSF with high potential, and expand coverage of national agriculture statistics and national food composition data on FSF for evidence-based decision making
6. Document and validate best-bet FSF case studies, compile indigenous knowledge related to FSF, undertake clinical and field studies to demonstrate the health benefits and climate resilience of FSF, and assemble quantitative data for public dissemination
7. Enhance public awareness of the importance of FSF by developing nutrition and climate-change education materials and curricula on the importance of FSF for

consumers, traders, producers, health professionals, researchers, teachers (e.g. school curricula), farmers, women and youth

8. Identify key entry points in the value chain and encourage value-chain development for specific FSF, including innovative and targeted interventions for promotion (e.g. ready-to-use food products) and increase funds for research, development and extension capacities on FSF production and processing technologies

9. Identify key entry points in the value chain and encourage value-chain development for specific FSF, including innovative and targeted interventions for promotion (e.g. ready-to-use food products) and increase funds for research, development and extension capacities on FSF production and processing technologies

10. Establish a regionally coordinated network on FSF to facilitate the exchange of information, policy, technologies and genetic resources, as well as FSF promotion, in target countries."

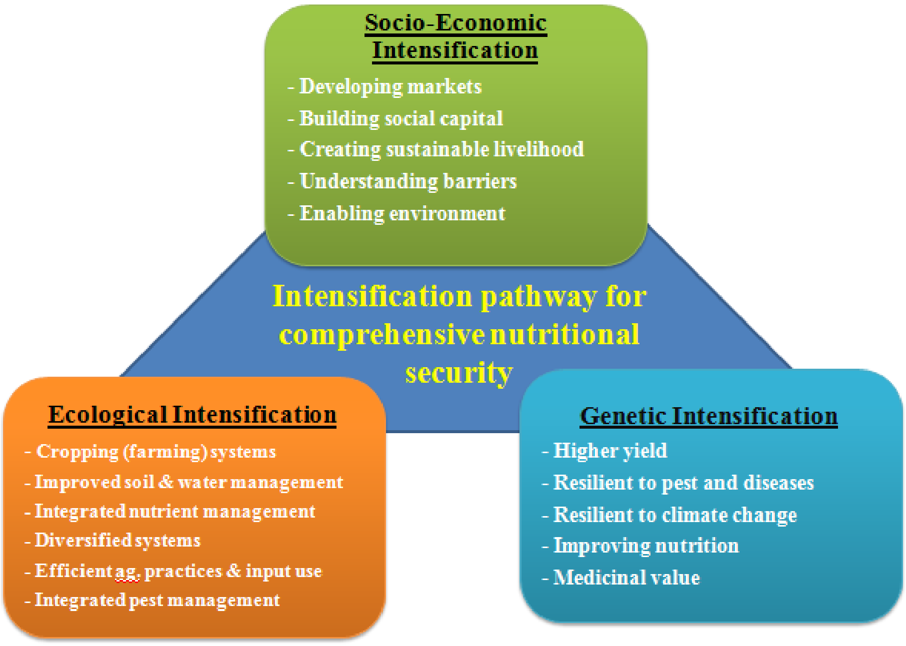
In context of underutilized crops, it is encouraging to note that recently, based on India's proposal, FAO has agreed to celebrate 2023 as the International Year of Millets towards improving productivity, profitability, and consumption of millets throughout the world, which are power house of nutrients but also climate resilient. This will fall within the UN Decade of Action on Nutrition 2016 to 2025. The important nutrition cereals include millet, sorghum, finger millet, foxtail millet and buckwheat. Formulation of effective policies – policy options and actions can greatly benefit from policy frameworks and international laws prepared by concerned UN systems, which have developed and implemented several policies for promoting NUS/FSF into AFS, such as International Undertaking 1983, Convention of Biological Diversity 1992, International Treaty on Plant Genetic Resources for Food and Agriculture 2004, and Sustainable Development Goals 2015.

4.6 Intensification for Nutritional Security

4.6.1 Congruence of vital components of development

Intensification for nutrition should be based on congruent intensification of socio-economic, ecological, and genetic components for holistic development (Figure 11), as recently elaborated by Vara Prasad (2018).

Figure 11. Intensification pathway for comprehensive nutritional security

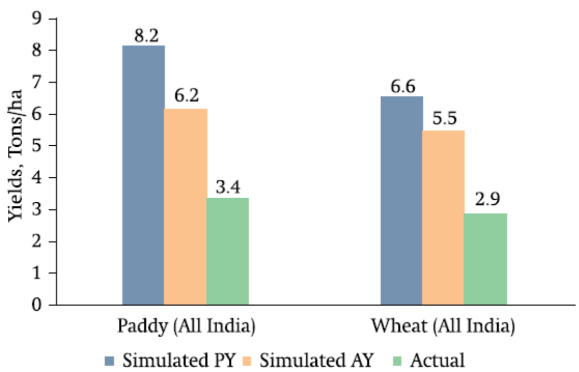


Source: Vara Prasad, 2018

4.6.2 Bridging Yield Gaps

Enhanced yields of the major commodities are the main contributors to the Green Revolution process. However, despite doubling and tripling of wheat, rice and maize yields serious yield gaps exist at various levels. Huge yield gaps exist in major crops like wheat and rice (Figure 12). The gaps may be attributed to the 'extension problem', failure of the farmers to use the new technology or to the failure in fully realizing the potential of the technology. In the fast expanding knowledge domain and global competiveness, knowledge intensive agriculture should be promoted to moderate the input-intensive agriculture. Suitable policy interventions are needed to enhance production and productivity of small and marginal farmers. While the on-going miniaturization of farm sizes should be halted and reversed through promoting off- and non-farm rural employment, land reforms and land leasing and other measures are needed for improving small farm productivity.

Figure 12. Yield gaps, all India



Source: World Bank, 2014

Low yield areas should be mapped and location-specific causes of the productivity gaps and land factor productivity should be identified and specific land and water use decisions should be promoted by restructured and retooled State Land Use Boards to realize the yield and income potential. Crop diversification should be promoted in consonance with market opportunities, farmers' income and ecological sustainability. Farmer-to-farmer learning by establishing farm school in each block, adopting location-specific Integrated Farming Systems (IFS), ensuring timely availability of quality seeds, integrated and balanced nutrient application and management, and proper water management and efficient water use, including Million Well's Recharge Programme, mandatory water harvesting and water use efficiency per drop more crop deserve highest priority.

As mentioned earlier, productivity of livestock in India is also low due to fodder, feed, healthcare, market, and price constraints. Integrated crop livestock- fish farming systems, cooperatives (Amul being world famous experience), SHGs, especially women SHGs for livestock and agriclinics operated by veterinary and farm science graduates and paravets, coupled with fodder and feed banks will immensely increase the productivity and income of livestock owners. Livestock insurance should particularly be accessible to smallholders. In view of the setback to poultry industry due to bird flu outbreaks, quarantine and testing facilities at all ports of entry should be established. Poultry rearing should be recognized as an agricultural activity and appropriate support should be extended to backyard poultry farmers to establish Small Holders' Poultry Estates.

4.6.3 Total Factor Productivity Growth

The agriculture sector had registered an overall growth rate of only about 2.6 per cent during 1991 to 2006. Fortunately, during the subsequent five to seven years, a growth rate of 3.5 to 4 per cent was achieved, but has again slipped back to about 2 per cent, during the 12th Plan, and needs to be bought back to about 4 per cent and sustained in the future to meet the demand. The production growth has accrued essentially through yield enhancement. Yet, average yields of most commodities, including milk and other livestock products are low. Hence, there is ample opportunity for improving yields. Moreover, given that there is no scope for horizontal expansion of cultivated land, the doubling of the food production by the year 2050 must be realized through doubling the yield/ha.

The total factor productivity (TFP) growth rate has been sluggish (Table 11). Compared to China, especially recognizing that average yields of most major commodities in India are about 40 to 50 per cent of those in China, there is ample scope for improving India's TFP through increasing inputs use efficiency, productivity, and profitability. Needless to assert, TFP is now the primary source of global agricultural growth. It increases when outputs rise and inputs remain constant or even decrease. It is this fact which will help the Government in implementing its policy of agricultural produce price being equal to CII + 50 per cent of CII to the satisfaction of both farmers and consumers, and for Doubling Farmers' Income.

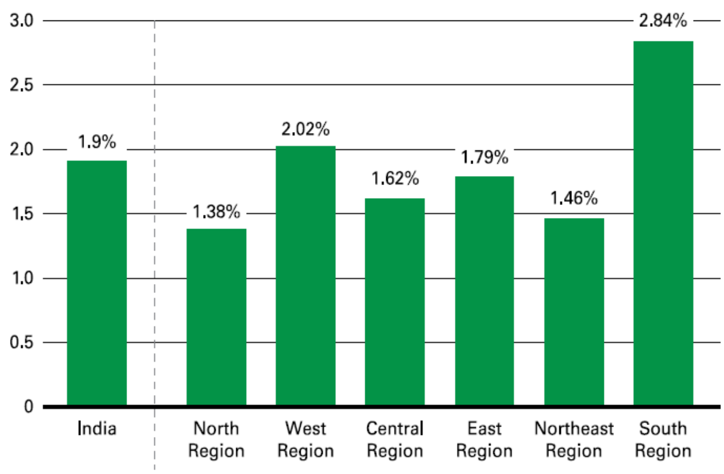
Table 11. Average annual growth of agricultural output and total factor productivity (TFP) in India and other selected countries

Country	Output growth (per cent)			TFP progress (per cent)		
	1991-2000	2001-2006	2007-2012	1991-2000	2001-2006	2007-2012
India	2.6	2.6	3.5	1.1	1.5	2.0
China	5.1	3.2	3.5	3.1	2.5	3.1
Bangladesh	3.2	2.9	0.1	2.0	1.4	-1.6
Pakistan	3.5	2.5	2.6	1.5	0.4	1.4
Sri Lanka	1.0	1.4	2.6	0.8	0.9	2.1

Source: Gap Report, 2014

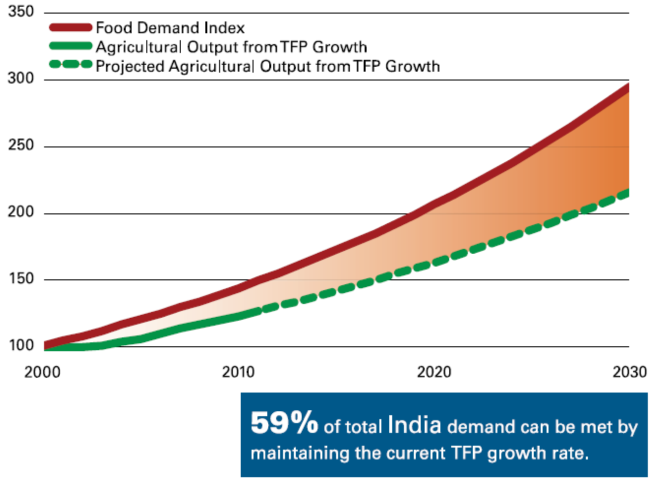
A World Bank / FAO 2014 study, cited in the Gap Report, had shown that the TFP growth rates in India vary from region to region. For the North region, during 1980 to 2008, the TFP growth rate was 1.38 per cent against 2.84 per cent for the South Region (Figure 13). Nearly half of the inter-region variation in the TFP was attributed to state-specific policies, institutions and public investment. The study had also shown that ineffective technology transfer and inefficient enhanced use of inputs in highly subsidized systems had negatively affected TFP, compromising future productivity growth. The GAP analysis projects that with the business as usual, only 59 per cent of total India demand of food and agriculture production will be met by the year 2030 (Figure 14).

Figure 13. Comparative 1980-2008 TFP growth rates for India and its six regions



Source: GAP Report 2014

Figure 14. Food demand compared to agricultural output from TFP growth in India, 2000-2030



Source: GAP Report 2014

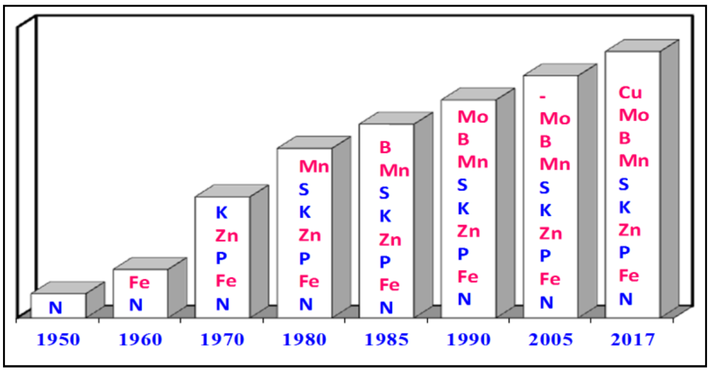
Towards capturing the opportunity to meet our food and agricultural production demands, accelerated agricultural growth calls for:

- Getting technology moving and ensuring access of farmers to the technology by re-establishing a trained, retooled and dedicated cadre of extension workers, strengthening of agricultural research and technology development and transfer systems
- Increasing investment, efficiency and systems support, rationalizing subsidy and ensuring timely flow of cost-effective quality inputs and credit, insurance and other institutional support systems
- Augmenting the physical and economic connectivity of farm to market, post-harvest operations including the role of food processing industries, cautious diversification without jeopardizing food security and ultimately enhancing farmers' income and rural employment security
- Promoting inclusiveness by enhancing access to land, water, credit, market, skills and technology on the part of the poor and smallholder farmers.

4.6.4 Natural Resource Management for Sustained Nutritional Security

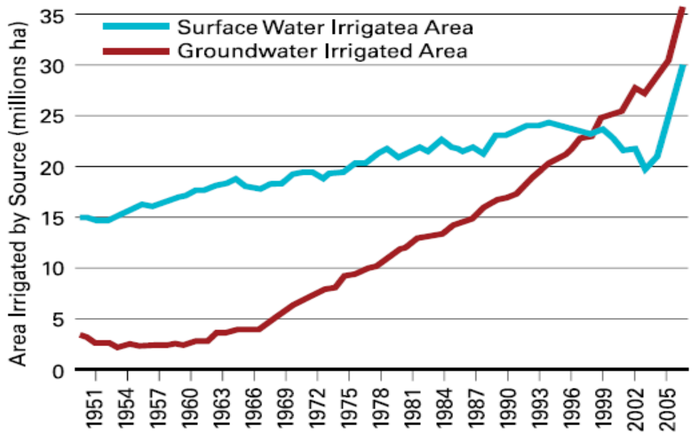
Major cause of declining TFP is imbalanced soil fertility and water management. Nutrient deficiency in our soils is ever-increasing (Figure 15). Our soils being both hungry and thirsty, the TFP is bound to be low. Thousands of well-equipped and well-functioning soil testing laboratories should be established and strategically located throughout the country (in which the private sector, agri-clinics and entrepreneurs can be effectively partnered) and each farmer should be issued a soil health card. Farmers should be oriented and convinced to get their soils tested on regular basis and manage their soil fertility through integrated nutrient application. Millions of Soil Health Cards have been insect, but their impact to yet to be seen. Conservation agriculture involving technologies like zero/reduced tillage are both time and cost saving in popular intensive cropping systems e.g., rice-wheat or maize-wheat rotation or potato plus maize (intercropped) and other diversified systems should be adopted extensively. This movement is catching up in Punjab and Haryana, and during the 2018-19 crop season, through 'Uberization' of Happy Seeder, nearly 8,00,000 ha has been brought under conservation agriculture.

Figure 15. Progressive expansion in the occurrence of nutrient deficiencies



Water is the scarcest natural resource and despite a viable national water policy being in place, water continues to be the most misused commodity. The surface water use has declined over the years while the groundwater irrigation use has steadily increased (Figure 16). A countrywide campaign is required to conserve water and to optimize its use as per resources. Other policy measures for water conservation and efficient use should include : (i) restoring water bodies around the country including village ponds, implementing the Million Well Re-Charge programme and promoting mandatory rain water harvesting in rural as well as in urban India and managing water bodies and reservoirs by stakeholders and water users with the participation of Gram Panchayats and other local democratic bodies and self help groups (SHGs) including women representatives; (ii) withdrawing and not repeating all populistic orders like free electric supply to farmers by various State Governments, that are encouraging excessive pumping of ground water and its wastage; the use of surface water irrigation has declined, and is being increasingly compensated by over exploitation of groundwater, threatening sustainability of the system in several states.

Figure 16. Surface Water and Groundwater irrigation



Source: Faures and Mukherj, 2011

While Indian agriculture is faced with limited and declining availability of land and water, both the resources are stressed by the fast changing climate. Our approach to agriculture, therefore, needs to be redefined in the context of this changing scenario. Increased production will require enhancing productivity levels of existing resources, through increased input use efficiency leading to enhanced net returns to farmers and improving the terms of trade in favour of farmers. In retrospect, the Green Revolution had by-passed the vast rainfed areas. Livestock, including goat and sheep have tremendous potential of greening the grey areas, niche production of specific local breeds and species should be promoted. Likewise, horticultural crops, especially drought resistant fruit and plantation crop species, are particularly suited to rainfed areas, as amply demonstrated in Maharashtra.

Micro-irrigation-drip and sprinkler should be adopted widely to save water and enhance yield. Per capita water storage capacity, India is only 219 m^3 against 1110 m^3 in China and 3145 m^3 in Brazil. The National Commission on Integrated Water Resources Development has announced that “it should be possible to achieve 60 per cent and 75 per cent efficiency by 2050 in surface water and ground water use respectively. Recognizing that agricultural productivity has a direct correlation with farm power availability and labour productivity, the present availability of 1.7 kilowatt per hectare is quite inadequate to achieve the desired productivity levels. In a scenario of rising energy costs and overdependence on non-renewable energy, it is vital to enhance energy use efficiency as well as develop renewable energy. Recent thrust of the Government on solar and wind energy is admirable and should be implemented vigorously with multiple advantages. At small scale, animal-based manures, bio-gas, recycling of biomass and animal-wastes and bioenergy are eminent opportunities and must be harnessed. The rural youth, especially the unemployed ones, should be trained and empowered to establish renewable energy systems.

4.6.5 Value Chain, Market Linkage, and Farmers' Income

Assured and remunerative markets hold the key to retaining the interest of farmers in farming, and also to attract the youth in farming. While FDI in agriculture is bound to be promoted under "Make-in-India" thrust, farmers should be looked at as agri-preneurs who interact with corporate entrepreneurs, needing business models to be worked out to provide win-win options. Appreciating that agriculture is the biggest private sector economic activity in India, we must move from 3Ps to 4Ps i.e. Public- Private-Producer-Partnership.

Prevention of post harvest losses, processing and product development deserve priority in our agricultural policy framework. Post-production losses of perishables and semi-perishables especially in milk, meat, fish, fruit and vegetables are high, estimated at Rs. 50,000 crore annually. About 50 per cent of these losses are preventable using suitable post-harvest technologies. Cost-effective processing, value addition, packaging, cold chain, product quality and safety and prolonged shelf life technologies are the need of the hour, not only for saving the harvest, but also for providing additional off-farm employment. Let us remember, that a grain saved is a grain produced, and an unsafe food is no food, and is also a health hazard.

As we live in a globalized and liberalized world, greater understanding of market intelligence mechanisms, good trade practices, and legal aspects of the multilateral trade regime and agreements and intellectual property rights is absolutely necessary. This calls for the development and institutionalization of user-friendly knowledge systems to support decision-making by various client groups. In line with the nation's Food Bill and Right to Food, trade must first be a component of food security before meeting other obligations, as recently pursued by the Government at WTO and other bilateral and multilateral negotiations.

New Initiatives of the Government on e-NAM, creating a common Indian Markets and investment in establishing additionally 22,000 village markets will directly link the farmers with markets and help them realize remunerative prices for their produces, thus enhancing their incomes and access to adequate nutritive foods. Further, considering that poverty is one of the main causes of undernutrition the Prime Minister's call for Doubling Farmer's Income by 2022 is indeed topical and timely. To achieve this several of the diversification and intensification measures will need to be accelerated as shown in Table 12. Given the urgency and commitment of all stakeholders, the required growth rates are attainable and must be attained to render India Zero Hunger and fully nutrition-secure.

Table 12. Sources of farm income: achievement and required growth rate for doubling farmer's income

Sources	Period	Growth rate (per cent)	Required growth rate for DFI
Crop productivity	2001-2013	3.1	4.1
Livestock value added	2005-2014	4.5	6.1
Improvement in resource use efficiency	2005-2012	2.26	3
Crop intensity	2001-2012	1	1.3
Crop diversification	2003-2014	3.89	5.17
Better price realization	Karnataka reform experience	13	17
Shift to non -farm occupation	2005-2012	1.81	2.4

Source: Ramesh Chand, 2017

No country can feed over a billion people by allowing almost 40 per cent of food to be wasted. This is an area where India needs to do a lot in terms of research and action. Research in traditional methods of storage may have lessons for us. Changing cropping patterns, e.g. shift from rice-wheat cropping pattern in Punjab, to more diverse cropping will demand better methods of storage and value addition. Food safety is yet another issue where India should put its act together if it wants to sustain export. What may be acceptable by Indian consumers will not be acceptable by developed countries.

4.7 Climate Smart Agriculture

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) (2014), discussing the climate change drivers, impacts, adaptation and mitigation had highlighted that the climate change impacts on food security are happening now, and the tropical areas are most exposed to increasing climate risks which also house a large proportion of the world's food insecure and poor people. The AR5 has highlighted the following:

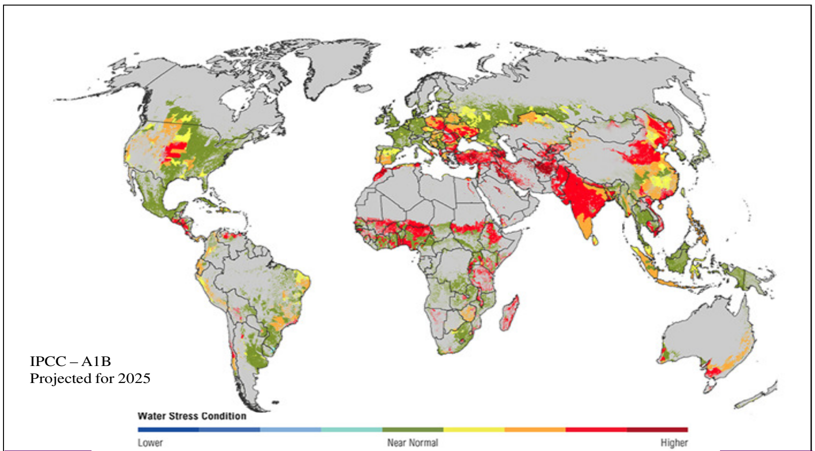
- Climate change has impacts on all aspects of food security – production, (availability), distribution, access to food (affordability), utilization of food and stability of food supplies over time
- Impacts of climate change on crop yields are already evident across several regions of the world. On an average, although some positive impacts are evident in certain areas/pockets, largely the impacts are negative, net global yields of maize and wheat will be suppressed by 4 and 5 per cent, respectively by 2050s, average yields for eight major crops in South Asia will decline by 8 per cent
- Climate change is affecting the current abundance and distribution of freshwater and marine fish harvests. By 2050s, while fisheries yields in high latitudes are predicted to increase by 30 to 70 per cent, these will decrease in the tropics by about 40 per cent,

primarily due to the rises in sea temperature. These changes will adversely impact small-scale coastal fisheries in tropical countries

- In recent years most price spikes for food have been related to climate extremes in major production areas. The spike hurts the poor the most as they spend more than 70 per cent of their income on food
- Climate change has impacts on the nutritional quality and safety of food. Elevated carbon dioxide levels cause decrease in protein and micronutrient contents. Further, often the mycotoxins levels increase from enhanced fungal infections in tropical regions
- Tropical crops, livestock and fisheries are most affected by current climate change; regions of major exposure to climate change coincide with high prevalence of poverty and food insecurity. India and other South Asian countries are most vulnerable to climate change and it is this region which has the highest concentration of food-insecure people and undernourished children
- Greater exposure to climate risks increases the vulnerability of food insecure individuals and households, particularly the marginal and sub-marginal farmers. High recurrences of climate extremes, such as droughts, floods, heat, and cold waves exacerbate the vulnerability of the hungry. Intense seasonal hunger further deepens chronic hunger, nutritional insecurity, and overall livelihood insecurity.

Freshwater availability in South Asia is likely to decrease. Even the most optimistic studies indicate that agriculture, in India and South Asia will be particularly hard hit by water stress by 2025 (Figure 17). During the last 130 years, the region has faced more than 26 droughts. Nearly 70 per cent of the land is drought prone, 12 per cent flood-prone and 8 per cent cyclone-prone. While frost is common in northern regions, heat is a frequent incidence at many places.

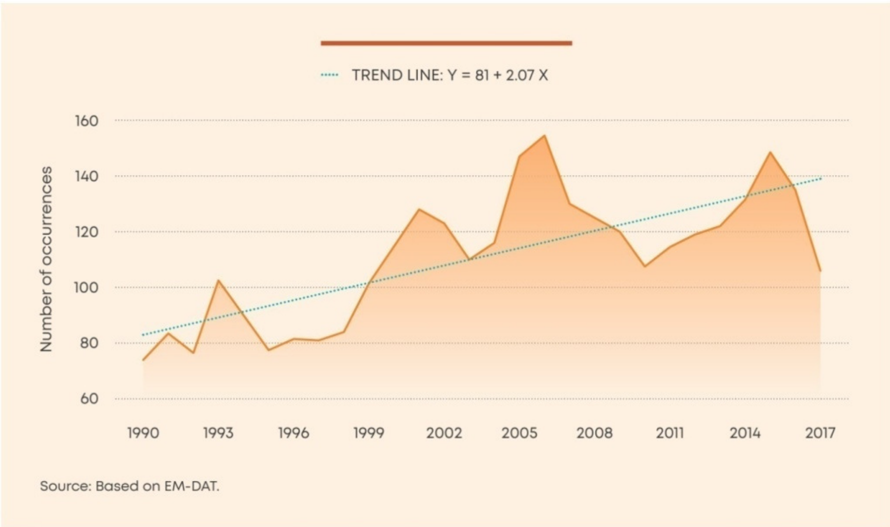
Figure 17. Future Climate Change: Water Stress



Considering the demand of water from agricultural, urban, industrial and human demand, and heat load, modeling data projects water stress around the globe will be increased. Severe stress in regions of India.

Incidence of climate-related disasters have been rising in the Asia-Pacific Region (Figure 18) causing an estimated staggering loss of US$ 48 billion during 2005-2015 (FAO, 2017). FAO warns that "while climate change and extreme weather events are impacting the environment in many ways, agriculture and food production in Asia and the Pacific are among those hardest hit and must be first in line to defend".

Figure. 18 Trends in the Occurrence of Climatic Hazards in the Asia-Pacific Region



Source: FAO, 2018. Asia and the Pacific Regional Overview of Food Security and Nutrition 2018

While South Asia as a whole is projected to suffer highly from the climate volatilities, India is projected to suffer the most in the world in terms of loss of agricultural productivity (Table 13).

Table 13. Projected changes in agricultural productivity from climate change at 2050

Country	% change
Australia	-17
Canada	-1
United States	-4
China	-4
India	-25
Brazil	-10
European Union	-4
Least developed countries	-18

Poorest Hardest Hit by CC, India has largest no. of poor & hungry

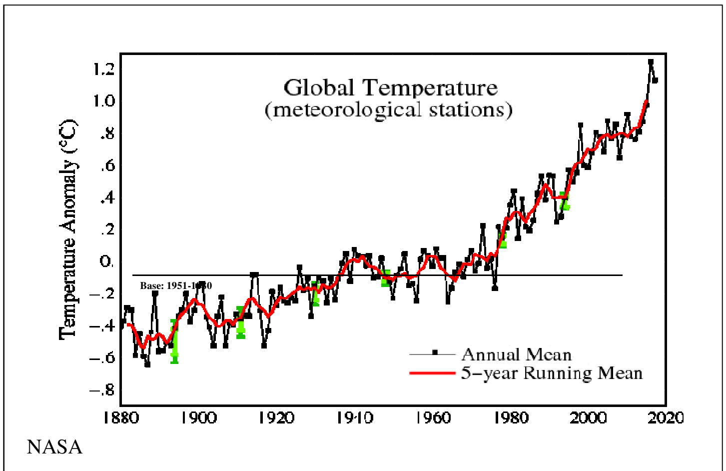
Crop models indicate that average yields in 2050 may decline by about 50 per cent for wheat, 17 per cent for rice, and about 6 per cent for maize from their 2000 levels. The Indo-Gangetic plain, which produces one-fifth of the world's wheat, is likely to be especially adversely impacted. This alone could threaten the food security of 200 million people. Globally, over 1.4 billion will be affected by the increasing frequency of drought and decreasing precipitation. According to an IFPRI study (Nelson et al, 2010), an increase of between 8.5

and 10.3 per cent is expected in the number of malnourished children in all developing countries, relative to scenarios of perfect climate change mitigation.

The Crisis Management Plan of the GoI (2012) reported that annually 50 million people are exposed to chronic drought. Sixteen per cent of India's land area is drought prone and 68 per cent of the land area sown is exposed to drought. The Southwest monsoons account for 86 per cent of rainfall occurring in 100-120 days. Thirty three per cent of land receives less than 750 mm of rainfall, and is classified as chronically drought prone. Rainfall is erratic in four out of ten years. Per capita water availability is rapidly declining due to population and urban growth, industrialization, cropping intensity and depleting groundwater. Unfavorable rainfall pattern and frequency of occurrence of extreme events such as drought and temperature events are becoming highly discernible over the years. As per a GoI estimate in 2012, 5700 sq. km of coastal area in India will be lost due to 1 m sea level rise, displacing 7.1 million people resulting in significant economic losses.

Annual temperatures have changed (risen) more rapidly in recent years (Figure 19). Excessive and untimely rains, hailstorms and strong winds in recent years have caused 15 to 50 per cent crop losses in several states of the country and exacerbated livelihood security of millions of small and marginal farmers. Increased chances of El Nino, coupled with the global warming, will create serious disturbances in rainfall patterns. Such uncertainties have intensified in recent decades and seek priority attention of all stakeholders and development partners.

Figure 19. Past / Current Climate Change: Temperatures



Mean temperatures have increased about 1° C in the last Century.
Annual temperatures have changed more rapidly in recent years.

The UN Conferences on Sustainable Development, the first one in June 1992 in Rio and the second one 20 years later, Rio+20 in 2012 June, again in Rio, as enumerated in the SDGs, had emphasized that the humanity will face threats to water, food, biodiversity and other critical resources which will continually intensify economic, ecological and social crises under the fast changing climate. These have emphasized Green Economy for improved human well-being and social equity, whilst significantly reducing environmental risks and ecological scarcities. FAO (2012) has emphasized that Green or Climate Smart Agriculture (CSA) is needed for achieving Green Economy, and suggested the following steps:

- Assess the current situation, defining the baseline (business as usual) and alternative development pathways
- Understand barriers to adoption of CSA and germplasm conservation practices which may include technological, institutional, financial, services and market constraints
- Collect information on existing and expected social, economic and environmental development settings as assessed through deploying effective and realistic indicators
- Assess efficacy of various CSA practices and strengthen both autonomous adaptation and adaptation to abnormal weather fluctuations and to extreme variations, and enrich insurance products and provisions
- Define coherent policies (technical, institutional and economic) and provisions and policy levers for adoption of cost-effective adaptation and mitigation measures, such as community gene banks and *in situ* conservation and farmers' participatory breeding
- Guide investment based on cost benefit analyses of various adaptation and mitigation practices, including adoption of climate resilient crop varieties, and the trade offs.

The climate smart agriculture movement should be rooted in climate smart villages. Such villages could be created only by ensuring them to be congruently water smart, energy smart, carbon smart, nitrogen smart, weather smart and knowledge smart. Under the *Saansad* Model Village initiative of the Govt, each Member of Parliament may develop at least one climate smart village.

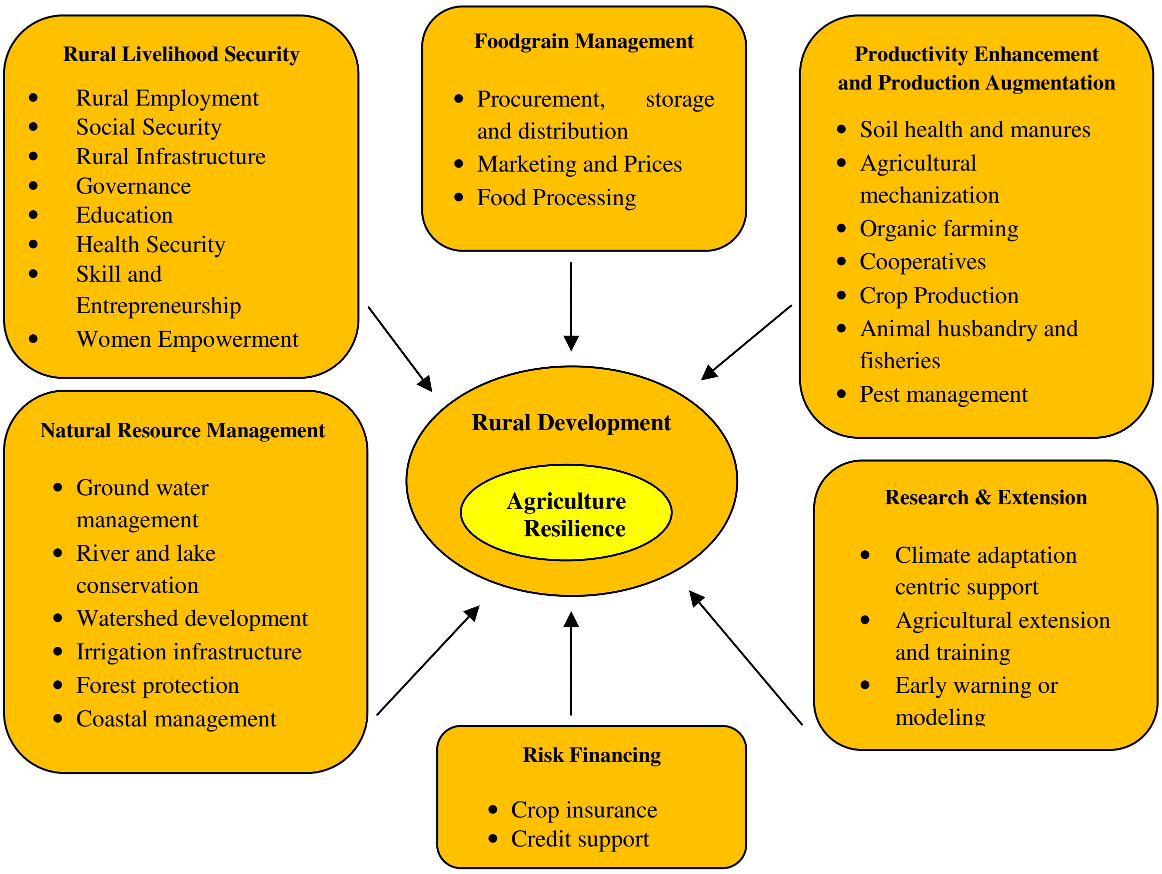
The approach must be to create rich and dynamic knowledge domains to produce more from less. This is very much in line with FAO's call "Save and Grow", and one can often substitute knowledge for purchased inputs. In this context, selecting the most appropriate variety, the landraces, changing land-use practices such as the location of crop and livestock production, crop rotation, especially inclusion of legumes in the rotation, sequence and duration, rotating or shifting production between crops and livestock, and altering the intensity of inputs use can help increase productivity and at the same time reduce risks from climate change in farm production. In this direction, the National Initiative on Climate Resilient Agriculture (NICRA) project of India, encompassing: (i) strategic research to address long-term climate change, (ii) demonstration of innovative and risk management technology in different parts of the country, (iii) funding competitive research, and (iv) capacity building of different stakeholders for greater awareness and community action, is an exemplary step and deserves continued support.

As we move forward, adaptation and mitigation must be seen as two mutually reinforcing pillars of climate smart agriculture, and adaptation-led mitigation should be the way ahead. Moreover, climate is ever-changing, hence one-time adaptation response is not enough, and the adaptive capacity should continually be improved. India's agriculture, agroecologically diverse as it is, should be assessed for its carbon, methane and N footprints across agro-ecologies and differentiated adaptation mitigation plans should be prepared. In particular, dynamic relations of rice ecologies and livestock farming in context of GHG emissions should be analyzed. Genetic restructuring, altered agronomic practices, diversification, integrated cropping and farming systems, and efficient use of biodiversity and other natural resources should meet the micro (farm level) as well as macro level situations.

Risk profile of CSA practices should be understood to be prepared to reduce the vulnerability of farmers to climate risk. New studies undertaken by the South Asian programme of the CCAFS of the CGIAR has recently come up with improved weather-based crop insurance which offers triple wins: a) reduced premium rate, b) expanded, most effective and timely disbursement, and c) savings for the Govt in terms of reduced subsidy, hence lesser load to the exchequer. This product is based on scientific knowledge and is a win-win situation for all stakeholders-farmers, industry as well as the Government. In the rainy season in 2015 alone, more than 1 million farmers in Maharashtra had used it. This new product should be widely piloted and linked with the Prime Minister's Jan Dhan Yojana.

Efficacies of different policies related to climate resilient agriculture and effectiveness of their implementation should be critically assessed. Policies such as those on Agriculture, Biosecurity, Biodiversity, Disaster Management, Food Security, Water, Land etc. should be synergistically converged at different levels, particularly at the grassroots, such as at the level of the climate-smart villages. Institutional adjustments and interministerial convergence are needed to ensure judicious implementation. Development of climate smart agriculture and germplasm conservation should be mainstreamed into the national policy with suitable investment and financing provisions. Singh *et.al.* (2017) have identified following six critical domains with specific sub-groups of rural development for integrating climate adaptation planning as reproduced below:

Figure 20. Critical domains and sub-groups of rural development for integrating climate adaptation planning



Source: Singh et.al., 2017

In line with the Sustainable Development Goals of ending poverty, achieving food security, and promoting sustainable agricultural development, the various stakeholders- Central and State Governments, relevant national (ICAR-SAUs) and international (CGIAR), specially (CCAFS) research and technology development institution, corporate sector, farmers organizations, local communities have jointly identified suitable models of Climate Smart Agriculture and bringing these to scale in several Indian states. A number of tools and tool boxes have been developed for various components of the process. Some of the success stories from CCAFS in India include the Climate Smart Village (CSV) approach, India's Agro-Forestry Policy to promote CSA, growing solar power as a remunerative crop to minimize climate risks in agriculture, improved weather based crop insurance, underground taming of floods for drought management, and precision nutrient management for tackling GHG emissions. Other ongoing and emerging initiatives include India's Food Security Bill explicitly promoting climate resilient coarse grain cultivation, precision land leveling, public private partnership, citizen science approach, manstreaming gender in national adaptation plan, mapping hotspots of germplasm collection, flood mapping and insurance, loss assessment for crop insurance, and empowering women leaders.

Some researcher suggests that the quality of our food is deteriorating in terms of nutrient content (Davis *et al.,* 2004; http://www.theguardian.com/environment/2014/ may/07/climate-change-food -crops-nutrition). This has been attributed to rise in atmospheric carbon dioxide levels. Elevated carbon dioxide levels affect assimilation of nitrate into proteins. There has to be continuous monitoring of nutrient content of hybrids and GM foods. There is also evidence that the micronutrient content of vegetables is declining. Constant monitoring is needed and this is possible only if agriculture universities and government agriculture department have this capability. The KVKs can play an important role in this task.

FAO (2018) has recently summed up that, "a holistic response cycle to disasters comprises elements of prevention, mitigation and response. In addition to post-disaster relief and rehabilitation, it is necessary to comprehensively consider disaster risk reduction, climate change adaptation and mitigation measures as more effective responses to climate-related disasters. This would include investments in anticipatory capacity (e.g. risk assessments and early warning systems), adaptive capacity (e.g. adapting agriculture to new climate trends with the use of new technologies and support for income diversification of vulnerable farmers) and absorptive capacity to reduce the devastating effect of shocks (e.g. social protection and insurance programmes). These measures, among others, are conceived as part of an integrated response package aimed at strengthening the resilience of communities, households, agriculture and the economy as a whole".

4.8 Science, Technology, and Innovation for Nutritional Development

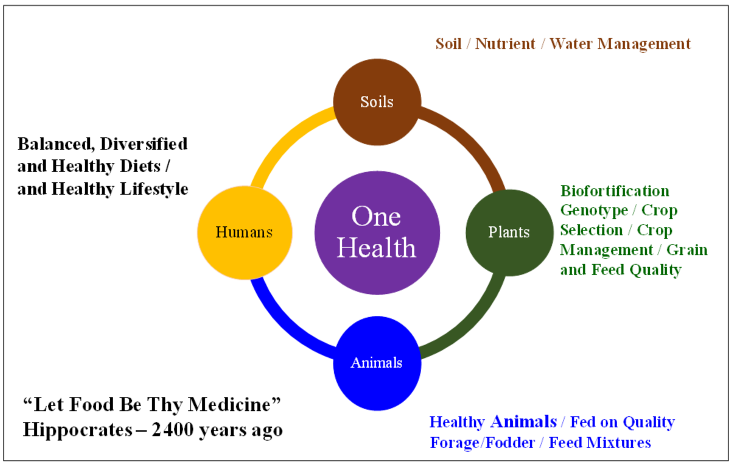
Science, Technology and Innovation (STI) are key drivers for empowering individuals, societies and nations to meet the challenges. We must increasingly appreciate that innovations are the key to prosperity and progress and are needed to trigger technological and economic transformation of farm operations along value chains. Richness of the synergy of science, technology and innovation will underpin competitiveness at various levels in this fast changing world and expanding knowledge economy era. STI should be evolved to simultaneously and dynamically meet the fast changing demands in the humanitarian (socio-economic), environmental, and climate change management goals.

STI for Agenda 2030, especially for meeting the first three SDGs, is a profound global movement primarily through diversification in production and product development, linking the products with national and international markets, and creation of new knowledge, e-connectivity, and the National Knowledge Network (NKN) leading to enhanced inclusivity, employment and ecological security. Towards harnessing its demographic dividend, India must meet the needs of her children and youth for nutrition, health, knowledge, skill, connectivity and identity. The quality and relevance of agricultural research must be enhanced to bring within its domain cutting-edge technologies like biosensors, genomics, biotechnology, nanotechnology and alternative nutrition and energy sources.

Rosegrant *et.al.* (2014) reported that in the developing nations, the number of food-insecure people could be potentially reduced by 12 per cent if nitrogen use efficiency technologies were successfully developed and adopted, by 9 per cent if no-till is adopted more aggressively and by 8 per cent with widespread adoption of heat tolerance and precision agriculture. Results show that irrigation water savings on fields under drip irrigation are 24 to 27 per cent, depending on crop and climate change scenario, much higher than water savings for sprinkler irrigation systems calculated at 11 to 12 per cent. At an aggregate level, if all the 11 technologies (no-till, drip irrigation, sprinkler irrigation, drought tolerant, heat tolerant, precision agriculture, nitrogen use efficiency, crop protection, water harvesting, organic agriculture, and integrated soil fertility management) with positive yield impacts were adopted together for maize, wheat and rice, their prices could be reduced by 49 per cent, 45 per cent and 43 per cent, respectively. This is equivalent to reducing the number of people at risk of hunger by 40 per cent, globally.

The XIth Agricultural Science Congress organized by the National Academy of Agricultural Science (NAAS) in 2011 had its theme One Health: Healthy Soil- Healthy Plants – Healthy Animals – Healthy Humans (Figure 21). It underpinned the Agriculture Food System approach for attaining sustainable comprehensive nutritional and health security. This concept must influence all stakeholders along the value chain, from farm to fork to adopt multidisciplinary collaborative approach in achieving their common goal of a healthy world.

Figure 21. One Health Better Soils – Better Plants – Better Animals – Better Humans



Biotechnology, encompassing wide range of technologies such as cloning, marker assisted selection, transgenics, and veritable ‘omics’ should be used judiciously for augmenting tolerance/resistance to biotic and abiotic stresses, improved nutritional quality, enhanced physiological efficiency, nutrient use efficiency, and bio-products. Recent developments in genome editing (CRISPR-Cas9) have far reaching implications for future agriculture and food systems. A good number of rice, wheat, maize, soybean, sweet potato etc. rich in vitamin A, Vitamin E and other nutrients have been developed and rapidly adopted by farmers and commercialised.

The National Academy of Agricultural Sciences has recently brought out a monumental book “Hundred Years of Agricultural Sciences in India” 2016 (ed. R.B. Singh). All the eight chapters of the book have some elements related to nutrition. More importantly, it contains an exclusive section on Human Nutrition contributed by Mahtab Bamji, a noted nutritionist and NAAS Fellow. Among other things, she has highlighted the Trends in Nutrition Research, Double Burden of Diseases, Prevention of Micronutrient Deficiencies, Food Fortification, and Biofortification as elucidated below.

4.8.1 Trends in Nutrition Research

The Indian Council of Medical Research (ICMR) and the National Institute of Nutrition (NIN) lead and augment the human nutrition research in the country. The National Nutrition Monitoring Bureau and the National Family Health Surveys periodically publish the status and trends of human nutrition in the country. The book on Nutrition Value of Indian Foods, periodically updated by ICMR/NIN, is an invaluable source of information. Their work on functional consequences of malnutrition; development of biochemical/physiological tests for assessing nutritional status, and using them to assess subclinical malnutrition, and derive Recommended Dietary Allowances (RDA) for different nutrients - periodically updated based on new data; nutrition for special groups - infants, children, pregnant and lactating women, and adolescents; prevention of nutritional problems of public health importance; nutrition-infection interaction; chronic diseases and their nutritional basis - validation of the hypothesis of fetal origin of adult diseases; food toxins, their impact on health and methods of their elimination; interaction of nutrients with drugs and other chemicals; nutrition communication etc. are extremely helpful. More recently molecular tools and stem cells are being used to understand the mechanism of action of nutrients at cellular and molecular levels. Emphasis in recent years has shifted slightly from deficiency diseases to obesity and adult –onset chronic diseases like diabetes, hypertension, cancer, osteoporosis etc.

Bamji has further elaborated the role of health-promoting phyto-chemicals (nutraceuticals) present in plant foods besides known nutrients. The NAAS had brainstormed the role of functional foods as well as the role of the Central Institute of Medicinal Plants in human health management and rural economy. Practical dietary guidelines for meeting nutrient requirements based on Indian diets have been evolved. Besides NIN, other institutions like All India Institute of Medical Sciences (iodine deficiency disorders, degenerative diseases) and nutrition departments of Home Science colleges under Agriculture Universities and other universities have also contributed; latter particularly towards development of balanced diets, complementary foods and communication strategies. Agriculture universities have contributed to developing nutrient-dense varieties of plant foods and analysing the nutrient composition of regional foods. The latter has mostly been confined to measurement of macronutrients and a few micronutrients like iron, calcium, vitamin C, β carotene, and provitamin A. Adopting a multidisciplinary approach, the various efforts described above should be intertwined in the One Health Movement.

Agriculture universities should have state-of-the- art laboratories for analysing a range of macro and micronutrients. Following the recommendation of the Fifth Deans' Committee, the Home Science Colleges are being transformed into Nutrition and Community Science Colleges, and the curricula have been revised accordingly. These departments are required to undertake interdisciplinary collaborative research on nutrition sensitive agriculture. Besides the analysis of known nutrients, there should be capability to analyse heath-promoting phytochemicals – anti- oxidants, detoxifying agents, immune stimulants etc to identify functional foods. Plant foods are high in fibre and other anti-nutritional factors- phytate, phenols, etc. These impair absorption of micronutrients, particularly minerals and trace elements. Therefore, apart from measuring the nutrient content, bioavailabilities of nutrients also have to be measured using *in vitro* and *in vivo* methods. In the case of nutrients like ß - carotene (provitamin A), conversion factor to vitamin A has to be determined. Current research is addressing the issue of bio-availability from raw foods and effects of processing.

4.8.2 Double Burden of Diseases

India being a country in developmental transition is facing the double burden of pre-transition diseases - undernutrition and infection, with steadily growing burden of post-transition diseases like obesity, diabetes, hypertension, cardiovascular diseases, cancer, etc. What is often not recognized is that undernutrition in early life can contribute to both. The first one thousand days from conception are the most important for physical as well as mental development. Many seem to miss the window of opportunity for correction as the incidence of post-transition diseases like obesity and diabetes in India is growing and the country is becoming the diabetes capital of the world. Shift from consumption of natural and unrefined foods rich in fibre to highly refined and processed foods rich in salt, sugar and saturated fat typical of modernization is not conducive to good health. Thus, the importance of life-cycle approach to nutrition can hardly be overemphasized.

4.8.3 Prevention of Micronutrient Deficiencies

Anaemia is one of the most worrisome nutritional disorders with serious effects on morbidity, productivity and mortality. Major cause is dietary deficiency (and poor bio-availability from plant foods) of iron and to a lesser extent of folic acid and perhaps vitamin B12. Worm infestation also contributes. The Government of India's anaemia prophylaxis program involves administering supplements of iron and folic acid to pregnant and lactating women and children 6 months to 5 years. The quantum of supplements to be given was prescribed by nutrition scientists. However, due to administrative infirmities, the program has failed to reduce the incidence of anaemia.

A lifecycle approach has been proposed in the recent iron+ initiative of the Ministry of Health and Family Welfare, by bringing in other age groups like adolescence, and nonpregnant, non-lactating women. This initiative not only prescribes the quantum and periodicity of supplementation, but also service of packages for treatment and management of anaemia, and delivery systems. Currently research is going on to see the absorption of iron given daily vs. less frequently (weekly) and interaction of iron with other minerals at the intestinal level. Whether or not, de-worming should be uniformly adopted is controversial due to lack of consensus among pediatricians. Inclusion of other micronutrients like vitamin C (for better iron absorption), B-12, and zinc, also needs to be examined.

The National Prophylaxis Program against Nutritional Blindness due to vitamin A deficiency should be continued and strengthened to eradicate vitamin A deficiency of all forms. The plenty of β carotene (vitamin A precursor) in plant foods, should be exploited with diversified cropping patterns. Agriculture scientists can play an important role in promoting such food-based strategy to combat vitamin A deficiency. Some studies from Indonesia claim that β carotene from vegetables is not absorbed. However, many studies from India suggest that this does not apply to Indian children who are deficient in vitamin A. Availability of β carotene from foods is higher in deficient individuals. Inclusion of little fat helps absorption of β carotene, but this aspect needs to be critically researched to make smart recommendations. The conversion ratio of beta carotene to vitamin A is an area of some controversy. ICMR has recently revised this ratio from 1:4 (weight /weight) for vitamin A produced from beta carotene to 1:8.

India has two national programmes -Integrated Child Development Services (ICDS) and the school Mid-day Meal (MDM) programme. In ICDS supplementary food is provided to vulnerable groups- children, pregnant and lactating women to meet the energy and protein gap. Bridging the micronutrient gap through inclusion of vegetables, fruits and animal products is missing in many states, though some southern states like Andhra Pradesh are including eggs and milk. Though ICDS has been in operation for many years it has not made the expected impact on child nutrition. The barrier should be identified and removed. Nutrition scientists have provided the guidance for the quantity and quality of the supplementary food to be given based on nutrient gaps reported in national surveys. Locally suitable ready to cook, packaged complementary foods instead of take-home rations of cereals and pulses, may be better targeted.

4.8.4 Food Fortification

As seen with iodized salt, food fortification is a promising method for reaching micronutrients to the vulnerable groups. The micronutrient added should be stable and absorbed. Iodized salt was initially tested by Late Prof. Ramalingaswamy and colleagues at the AIIMS in the Kangra valley. Based on their findings, National Goitre Control programme was introduced. The Government of India in 1984 launched the programme of universal iodization of salt. Recent ICMR survey shows very favourable impact. Stability of iodine in salt has to be ensured. NIN has developed a simple kit for estimating iodine content of salt which can be used for monitoring. Since in the areas which are endemic for iodine deficiency, anaemia is highly prevalent, the NIN has developed iron-fortified iodized salt (double fortified salt-DFS), to address the dual problem of iodine and iron deficiency. The technological problem of stability of the two nutrients and availability has been overcome. A technical committee constituted by the Government of India has recommended use of NIN-DFS salt in nutritional programmes for vulnerable groups. Commercial production of DFS has also started in different parts of India.

One laudable development is the involvement of state governments like Tamil Nadu in production and distribution of iron and iodine fortified salt. The quantum of fortification of iodine and iron was determined on the basis of consumption of 10g salt per day. However, cardiologists now recommend much lower (5g) consumption of salt to prevent hypertension. This is a new dimension which needs to be addressed. However, even with lower intake of salt, it may be possible to supply 5 mg of iron. With more vehicles for fortification on the agenda, fortification can be a useful approach to reach iron through food. Attempts are being made to fortify wheat flour with iron. The new Fe-fortified wheat, maize and rice varieties will help solve the hidden hunger problem.

Bio-availability of iron from fortified wheat flour is a problem because of pyhytate content. This antagonism must be resolved soon as a good number of iron and zinc rich wheat varieties have been developed and released. Wheat being a major staple and foremost PDS grain, the impact will be overwhelming. Though foods such as sugar and soy sauce have been used in some countries for fortifying with vitamin A, they are not suitable for India. Oil fortification with fat-soluble vitamins is being tried in Gujarat. The outcome of this effort should be assessed critically, and the successful experiences should be adapted by other states.

4.8.5 Biofortification

Agriculture scientists are attempting to improve the nutrient content of foodgrains and vegetables through conventional breeding, marker-driven molecular breeding and genetic engineering, although the latter has become a subject of controversy. While ample care is needed for ensuring safety to health and environment (biodiversity), misguided opposition needs to be countered. The Consultative Group on International Agricultural Research (CGIAR) has initiated the bio-fortification of seven food crops, including wheat, rice, pearl millet and maize through its *Harvest-plus initiative* (harvestplus@cgiar.org. www.harvestplus.org. Accessed Jan 3, 2011), involving conventional breeding (Chakraborty *et al.* 2010). India is an active partner in this initiative. India commercialized the cultivation of iron-rich-pearl millet in 2012, and this variety is being grown in few hundred acres. It is being marketed by Nirmal seeds. This firm is also trying to develop high-zinc wheat. Bangladesh Rice Research Institute has developed zinc-rich rice. Sweet potato varieties enriched with β carotene have also been developed. Work at the NIN has shown that about 25-50 g of the richer varieties can meet the preschool child's requirement of vitamin A. Bioavailability of β carotene from orange-flesh sweet potato has been found to be good. Agriculture scientists need to work closely with nutrition scientists to promote such varieties. Biofortified varieties do not pose the problem of vitamin A toxicity that chemical supplements do, since there is regulation in absorption. Golden rice, enriched with β carotene has been developed by genetic engineering involving introduction of three genes. Its safety, bioavailability and acceptability have been tested already and registered as safe in Australia, Canada, New Zealand, and USA. Bio-availability of micronutrients from bio-fortified crops should be the constant agenda for research since excess of one micronutrient, particularly trace elements and minerals is known to inhibit the absorption of other micronutrients competitively.

The National Agricultural Research System (NARS) has developed and released a series of biofortified varieties for ten different cereal, oilseed, vegetable and fruit crops (Yadava et. al., 2018) as given in Table 14. With wide adoption and adaptation of these varieties, agriculture-based alleviation of malnutrition, especially undernutrition will become a reality. Several studies on impact of feeding products from such fortified varieties in India and elsewhere especially in Africa, have confirmed efficacy of such varieties in improving human nutrition and child health. All crop improvement programs must include nutritional quality traits in their genetic improvement objectives and ensure adequate availability of certified seeds of such varieties. Assured premium remunerative price for biofortified products will help faster adoption of such varieties for realizing widespread impact.

Table 14. Details of baseline level of nutrients in targeted crops and levels achieved through biofortification

Crop	Nutrient	Baseline levels	Levels achieved
Nutritional Factor			
Rice	Zinc	12.0-16.0 ppm	>20.0 ppm
	Protein	7.0-8.0 per cent	>10.0 per cent
Wheat	Iron	28.0-32.0 ppm	>38.0 ppm
	Zinc	30.0-32.0 ppm	>40.0 ppm
	Protein	8-10 per cent	>12.0 per cent
Maize	Lysine	1.5-2.0 per cent	>2.5 per cent
	Tryptophan	0.3-0.4 per cent	>0.6 per cent
	Provitamin A	1-2 ppm	>8.0 ppm
Pearl millet	Zinc	30.0-35.0 ppm	>40.0 ppm
	Iron	45.0-50.0 ppm	>70.0 ppm
Lentil	Zinc	35-40 ppm	>50.0 ppm
	Iron	45-50 ppm	>62.0 ppm
Cauliflower	β-carotene	Negligible	>8.0 ppm
Sweet patato	Anthocyanin	Negligible	>80.0 mg/100 g
	β-carotene	2.0-3.0 mg/100 g	>13.0 mg/100 g
Pomegranate	Vitamin C	14.2-14.6 mg/100 g	>19.0 mg/100 g
	Iron	2.7-3.2 mg/100 g	>5.0 mg/100 g
	Zinc	0.50-0.54 mg/100 g	>0.6 mg/100 g
Anti-nutritional factor			
Mustard	Glucosinolates	>120.0 ppm	<30.0 ppm
	Erucic acid	>40 per cent	<2.0 per cent
Soybean	(Kunitz trypsin inhibitor)	30-45 mg/g of seed meal	Negligible

4.8.6 Water, Sanitation and Hygiene (WASH)

The Swachh Bharat Swasth Bharat campaign of our Hon'ble Prime Minister Shri. Narendra Modi is a most timely and profound call for building a nutrition – secure New India. Researchers have shown that a child's risk of stunting at 24 months of age was multiplied by a factor of 1.05 for each episode of diarrhoea the child had experienced in the first two years of life (Block et. al., 2013). The evidence suggests: WASH improvements reach high coverage throughout the whole community (not just the home or compounds of pregnant women and young children); water treatment technologies are effective against all known pathogens (not just some); and the long-term and complex nature of behaviour change related to WASH practices (e.g. handwashing, household water treatment, safe disposal of children's feces, etc.) is addressed with ongoing innovation and creative new communication approaches to effect sustainable behaviour change.

The recent thrust of the Government on providing piped drinking water to every household is most timely as 742 million people in India are without piped water supply in their premises, against 308 million in China (FAO, 2018). Likewise, India's access to basic sanitation is around 45 per cent against more than 75 per cent in China, in 2015.

4.9 Way Forward to Eradicate Malnutrition

Under each section, policy options, actions, and priority research and development pathways have been suggested. This section deals with overarching solutions and suggests pathways for meeting the goals of freeing India of malnutrition.

The Government had recently announced Kuposhan Mukt Bharat, National Nutrition Strategy: Vision 2022. The strategy envisages:

- "Healthy, optimally nourished children, realizing their growth and development potential, active learning capacity and adult productivity
- Healthy, optimally nourished women realizing their social and economic development potential
- In protective, nurturing, gender sensitive and inclusive community environments
- That enhances human and national development in the present – and in the future."

In consonance with the strategy and the recommendations and suggestions of various national and international programs described earlier, the following framework is suggested for National Actions to eradicate malnutrition in India and elsewhere.

4.9.1 Make the political choice to end all forms of malnutrition and make nutrition key goal of Agriculture

In countries off course to attain targets for nutrition, political leaders as well as leaders in civil society, businesses and corporate sector must make SMART commitments to nutrition and plot development trajectory at various levels – individuals, households and country, to address the various forms of malnutrition as per location-specific needs and prospects. Comprehensive nutritional security should be the key goal of agriculture. Leadership at all levels and governance should ensure convergence among concerned ministries and sectors. Inter-Ministerial collaboration is needed to congruently improve health, nutrition and farmers' income.

4.9.2 Keep the Smallholder Farmer at the Centre Stage

Smallholder farmers, accounting for India's 85 per cent of all farmers, 48 per cent of the cultivated land and over 50 per cent of the total agricultural production, are vital not only for India's agriculture and agrarian economy, but also for achieving the Sustainable Development Goal of reducing hunger and poverty in the world as a whole. Over 50 per cent of the smallholders possess less than 0.5 ha land, referred to as sub-marginal farmers, and their number has been increasing with the increase in the population. Thus, the small is getting smaller. Despite their higher per unit productivity, the extremely small and fragmenting holdings are becoming economically nonviable, and the sub-marginal and marginal farmers are swelling the ranks of the hungry and poor (Table 15).

Table 15. Proportion of poor and undernourished person in different farm-size groups in rural India, 2004

Farm Size	Share of each group in total poor, per cent	Share of each group in total under-nourished, per cent
Agrl. Labourer	26.4	22.0
Marg. Farms	56.8	51.3
Small Farms	2.9	3.9
Med. Farms	1.3	2.1
Large Farms	0.4	0.6
Other Rural	12.2	20.1

Agenda 2030, especially SDG2 seeking actions of all stakeholders to eliminate hunger, all forms of malnutrition and poverty, and doubling of agricultural productivity and income of smallholder farmers, is most pertinent in the context of unethical and paradoxical increase of hunger and poverty among the majority small, marginal and sub-marginal farmholders. Therefore, our efforts must focus on the betterment of the smallholder farmers to break the India enigma.

The business as usual has failed to adopt a holistic pro-smallholder approach for the entitlement to land and other production resources, acquisition of agricultural knowledge, technology generation and transfer, linking farmers with markets, enhancing their incomes and management of climate change and risks. We need to answer the questions as to how can the requisite empowerment be accomplished, and the smallholders enabled to accept the challenges and opportunities of new developments, such as bio-technology, informatics, and globalization? What socioeconomic policies shall facilitate the empowerment?

The land reforms and land use policies must not encourage conversion of rural poor into urban destitute. Fragmentation of farms below a certain size, say 0.5 ha, should be stopped. Land lease markets should be liberalized to promote scale of economy and to aggregate miniscule holdings. Land acquisition rules and guidelines should not only be transparent, but also be pro-poor and improve farmers' income and employment security.

The potential of smallholders will be realized only when the smallholders are empowered to access the crucial resources and entitlements viz. land, water, energy, credit, insurance, markets and appropriate technologies. They should have opportunities to develop skills and to access the information wherewith to use them. They should be linked with functional and fair markets both for products and inputs and reduced market risks and transaction costs. Enhanced employment off-farm and non-farm and income security, health care and sanitation, and education and social services will go a long way in empowering the smallholder farmers.

Small Farmer's Agribusiness Consortium of the Ministry of Agriculture could proactively develop agribusiness projects and arrange venture capital flow for development of agribusinesses in the country in association with commercial banks. Rural India will have to take a plunge in the main stream of globalization and compete globally for gaining leadership to generate wealth and job opportunities in order to remove hunger and alleviate poverty. The "Rural Business Hubs" concept of corporate sector should become a popular movement. Agri Marts, Agriclinics, Contract Farming (farmer-friendly), Agri Parks, Special Agri Zones, Producer Companies, Primary Cooperatives etc. could all become instruments of farmer-market-rural employment linkage design and strategy. IFPRI studies have shown that farmers could substantially enhance their incomes through contract farming. Government should play a facilitating role to empower farmers to come on grips with market mechanism and, if necessary, provide support in form of direct subsidies to the deprived ones.

Research must become more development oriented with focus on the 0resource-poor smallholder farmer. Some of the issues which should be researched on priority basis to inform policies are: (i) reliable biosecure measures towards harnessing biotechnology and other cutting-edge technologies with smooth and cost-effective flow of quality seeds, (ii) insulating the poor from the uncertainties of market and climate change and translating price incentives into increased net income and welfare of farmers, especially the smallholders, and (iii) prospects of agricultural diversification and enhanced labour-productivity.

4.9.3 Nutrition-Specific Allocation

The various initiatives notwithstanding, nutrition-specific details were seldom reflected in India's development plans, and details of nutrition-specific allocations and spending, and their impacts, were not available. Since improved nutrition is the platform for overall progress, investment in and financial allocation to nutrition should be explicitly reflected in the national plan as being now adopted by the concerned ministries and NITI Aayog. Specific Measurable Achievable Relevant Time-bound (SMART) targets should be explicitly defined in the national policy and plan documents, and should be followed coherently and judiciously.

4.9.4 Invest more and allocate better

As demonstrated in Maharashtra and Odisha, targeted investment in undernutrition pays off highly. Specific allocations for alleviation of undernutrition in concerned ministries and sectors, *viz.,* agriculture, health, education, food, water, sanitation, hygiene and social welfare should be effectively monitored, synergized and integrated to end malnutrition in all its forms. Convergence of efforts of scientists in the different related ministries and departments will enable interdisciplinary efforts to yield holistic outcomes.

4.9.5 Collect the right data to maximize investments and join the World Data Revolution

Data gaps are adversely impacting nutrition planning, implementation and progress. Given the high intensity and spread of undernutrition in the country, a national grid for collecting nutrition data should be created to bring out the ground facts (data) every three years for effective planning and resources allocation. India should actively participate in the World Data Revolution for Sustainable Development Forum to strengthen nutrition presence in the data revolution and also to put its own nutrition data in a format compatible with the UN Systems, especially the SDGs platform and FAO. The Indian Agriculture Statistics Research Institute (IASRI), and concerned Departments of the Ministry of Agriculture and Farmers Welfare, the Ministries of Statistics and Programme Implementations, the Ministry of Food, and the Ministry of Health should ensure reliable data and analyses to ensure effective interventions along the AFS value-chain to achieve comprehensive nutritional security.

4.9.6 Scale-up and invest in carrying out proven and evidence–informed solutions – and in identifying new ones

There are several success nutrition stories within India and outside, such as the Brazilian Zero Hunger Campaign, which must be scaled-up and scaled-out. Keeping the local context and knowledge gaps in mind, proven specific interventions, policy options, actions, and processes, should be identified and adopted. An excellent opportunity exists for ICAR, ICMR, the concerned Ministries and NGOs to work together to synergize the efforts of researchers and development agencies to ensure that none is left out in the SDG era. Recognizing that nutrition is most effective entry point for human development, long-term investment in nutrition at different levels will have highest development impact. Adopting an "All-Hands-on-Deck" approach, capacities of nutritional professionals in all concerned sectors should be strengthened to motivate them to apply a nutrition lens.

4.9.7 Need-Based Diversification and Intensification

Adopt and adapt a socio-economically and agro-ecologically differentiated approach in adopting new technologies and products. For instance, Quinoa, a NUS crop, which was initially confined to Peru, Bolivia and Ecuador, has now spread to 70 countries, including India. Current status and future prospects of quinoa in India should be critically assessed and future plans prepared accordingly. Likewise, the role of pulses in rice fallows should be analysed and future actions planned to render India sustainably self sufficient or even surplus in pulses. In a counting like India where most people are vegetarian, pulses, being nutritionally dense, climate resilient, economically viable, and locally adaptable, should be used as FSF suitable for closing nutrition gaps and enhancing sustainability. Availability of quality certified seeds of the recommended varieties are essential for achieving desired diversification and intensification. The existing seeds, keeping in mind the increasing use of novel seeds, should be updated and a broader definition of seed should be accepted. The Central Government is hoping to roll out a Social Protection: There should be multiple instruments to reach the unreached to render the program equitable and need-based. Appropriate instruments should be identified for different climatic shocks and socio-economic settings, including index-based insurance that save lives livelihoods, and should be equitably supported.

4.9.8 Tackle malnutrition in all its forms

Unfortunately, India is home not only to largest numbers of stunted and wasted children and anaemic mothers, but also is the world's diabetes capital, and obesity is sprawling fast – the "New Normal". Systems approach is needed to change "obesogenic" environments into enabling environments and ensure that interventions to tackle undernutrition do not inadvertently contribute to obesity. Our policies, actions, and interventions must integrate the efforts to control the non-communicable diseases (NCDs) simultaneously. The stakeholders should implement "double-duty" actions and apply a nutrition lens in their work to clearly see the sprawling "invisible" to tackle malnutrition in all its forms. Actions are needed at the level of individuals (direct nutrition interventions), at the level of households and communities (nutrition sensitive interventions – health, sanitation, awareness etc), and at the level of the country (national policy, planning and programming) to achieve comprehensive nutritional security.

4.9.9 Awareness Raising and Nutrition Literacy

For nutrition security, there has to be awareness and access at affordable cost not only to balanced diet but also to healthy, disease-free environment (to ensure absorption and assimilation of nutrients) and health care outreach. The "One Health" concept should be adopted by all stakeholders to achieve universal nutritional and health security.

There is enormous scope for creating nutrition literacy not only in the community but also among the politicians, the policy makers, the administrators, and health, agriculture and management professionals, teachers, social scientists, NGOs, corporate sector and others. For that, nutrition scientists have to work with mass communication specialists. Media and modern IT technologies can play an important role. Nutrition component of medical, agriculture, management and school curricula need to be strengthened.

It is encouraging to note that, among other programs, POSHAN Abhiyaan - the National Nutrition Mission, launched by Prime Minister Narendra Modi on March 8 this year, has decided to celebrate September as the National Nutrition Month every year to spread broad awareness on the issues related to malnutrition like stunting, under-nutrition, anaemia and low birth weight in children. The Nutrition Month will also focus on adolescent girls, pregnant women and lactating mothers to eliminate the deficiencies prevailing in the health sector. The Women and Child Development Ministry is trying to reach about 11 crore women and children during this month through various grass-root activities, with the convergence of different ministries.

4.9.10 Policy Support and Actions

Recognizing that promoting growth and development in the agriculture sector is most crucial to alleviating hunger, poverty and undernutrition, Agricultural Policy must focus to promote smallholder agriculture, especially their access to production resources, land entitlement, technology, knowledge, credit, market and price realization. Access to clean drinking water and sanitation is equally important.

Government schemes such as Public Distribution System (PDS) and National Rural Employment Guarantee (NREG) must improve access to food through increasing physical and economic access to food. The Food Security Act is a step in the right direction, provided it is backed up by nutrition communication to ensure that money saved in buying staple cereals is used for purchasing other protective foods. Development of warehousing and proper food storage should receive immediate attention for the act to be implemented successfully. Every effort should be made to enlarge the basket of foods in the PDS/FSA, to include pulses, oil and vegetables even if not as entitlement.

The Central and State Governments, in the spirit of cooperative federalism, must develop science-informed policies (science for policy making) and institutions to enable the best of science, technology and product to quickly reach the farmers and other users along the value chain. Appreciating that unsafe food is no food, we must ensure that safe, nutritive, quality, and cost-effective food is not denied to reach the hungry in time. Unfortunately, this is not happening in India, particularly in case of several biotechnological products. Emotions, unfounded fear and un-scientific personal belief have shrouded science-based objective facts, which are referred to as 'post truth' – our policy makers should particularly commit themselves to scientific truth.

A more lasting approach would be education and training particularly of women to empower them with knowledge, and improve their employment potential.

4.9.11 Measure to Manage and Ensure Effective Implementation Pathways

With the availability of comprehensive and quality data it should be possible to undertake informed designing, planning and programming, and also creation of science-based parameters *viz*., Hunger Index, Human Development Index etc, which should enable effective monitoring and evaluation of intended outcomes and impact pathways analyses to keep track of the progress and to adopt need-based approaches. The process of differentiated responsibility and accountability should be instutionalized for ensuring desired progress. The health, food, nutrition, education, sanitation and hygiene, and equity indicators should facilitate in reaching the unreached with wholesome solutions.

Setting targets and guidelines is one thing, but judicious implementation of the agreed actions and scientifically designed programs is yet another thing. Generally the targets set are most encouraging, but often, they are not met in their entirety. Great effort is needed on the implementation and monitoring. The NAAS – a neutral forum of intellectuals should be strengthened to regularly monitor the outcomes of the defined action plans, and, if needed suggest the mid-course corrections for achieving the goals/targets.

Early - warning signals for impending problems of malnutrition can be picked up through a well-planned and executed system of constant monitoring and surveillance. NNMB can be given additional task of nutrition surveillance. Methodology for nutrition surveillance has been researched at NIN, but remains to be implemented.

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Chapter 5

Doubling Farmers Income

5.1 Call for a Paradigm Shift

The Hon'ble Prime Minister's call for Doubling Farmers Income (DFI) by 2022 conveys the strong message that "farming must be treated as an enterprise, and the future agricultural development will have the returns and not just the outputs from the farms as its prime objective". Thus it is agriculture plus plus with comprehensive strategic geo-political significance, especially for minimizing the widening inequalities and the huge income gap between farmers and non-farmers.

Policy imperative of the Prime Minister's call is to accelerate transformation of Indian agriculture, involving structural changes in the production, inputs use, markets and employment. This process shall be facilitated by institutional innovations in delivery of inputs and services, marketing of produce, and value chain development. These innovations coupled with technological innovations for higher productivity, better resource use efficiency, climate-smart farm practices and quality assurance shall transform food and agricultural production systems into more efficient, sustainable and income generating systems. These innovations shall however be encouraged by availability of necessary infrastructure, incentives to the innovators and access to improved technologies and capital. Therefore, public investment, price support, trade and credit policy shall have major impact on the innovation capacity and increasing agricultural productivity. It is likely that present policy of low input and low output prices will continue because of food security reasons, and there will be increasing focus on increasing availability of institutional credit, which should provide some resources for investment in agriculture, but public investment should also be enhanced. Agricultural exports though important for higher farm income, support for infrastructure and capacity to comply with SPS requirement should be in place, particularly for products like fruits, milk and milk products, meat and meat products, and fish and fish products.

Recent policy stimulus allowing 100 per cent FDI should accelerate development of agro-processing sector and promote innovations and value creation along the supply chains. The need for strengthening concerned institutions at village and community level to improve delivery of services, increase economy of scale, better targeting of development programs, and promotion of entrepreneurship can hardly be over emphasized (see chapter 6). The government should invest in these institutions, along with capacity building of farmers, rural youth and women, which are necessary to bring structural changes in rural employment and income patterns. The economy of scale in the production and marketing can also be enhanced by legalizing tenancy and, land rights, therefore, reforms in this area should be stepped up and larger responsibility for this and other market reforms rests with the state governments.

5.2 Recommendations of the Inter-Ministerial Committee on DFI

The Inter-ministerial Committee on Doubling Farmers' Income, Chaired by Dr. Ashok Dalwai, has made comprehensive recommendations to achieve the goal (2018). It had suggested a redefined mandate of Agriculture as: "to generate both food and raw material, to meet the requirement of modern society for feed, fibre, fuel and other, industrial uses, and in a manner that is sustainable and aims to bring economic growth to farmers." The detailed mandate of redefined Agriculture was suggested as below:

- Agriculture has the moral responsibility of meeting food and nutritional security of the country in consonance with the agro-ecological backdrop
- It has to generate gainful employment resulting in income gains to make the farmers more economically secure
- It has to generate gainful raw material that will directly support agro-processing of food and non-food products to support secondary agriculture
- It has to support agro-processing industry to produce primary and intermediate goods, which will feed the manufacturing sector
- Agricultural practices need to be on a sustainable basis.

Adopting a differentiated and disaggregated approach through a holistic, multidisciplinary and inter-ministerial process of agri-food system management, should meet this difficult but noble goal. The committee has projected to raise the average annual income of farmer household to Rs. 2,19,724 by 2022-23, from Rs 96,703 in 2015-16. Currently, the average monthly income of farmers is about Rs. 9,000 against the overall national monthly average income of Rs. 1, 25,397. Research, technology, and innovation synergized with pragmatic policies, targeted budget allocations, and governance should be able to achieve the target.

5.3 Source of Growth

The following seven sources of growth were identified:

5.3.1 Within the agriculture domain

- Improvement in crop productivity
- Improvement in livestock productivity
- Resource use efficiency or saving in cost of production
- Increase in cropping intensity
- Diversification towards high value crops
- Improvement in real prices received by farmers.

5.3.2 Outside the agriculture domain

- Shift from farm to non-farm occupations.

5.4 Strategies

The following strategies were suggested to meet the 'growth targets':

- Adopting a "demand-driven approach" for efficient monetization of farm produce and to synchronise the production activities in Agriculture & Allied Sectors
- Improving and optimizing input delivery mechanism and overall input efficiency [technologies, irrigation methods, mechanization, Integrated Pest Management (IPM), Integrated Nutrient Management (INM), farm extension services, adaptation to climate change, integrated agri-logistics systems, Integrated Farming Systems Approach, etc.]
- Offering institutional credit support at the individual farmer and cluster levels
- Strengthening linkages with MSMEs (micro, small and medium enterprises), so as to accelerate growth in both farm as well as non-farm incomes along with employment creation.

5.5 Group of economic activities highlighted for action

The Committee has highlighted the following priority economic activities:

- Demand Driven Agricultural Logistics System for post-production operations such as produce aggregation, transportation, warehousing, etc
- Agricultural Value System (AVS) as an integration of the supply chain and to drive market led value system to promote individual value chains to collaborate and integrate into a sectorwide supply chain
- Farmer-centric National Agricultural Marketing System by restructuring for a new market architecture, consisting of primary retail agriculture markets and primary wholesale agricultural markets as also secondary & tertiary agricultural markets, all of which are networked by online platforms to facilitate a pan-India market access; as also integrating the domestic market with export market
- Developing Hub and Spoke System at back-end as well as front-end to facilitate and promote an Agri-Value System (AVS) (which includes a combination of input providers, farmers, transporters, warehousing, wholesalers, food and agro-processors, retailers, etc)
- Marketing Intelligence System to provide demand led decision making support system - forecasting system for agricultural produce demand and supply, and crop area estimation to aid price stabilisation and risk management

- Promoting Sustainable Agriculture through Promoting climate resilient agriculture, rainfed agriculture, conservation agriculture, ecology farming, watershed management system, integrated farming system, organic farming, agro-climatic regional planning, agricultural resources management and micro-level planning, etc

- Effective Input Management achieving resource-use-efficiency (RUE) and total factor productivity (TFP) – Water, soil, fertilisers, seeds, labour-farm mechanisation, credit and precision farming, so as to reduce farm losses, while ensuring sustainable and eco-friendly practices

- Enhancing Production through Productivity to achieve & sustain higher production out of less and less land and water resources to diversify into higher value farming for enhanced income. In the USA, since 1948, the increase in agricultural production has occurred only due to increase in TFP (Winberg, 2019)

- Farm Linked Activities including secondary and tertiary sector activities of KVIC (Khadi and Village Industries Commission) and MSME (Micro, Small and Medium Enterprises) scales, for promoting near-farm and off-farm income generating opportunities as well as to facilitate more of the produce capturing more of the market value

- Agricultural Risk Assessment and Management including drought management, demand & price forecast, weather forecast, management of biotic stress including vertebrate pests, access to credit among farmers for farming operations; providing long term credit, post-production finance to preventing distress sale by farmers, and crop & animal risk management through insurance

- Empowering Farmers through agricultural extension, knowledge diffusion and skill development

- Research & Development and ICT designed to support the Doubling of Farmers' Income strategy in the short run, and help accelerate the pace of income enhancement on a sustainable basis in the long run

- Structural and Governance Reforms in Agriculture, including building a database of farmers, facilitating farmer & produce mobilization, institutional mechanism at district, state & national levels for coordination & convergence, digital monitoring dashboard at district, state & national level for seamless & real-time monitoring of field delivery, utilizing Panchayat Raj Institutions, and farm income measurement as key delivery channels for transparent and inclusive development. It also calls for paying special attention to non-timber forest produce (NTFP) to support tribal farming communities to capture higher value and non-farm incomes there from.

5.6 Five pillars for sustaining a steady income growth in the long run

The Committee had suggested the following main routes for attaining sustained farmers income growth:

1. Increasing productivity as a route to higher production, enhancing TFP level and growth
2. Reduced cost of production / cultivation, increasing input use efficiency
3. Optimal monetization of the produce, optional price realization
4. Sustainable production technology, from discovery to delivery
5. Risk negotiation all along the agricultural value chain, resilience and risk insulation of smallholder farmer.

Low farm income, decreasing land-man ratio and high risk will make farmers vulnerable to various shocks. This coupled with eroding village social safety nets like joint holdings, shrinking common property resources, and individualistic approach shall make farmers more vulnerable. Therefore, there will be need for government programs to improve farmers welfare. The need for focusing on farmers welfare has also been emphasized by the National Commission on Farmers (2004) and a National Risk Fund was recommended to meet the volatilites. Initiative of the Union Government to double farm income by 2022 and covering most of the farmers under Pradhan Mantri Fasal Bima Yojana are welcome steps to ensure higher and stable income. In addition, strengthening of farm services, health and other family welfare programs shall provide much needed support to enhance capacity of rural workers and famers for income generations. In this context, farm women and agricultural labour will need special interventions. For an equal job done, there should be no gender disparity in the wages.

Opportunities to augment farm household income like non-farm employment, security of land, and responsiveness of local institutions will be needed. Individualistic approach in use of natural resources is likely to increase rural conflicts, especially in hilly and rainfed areas, and the local institutions should have capacity for resolution of these conflicts. One can also consider the role corporate sector can play in using the resources earmarked for corporate social responsibility for farmers' welfare. Finally, farmers often face problem with regard to quality of services and inputs and therefore making the consumer protection mechanism effective shall help farmers in overcoming several production constraints and reducing income losses.

5.7 Top Line Recommendations of the Committee

Distilling from the 14 Volumes of the Report, the Committee had come up with the following top line most vital recommendations as reproduced below:

(1) It is time to recognize agriculture in India as an enterprise, that should be based on the principles of profit. Despite India ranking second in agricultural production globally,

overtaking countries such as USA, Russia and Brazil, the farmers are yet to realise sustainable profits as seen from low average monthly income of the families. However, practicing agriculture as an enterprise will call for optimal scales of operations at all the stages of the agricultural value system, which currently is challenged by structural weaknesses as manifest in atomisation of India's large arable geography into small and marginal farms. The answer to this lies in adopting all legal and organisational principles to enable pooling of land, mobilisation of farmers and aggregation of farmers' produce. In this context, the key recommendations are:

i. Pursue adoption of NITI Aayog's Model Land Leasing Act by all the states and UTs in a time bound manner. A high percentage of cultivable land that now is rendered futile on account of both current and permanent fallows will come into much needed use for operational efficiency at both input and output management stages. Hence, promote –

- Farmers' groups – VPOs & FPOs (societies, cooperatives & companies); CIGs (Commodity Interest Groups); Farmers' Federations, and the like
- Contract farming and services. In this regard:
  - ensure that the right, title and interest (RTI) of the landowner in his property is not compromised in any way
  - pursue with the states to adopt Model Contract Farming and Services Act, 2018
  - draft and release Model Contract Farming and Services Rules.

ii. Enable farm owners to transit from the status of cultivators to farm managers by outsourcing all possible farm operations, so as to achieve both resource use efficiency and effective outcome, besides realising reduced cost of cultivation. This entails encouraging a system of professional service providers (including the Original Equipment Manufacturers – OEMs) who will take over responsibility for one or more of cultivation services such as pest management, irrigation management and harvest management etc. The service area can be a few hundred or thousand acres outsourced by farmers against payment or entering into service contract under the provisions of an Act. Preferably the farmers should transact with the service providers as a Group – VPO, FPO and the like.

Such an engagement will also bring in precision farming or smart agriculture even in small & marginal farms, where investment capacity of these farmers is low. The scope for deployment of new technologies like GPS, Drones, GNCC (Global Navigation Satellite System) etc. both resource use and output come to be more controlled and accurate.

(2) Redefine the mandate of agriculture so as to expand its horizon beyond the currently predominant deliverables – food and nutrition security. Agriculture should also be mandated to generate resources as raw materials to feed and support industrial enterprises – chemicals, construction, energy, fibre, food, medicinal, etc.

Such incorporation will provide greater elasticity to the markets now circumscribed by consumption as food and fodder.

(3) Adopt a production strategy characterised by:

- From 'at any cost' to 'minimal cost'
- From 'any how approach' to 'sustainable approach'
- From 'supply-push' to 'demand-pull' production system.

(4) The production system may be re-prioritized by adopting a market-led crop geometry and product matrix guided by nutrition yielding, job creating and income generating crop and sector diversification. The following shift in focus/emphasis is suggested:

- from major cereals (paddy & wheat) to nutri-cereals
- from only foodgrains (cereals + pulses) to fruits, vegetables and flowers
- from carbohydrates only to proteins (pulses)
- from only floral/vegetative proteins to floral + faunal/animal based proteins (eggs, milk, meat and fish)
- from field crops only to horticulture + dairy + livestock + fisheries, etc.
- from only farm activities to farm + on-and-off farm activities (primary + secondary agriculture)
- promotion of Secondary Agriculture (as defined by the Committee), is critical to impart vertical elasticity to the land, which is otherwise horizontally inelastic.

(5) Amongst the inputs, water may be treated as the 'determining factor' of production. Hence, highest priority may be assigned to water management:

- Creation of additional sources of water – an addition of 8 to 9 million hectares under irrigation (AIBP, MGNREGA etc.) by 2022-23
- Efficient use of water – 2 to 2.5 million hectares under micro-irrigation per year
- Saving on ground water and its sustainability through recharge
- Crop alignment based on 'path of least resistance'. It implies in promoting agroclimate based cropping/production system, the best option need not be the one chosen. It can be an option that is more acceptable to the farmers.

(6) Focus on productivity gains to enhance the needed gross output at the farmers' end by adopting the following approach:

- Bridge the yawning gaps that exist vis-a-vis the techno-economic potential of different crops

- One single intervention with total focus and diligent monitoring should be SEED
- Ensure SRR (seed replacement rate) and VRR (varietal replacement rate) as per recommended package of practice.

- Aim to maximise yield/acre per annum and not per season. Adopt a cropping pattern, which facilitates a higher cropping intensity to result in maximum possible cumulative tonnage/acre/year
- In the strategy for drought proofing of NICRA identified 151 districts, water-budget based crop alignment should be the core intervention.

(7) Recognize land and farm manpower as the two most potent assets of the farm family and enable full utilization of these both through enhancing cropping intensity and promoting secondary agriculture.

- By increasing availability of irrigation & water use efficiency and promoting new technology aim to increase the cropping intensity that now stands at 149 per cent substantively
- Secondary agriculture that promotes value addition activities by using the farm generated natural resources other than the principle yield should be taken up as one of the mandates of Agriculture, so as to create gainful jobs for the idle manpower during off-seasons. Hence, define Agriculture, which is a primary sector activity of the economy, as one that includes primary and secondary agriculture.

(8) As a basis to income led growth of agriculture and farmers' welfare, all policies and strategies must adopt 'Fork to Farm' approach, reversing the 'Farm to Fork' approach now accepted generally. Towards this:

- Adopt monetization of produce as the basis for maximizing the value capture for the farmers
- Maximize monetization possibilities by upgrading and harmonizing the agri-logistics (storage & transportation), agro-processing and marketing
- Adopt new market architecture comprising GrAMs, alternate Wholesale markets (APMCs - in private & public sectors) and Export market
- The target in respect of market architecture by 2022 should be – at least 5000 GrAMs to be established; all states and UTs to adopt Model APLM Act, 2017 and Model APLM Rules; a minimum of 1500 APMCs/other wholesale markets on boarded onto online platforms including eNAM; agri-export of US$ 100 billion
- Promote Agricultural Value System (AVS) as a link between farms and markets.

Marketing strategy should mean optimal monetisation by shifting:

- from 'sale forthwith' to 'sale at will'

- from ‘intermediation’ to ‘dis-intermediation’ in sale-purchase transaction
- from localised transactions to expand into cross geographical sales
- from sale of raw-harvests to primary processed or preconditioned harvests.

(9) However efficient the marketing system may be, the farmers will not be able to capture the optimal value from their produce unless they are facilitated to avoid/overcome distress sale. Hence, as a part of post-production strategy, the highest attention should be given to warehousing (both cold and dry), negotiable warehouse receipts and NWR linked post-harvest loans at interest subvention.

While marketing efficiency is a necessary condition, enabling the farmer to withhold his stock till he finds a remunerative price would alone be the sufficient condition and realising higher value returns on the farm output.

(10) Recognize that agriculture is globally one of the riskiest of professions and is vulnerable to risks and uncertainties at all three of its major stages, namely, pre-production, production and post-production. Hence, risk management strategies at all the stages of agriculture will require to be adopted, in the following way:

Pre-and Post-production stages:

- Replicate Meteorological Advisory Services across the country; on the lines of the technology platform adopted in Karnataka. The impact study of this initiative in Karnataka has shown that income losses linked to natural calamities reduce, if the farmers are offered advisories based on weather forecast
- Coverage of farming under Pradhan Mantri Fasal Bima Yojana (PMFBY) should become a norm
- Livestock insurance scheme needs to be restructured to cover both death and permanent damages; and made more farmer-friendly on the lines of PMFBY.

Market risks

- Adopt an institutional mechanism for price & demand forecasting
- Adopt an import-export duty structure, that helps domestic market sentiments to the advantage of farmer-producers.

(11) Extension system in the country be revitalized and reinvigorated by optimally blending manpower and ICT. Further, the extension responsibility may transition from only government led delivery to partnership based delivery. The partners should include government agencies, NGOs, private agencies and farmers themselves. The states need to be financially supported to fill all vacancies under ATMA, conditional upon them filling up all vacant openings in the Extension Directorates.

Further, transfer at least 25 per cent of the Extension staff from the Directorate of Agriculture to undertake Marketing Extension, and are duly trained thereafter. They can be made responsible in integrating the farmers with GrAMs in particular.

(12) Appreciate fully the positive correlation between capital investments (both 'In' and 'For' Agriculture) and growth rate. While fulfilling the recommended capital investments, attend to:

- Convergence of resources from various Ministries vis-a-vis the support infrastructure needed for agriculture
  - Maximise crowding in of funds under MGNREGA and PMGSY, without diluting their primary objectives
- Adopt policies that will crowd in private sector investments in agriculture.

(13) The speed & quality of implementation deserve total attention, as it is the first and biggest casualty in the system. In this context:

- Adopt various structural reforms and governance framework discussed in Volume XIII of the Report
- Set up an 'Empowered Committee' in the Ministry of Agriculture and Farmers' Welfare to operationalise the DFI strategy
- Adopt the recommended 'Institutional Mechanism' for effective coordination & convergence of resources – manpower, material, money, time & efforts (Refer Chapter 10, Volume XIII)
- An ICT based 'Monitoring Dashboard' be adopted at district, state and national levels for a seamless review and monitoring of the progress of policies and field operations.

(14) The Ministry of Agriculture has been predominantly production-centric. Contemporary and emerging challenges call for a correction. Hence, the Divisions within the two Departments of Agriculture, Cooperation and Farmers' Welfare (DAC&FW); and Animal Husbandry, Dairying and Fisheries (DAHDF) may be restructured and responsibilities reallocated, with the purpose to effect an enterprise mode and accordingly make the agricultural system market-led in its activities. There is the need to balance the production and postproduction activities (agri-logistics, primary and/or secondary processing and marketing), and unravel inherent economic advantages.

As a corollary, ICAR may also reorient its approach, where the output of research and development is led by demand; and adopts a compelling agenda of optimal pricing of the farmers' produce.

(15) The implementation will happen through different States/UTs, ministries and departments, and there is always a probability of losing both focus and direction in this mission to transform the way agriculture is treated.

It is recommended to set up an Empowered Body, headed by a senior officer, of appropriate seniority within the Ministry of Agriculture & Farmers Welfare, to monitor the new set of activities, as they are operationalised. This Empowered Body or Authority, can also be mandated to develop guidelines, based on an implementation framework, and provide the needed support system to the main stakeholders, namely, DAC&FW, DAHDF, DARE, other Departments and Ministries. The suggested role of such an Empowered Body is listed in the final chapter of Volume XIII of the Report.

5.8 Science of Delivery to Double Farmers' Income

ICRISAT strongly advocates Science of Delivery to Double Farmers' incomes and Suggests the Following Way Forward:

"National e-Governance Division (NeGD) can focus to DFI by working with State e-Mission Teams along with SAU, ICAR, CGIAR, private sector and FPO's to define state growth engines for each agroecological zone. Focus needs to be on a few leading States e-Mission team that has license to work across Ministries within the State. Key steps that need to be auctioned before the next production season:

- Spatial Dat Infrastructure (SDI) is supported by government and commercial cloud services that integrates spatial data assests starting with digital soil maps, hydrology and weather that will drive agroecologically focused innovation system and stimulate private sector investment, especially entrepreneurs

- Grades and standards for all major commodities (including horticulture, livestock, fisheries) are established that can be graded using mobile-based devices. This will support traceability needed to triple agri-exports by 2020 so farmers can access international markets

- National Nutrition Mission should integrate with Ministry of Education and Ministry of Agriculture to create consumer awareness of diets for children and young mothers to ensure children reach their full genetic potential and farmers can access local markets

- Shifting primary processing closer to farmers for value addition reduced postharvest losses and provide convenience to rural consumers to diversify diets.

Leverage Aadhaar IndiaStack and SDI to converge schemes with progressive States to deliver targeted and timely subsidies for farmers based on the ecology, soil requirements and forecast market requirements to dampen price volatility and prioritize local investments in processing and storage. Within a year, farmers in participating states could have a mobile-dashboard o optimize farm resources, access service providers and connect to e-NAM clusters, processors or consumers to compress value chains and consolidate logistics – to double their income."

5.9 NAAS Recommendations on DFI

In 2016, the National Academy of Agricultural Sciences had organized a Brainstorming Session on "Strategy for Transformation of Indian Agriculture for Doubling Farm Income and Improving Farmers Welfare". After analyzing the pattern of agricultural growth, productive capacity, institutional change (input use, linking farmers with markets, technology, livestock and fisheries), farm and non-farm linkages, and policy imperatives, especially farmers welfare, the following recommendations, as reproduced below, were made:

1. There is a need for doubling public investment in agriculture for infrastructure development and the priority areas are irrigation, R&D and markets. A significant proportion of these resources must come from the states

2. In order to facilitate institutional innovations, regulations governing agricultural sector should be revisited and corrective measures should be undertaken to liberalize the sector. A notable example is speedy implementation of model APMC Act in different states

3. It is important that private sector shall be an important ally of central and state governments in agricultural development and, therefore, present policy of private sector participation should continue in all sub-sectors of agriculture. Important areas are product market, agro-processing and delivery of inputs

4. Implementation of agricultural market reforms is slow by different states governments and this should be taken by them on priority. Legal framework for contract farming and direct procurement of farm produce by processing industry, retail chain, aggregator etc. should be promoted

5. Capital requirement for increasing household investment in agriculture and business investment in modernization of value chains should be met with greater focus on term loan by financial institutions, besides continuing emphasis on crop loan

6. In order to transfer work force from agriculture to non-agriculture sector, institutions for skill development for rural youth and access to venture capital should be given priority under 'skill India' and MUDRA initiatives of the government

7. Extension of Jan-Dhan-Yojana, Aadhar and Mobile (JAM) and implementation of tenancy reforms are important initiatives of the government. These initiatives along with Pradhan Mantri Fasal Bima Yojana would help farmers manage risk and extend benefits of other schemes directly to cultivator farmers. These programs should be supported with modernization of land records for effective implementation of the scheme

8. In order to learn from the reforms, there is a need for assessment of these policy reforms and development programs of the governments and their outcomes. The gaps

in implementation of these programs by the states and recommendations made by various committees may also be assessed for addressing the bottlenecks

9. There are some good examples of acceleration of the transformation of agriculture in different states. These examples often relate to balancing the roles of centre, states, private sector and civil society organizations in various development programs, farm services like extension and market reforms. Lessons from these examples should be drawn for their out-scaling in other states

10. Technology transfer programs should be given priority for use of available knowledge and technology for raising productivity of crops like pulses and oilseeds, sustain natural resource base in the context of climate change, and improve animal health. In order to reduce rising wage bills, farm mechanization with focus on small farmers in partnership with private R&D should be encouraged

11. There are sector-specific requirements for their transformation like capital and entrepreneurship development for dairy and meat. These sectors should be paid adequate attention and the government should provide necessary infrastructure and policy support. These sectors have specific requirement for quality assurance and SPS compliance, and actors at different stages of value chain must ensure product quality as per global standards

12. Doubling of farm income by 2022 needs targeting efforts for increasing productivity, diversification of product mix and realization of better prices. Bridging yield gaps and delivery of technology for higher total factor productivity and irrigation management can provide immediate benefits in terms of higher yields and farm income. This should be followed by diversification of production system towards high value crops for which demand is rising faster. This shall be a demand driven growth and diversification facilitated by dissemination and adoption of improved technology

13. Post-harvest management of produce, processing and value addition are other important areas which need priority in terms of attracting investment. In this context, facilitating regime for allowing corporate investment, technology delivery, and linkages with R&D and financial institutions are necessary. Development of post-harvest sector shall not only create value for realization of higher prices for farmers but will also reduce pressure on farm for employment, and thus, generating higher income and surplus for further investment on farms

14. Management of market risk shall be an important component of the strategy for improving farmers welfare. Besides PMFBY for yield risk, financial products and market mechanisms to manage price risk shall go a long way in protecting farmers against risk. Similarly, assurance of quality of farm inputs like seed, pesticides and animal health products is another area where existing mechanism like consumer forums should be made effective. Also, associations of companies can join forces to assure discipline and quality in input markets.

5.10 Policy Guidance from ICAR-NIAP

The ICAR-National Institute of Agricultural Economics and Policy Research (NIAP) has dynamically been providing policy guidance and policy options for Doubling Farmers Income (Ramesh Chand, Mruthyunjaya, P. Kumar, P.K. Joshi, Suresh Pal, P.S. Birthal, Navin Singh, Raka Saxena and others). Birthal *et.al.,* in the NIAP Policy Paper 30 (2017), emphasizing a targeted approach, underpin the need for identifying the poor, their characteristics and tailored solutions, and giving the poorest high priority for development. The eastern and western states having about 80% of the low-income marginal farmers should have the focus. The channels of income growth should be enhanced cropping intensity, increased efficiency along the value chain, and diversification towards high value commodities, especially livestock and horticulture. Moreovr, allocation of financial and human resources should be adjusted accordingly. The non-farm employment opportunities should be expanded for additional income. Technological breakthroughs and their ground level adoption/adaptation, rural industrialization, information and credit empowerment of smallholder, and infrastructural and institutional development, all converged in a holistic manner will help achieve the goal.

The next NIAP Policy Paper (no. 31) on Strategy for Doubling of Income of Farmers in India (Saxena *et. al.,* 2017) seeks re-orientation from intensification to diversification, from sustenance to commercialization and turning the agricultural unit to enterprises. Advocating a need-based differentiated and disaggregated approach, high priority should be assigned to total factor productivity, bridging yield gaps, labour transformation, terms of trade, market efficiency, household processing, and pricing policies. The various strategies suggested include : (i) reducing dependence on agriculture, (ii) value-chain approach, (iii) review of current programs and schemes, (iv) infrastructure development, (v) linking among the organizations and stakeholders, (vi) prioritization of areas for investment, (vii) centre-state linkages (viii) making the farmers party to the mission, and (ix) agricultural credit and reforms.

5.11 Keep the Smallholder Farmer at Centre Stage

Marginal and sub-marginal farmers, accounting for nearly 70 per cent of all farmers, comprise the majority of not only the rural poor but also nation's poor. The business as usual has failed to adopt a holistic pro-smallholder approach for the entitlement to land and other production resources, acquisition of agricultural knowledge, technology generation and transfer, linking farmers with markets, enhancing their incomes, and management of climate change and risks. We need to answer the questions as to how can the requisite empowerment be accomplished, and the smallholders are enabled to accept the challenges and opportunities of new developments, such as bio-technology, informatics, and globalization? What socioeconomic policies shall facilitate the empowerment?

The land reforms and land use policies must not encourage conversion of rural poor into urban destitute. Fragmentation of farms below a certain size, say 0.5 ha, should be stopped.

Land lease markets should be liberalized to promote scale of economy and to aggregate miniscule holdings. Land acquisition rules and guidelines should not only be transparent, but also be pro-poor and improve farmers' income and employment security.

The potential of smallholders will be realized only when the smallholders are empowered to access the crucial resources and entitlements *viz.* land, water, energy, credit, insurance, markets and appropriate technologies. They should have opportunities to develop skills and to access the information wherewith to use them. They should be linked with functional and fair markets both for products and inputs and reduced market risks and transaction costs. Enhanced employment and income security, health care and sanitation, and education and social services will go a long way in empowering the smallholder farmers.

Small Farmer's Agribusiness Consortium of the Ministry of Agriculture could proactively develop agribusiness projects and arrange venture capital flow for development of agribusinesses in the country in association with commercial banks. Rural India will have to take a plunge in the main stream of globalization and compete globally for gaining leadership to generate wealth and job opportunities in order to remove hunger and alleviate poverty. The "Rural Business Hubs" concept of corporate sector should become a popular movement. Agri Marts, Agriclinics, Contract Farming (farmer-friendly), Agri Parks, Special Agri Zones, Farmer Producer Companies, Primary Cooperatives etc. could all become instruments of farmer-market-rural employment linkage design and strategy. IFPRI studies have shown that farmers could substantially enhance their incomes through contract farming. Government should play a facilitating role to empower farmers to come on grips with market mechanism and, if necessary, provide support in form of direct subsidies to the deprived ones.

Research must become more development oriented with focus on the resource-poor smallholder farmer. Some of the issues which should be researched on priority basis to inform policies are: (i) reliable biosecure measures towards harnessing biotechnology and other cutting-edge technologies with smooth and cost-effective flow of quality seeds, (ii) insulating the poor from the uncertainties of market and climate change and translating price incentives into increased net income and welfare of farmers, especially the smallholders, and (iii) prospects of agricultural diversification and enhanced labour-productivity.

Besides addressing the challenges of the widening farmers-nonfarmers and rural-urban inequity and divides, India is managing 18 per cent of world population (and will soon be the most populous country of the world) from only 2.4 per cent of the world's arable land and 4 per cent of the world's agricultural water, whereas the land : man ration is worsening and rural youth population is bulging and most of them are under-employed or unemployed and their employability is low due to defective educational and human resources development spread. The situation is further exacerbated due to shrinking land, water and biodiversity resources and the accelerating climate change volatilities and market uncertainties.

With the above backdrop, India must adopt More from Less for More (MLM) approach, establish agricultural product-industry linkage, transform subsistence agriculture in to commercial agriculture, adopt an agri-entrepreneurial and agri-business approach along the entire value chain, and update the university curricula to promote ARYA (attracting and retaining youth in agriculture) and MAYA (motivating agricultural youth for agri-business). We must also take note of the fast increasing feminization of agriculture and have special programs empowering women farmers by enhancing their entitlements, entrepreneurial skill along the value-chain-processing and value addition, and paying them equal to men for performing equal work.

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Chapter 6

Agro-biodiversity and Farmers Rights Management for Sustainable Development

6.1 Introduction

Biodiversity, especially agro-biodiversity, is the life on earth. Providing veritable services for sustainability and growth, this vital component of the ecosystem has, however, been eroding fast. FAO has estimated that more than 75 per cent of global crop diversity has disappeared irrevocably over the 20^{th} century. With the advent of modern agriculture, particularly during the Green Revolution era, numbers of locally adapted crop varieties were replaced by genetically uniform, high-yielding modern varieties. India that once grew 30,000 rice varieties, the number has now reduced significantly and many local cultivars and land races have been restricted to small areas. Agro biodiversity loss leads to a decline in many ecosystem services threatening to undermine the productivity and sustainability of agriculture, reduced distribution and abundance of populations of species, loss of genetic diversity and the loss of habitats. This loss must be stopped and biodiversity concerns must be mainstreamed into national plans, strategies and programs.

6.2 Evolving Regimes of Genetic Resources and Related International Agreements for Development

Genetic resources, considered as the common heritage of mankind, were freely available to all bonafide users throughout the world to develop newer varieties. Norin-10, a height-reducing/semi-dwarfing gene, identified in Japan, reached CIMMYT, Mexico in the late 1950s, via USA, where Dr. Norman E. Borlaug and his colleagues used it for producing a series of semi-dwarf non-lodging input- responsive, photo-period non-sensitive, high yielding wheat varieties. Likewise, Dee-Gee-Woo-Gen a dwarfing gene from China, reached IRRI, Philippines, during more or less the same period, and its cross with a popular tall variety Peta resulted in a series of semi-dwarf, dwarf rice varieties which, like wheat, were input-responsive, non-lodging, photoperiod insensitive, high yielding and widely adapted. These two IARCs, shared the fixed pureline varieties as well as promising advanced generation breeding materials, thus generated with all interested countries. Adoption of these lines and their further improvement by local scientist, as per their local needs and rapidly expanding their production in several countries triggered the Green Revolution in the mid-1960s. Starting from the introduced Sonora 64 and Lerma Rojo 64A, and soon replacing with locally-selected Kalyan Sona and Sonalika, wheat production technology, productivity and production transformed quality. Likewise in Rice IR8 introduced from IRRI in 1967 and Jaya bred at DRR, Hyderabad, heralded the Green Revolution, which transformed India from ship-to-mouth situation to the Right to Food Act based on home grown. Dynamically enriching classical plant breeding, several landmark varieties were developed in all major crops. For instance, today Pusa Basmati 1121 and Pusa Basmati 1509, earn annually US $ 6 billion through export. Likewise in wheat, IARI varieties, namely HD2967, HD3086, HI1563, HI1554 account for 50 per cent of nation’s wheat production, valued at more than 1,00,000 crore (Singh *et al.,* 2016).

In the meantime two major developments have taken place which immensely impact crop improvement programs. Firstly, molecular biology and biotechnology, including gene editing have emerged as modern and innovative complements to conventional breeding providing unprecedented pace and precision to varietal development. Many of these discoveries are taking place in private sector, which as expected, are patented. Which IPR must incentivize innovation, suitable provisions and arrangements must be in place to ensure that the technologies are not out of reach of those who need it the most.

The Green Revolution has, however, somewhat decelerated while the demand for food is ever escalating due to increasing population economic, and social pressures. Furthermore the situation is exacerbated due to shrinking natural resources and increasing climate change volatility and vulnerability. This calls for newer technologies and innovations in plant breeding to produce still more efficient high yielding varieties combining resistance/tolerance to ever intensifying biotic and abiotic stresses. Thus, the need for new genes to meet the demands is ever greater.

The other development related to the enforcement of Convention on Biological Diversity (CBD), since 29 December 1993, recognizing the sovereign right of nations "to exploit their own resources pursuant to their own environmental policies" and calls on the Parties to establish conditions that facilitate access to genetic resources. It demands new participatory relationship between provider and user of genetic resources incorporating the instruments of ‘Mutually Agreed Terms (MAT)’ and ‘Prior Informed Consent (PIC)’ for access to genetic resources. CBD affirmed the holder’s rights over their knowledge, innovations and practices, and encourages governments to safeguard these entitlements either through an IPR law or by other legal or policy measures.

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) has come into force on 29 June 2004 for facilitated access to PGR, of which India is a signatory. The ITPGRFA provides a framework to ensure access to PGR, related knowledge, technologies, and international agreed funding. However, the core provisions on access and benefit sharing apply to only a specific list of negotiated sixty-four crops (Annexure I of the Treaty). The genetic resources of these crops are to be pooled into what is called the ‘Multilateral System (MLS)’ by the national gene banks of ratifying countries and the international genebanks of International Agricultural Research Centers (IARCs). The ITPGRFA restricts the recipient party to claim any intellectual property or other rights on the genetic resources or their genetic parts or components in the form received from the MLS. On development of commercial product, the Treaty provides for payment of an equitable share of the resulting monetary benefits as per Standard Material Transfer Agreement (SMTA). The ITPGRFA recognizes the enormous contribution of farmers and communities and their right to participate in national decision-making and equitably sharing that arises under the benefit sharing arrangements.

A new paradigm of IPR protection has emerged from the discussion in the General Agreement on Tariffs and Trade, later its successor the World Trade Organization (WTO), particularly, Article 27 of the Trade Related Intellectual Property Rights (TRIPS) Agreement. Wherein it was specifically stated that either patent or an effective *sui generis* system of protection must be provided for plant varieties. This has influenced the negotiations under the CBD. India in response to these developments has enforced two important legislations, Protection of Plant Varieties and Farmers' Right Act 2001 to provide protection to all plants (varieties), and the Biodiversity Act 2002 to provide protection to biodiversity with direct bearing on PGR related activities. Efforts are needed to harness the benefit of these provisions in the national interest.

The various Acts and provisions are, however, not harmonized, and are open to varied interpretations. Due to these disparities, even the courts are not able to take science-evidenced decision.

The recent Delhi High Court order on the gene judgement has invalidated the gene patent and by concluding gene on its own has no value unless it is integrated into a plant/plant variety, the protection of the donor variety and access to benefit sharing is to be provided only under the Protection of Plant Varieties and Farmer Rights Act (PVPFRA), as section 3(j) of Indian Patents Act prohibits patent on plants or animals. This judgement has effectively put more than 100 patents granted in India in agricultural biotechnology the risk of invalidation. It also causes confusion on the benefit sharing mechanism under the PPVFRA. The mechanism was set up to repay the society from where the bio resource was utilized for supporting the conservation and sustainable use of genetic resources and for strengthening the capability of the local population in carrying out such conservation and sustainable use.

6.3 NAAS's Leadership in Promoting Agro Bio-diversity Management for Development

According high priority to agro-biodiversity conservation, sharing and utilization, during the past 26 years, the NAAS has brought out the following Policy/Strategy Papers on the subject:

1 Conservation, Management and Use of Agro-biodiversity, 1998

2 Conservation and Management of Genetic Resources of Livestock, 2001

3 Intellectual Property Rights in Agriculture, 2003

4 Biosafety of Transgenic Rice, 2003

5 Transgenic Crops and Biosafety Issues Related to their Commercialization in India, 2004

6 Below Ground Biodiversity in Relation to Cropping Systems, 2006

7 Biosafety Assurance for GM Food Crops in India, 2011

8 The Accelerated Utilization of GE Technology for Food and Nutrition Security and Improving Farmers' Income, 2016.

Of the above 8, three, namely, 1, 2, and 6 strictly relate to biodiversity conservation and the remaining 5 deal with biotechnology, regulation and biosafety aspects. It is important to note that in 2003 the NAAS organized a comprehensive brainstorming session on Intellectual Property Rights in Agriculture (Policy Paper 19) which had made 42 recommendations under seven major areas: (i) Harmonization of IPR System, (ii) Awareness generation and Literacy in IPR, (iii) IPR education, training and human resources development, (iv) Strengthening the institutional mechanism-legal, regulating and administrative, (v) Strengthening the policy area, (vi) Harnessing IP linked technical opportunities in agriculture, and (vii) Linkages and cooperative adoption of the recommendations unfortunately implementation of the recommendations has been highly patchy, otherwise we would have been free from the prevailing multiple multilateral conflicts.

In line with the theme of this chapter, the policy papers at no. 1 and 6 are briefly summarized below.

6.4 Conservation, Management and Use of Agro-Biodiversity

NAAS, in collaboration with NBPGR, in 1997, involving 125 experts organised a National Workshop, first of its kind, with focus on agro-biodiversity as an entity distinct from biodiversity, (NAAS Policy Paper 4). The Workshop deliberated on four aspects: (i) assessment of diversity and infrastructural needs, (ii) sustainable equitable use of agro-biodiversity, (iii) eco-development concerns of natural versus agro-farming systems, and (iv) entitlement and needs of compensation to beneficiaries of benefits derived from PGR use/IPR. The Workshop had resolved that "The importance of agro-biodiversity must be recognized as distinct national issue of prime concern within the broader area of biodiversity."

In reaching the above resolution, the Workshop had contextualized the Convention on Biological Diversity (CBD), the Conference of Parties (COP), the Subsidiary Body for Scientific, Technical and Technological Matters (CGRFA), the revision of International Undertaking on Plant Genetic Resources, the Global Plan of Action (GPA), the Trade Related Intellectual Property Rights (TRIPS) in the General Agreement on Tariffs and Trade (GATT/WTO) and the Sanitary and Phyto-sanitary Agreements (SPS) in the World Trade Organisation (WTO).

The above considerations had led India to the need of ensuring partnership among all stakeholders for initiating conservation activities and ensuring access to these resources both for equity and benefit sharing.

The Workshop made 29 recommendations under seven heads as follows:

1. National Action Plan (1-4)
2. Agro-biodiversity Conservation (5-11)
3. Agro-biodiversity Management (12-16)

4. Germplasm Registration (17-19)

5. PGR Awareness Literacy/HRD (20-23)

6. Access and Benefit Sharing (24-25)

7. National PGR Policy (26-29)

The recommendations under sections 2, 6 and 7 are most pertinent to the present topic, hence are reproduced below for detailed consideration:

6.5 Agro-Biodiversity Conservation

In situ – on farm conservation should be promoted. For an effective *in situ-* on farm conservation of traditional cultivars/landraces, specific area, practices systems and species should be identified. A system at the national level is required to be evolved to assess farmer's views on and expectations from *in situ* – on-farm conservation of genetic diversity. Suitable modes and mechanisms for providing needed incentives to farmers should be evolved so as to ensure safe and effective conservation of genetic heritage through on-farm practices.

Ethnic communities, particularly women, have played an important role in the conservation of traditional varieties, especially in fragile agro-ecosystems. The role of women and communities must be recognized and rewarded while implementing on farm conservation strategies.

6.5.1 Access and Benefit Sharing

- A well-understood procedure for accessing the genetic resource materials owned by farming communities/individuals and a fair and equitable sharing of profits arising from their use should be established. The Percentage of profit going to communities can vary depending on margin of profit. For example, 5 per cent in case of crop plants and 10 per cent for medicinal and aromatic plants or plants of industrial value, etc. The revenue generated through benefit sharing should be transferred to a national gene fund and should be exclusively available for research and development relating to public good and/or for the community development activities

- Needed sharing of conserved materials among community/ national seed banks would be desirable in the national interest. A fair and equitable mechanism should, therefore, be developed jointly by all stakeholders in order to safeguard the interests of all concerned.

6.5.2 National PGR Policy

- A National Policy Advisory Committee with wide representation should be instituted to act as an advisory body to the central government on matters concerning agrobiodiversity conservation

- A national legislation on agrobiodiversity/genetic resources should be developed so that effective instruments are made available for conservation, management and use. In the proposed draft legislation on biological diversity, specific mention of agrobiodiversity distinct from the biological diversity, be made and appropriate provisions provided to establish a separate national authority for dealing with issues related to scope, access and conservation of agrobiodiversity. The Department of Agricultural Research and Education should be given the nodal role for these aspects at the national level in the best scientific interest and for required technical coordination

- A National Gene Fund must be established, keeping in view the dimensions of these activities and the urgency of the matter. It may include allocations from consolidated fund of India; royalty on finished products of proprietary nature, Percentage of profits as emanating from equitable sharing of benefits accrued from the use of PGR and tax-free donations from the users of these genetic resources.

The workshop emphasized that most of the developing world looks towards India for suitable models for agrobiodiversity conservation, management and use. It noted that the country is well poised for required interactions with the developed world, being equipped with the required institutional support and the human resource needed for generating improved technologies. Hence, our *sui generis* system for protecting agrobiodiversity should be both innovative and practical in dealing with all scientific, political and legal issues.

6.5.3 Belowground Biodiversity (BGBD) in Relation to Cropping Systems

- The NAAS, in 2006, analysed the state of below ground biodiversity in relation to cropping systems. It underpinned that soil, the “final frontiers”, harbours huge underground biodiversity, including 10 prokaryotes all comprising the continuum of the life in soil. These resources are irrevocably linked to land and soil productivity – sustainable cropping systems

- Belowground Biodiversity is a provider of ecosystem goods and services through the following process: (i) Nutrient cycling, (ii) Soil carbon sequestration and its impact on greenhouse gas (GHG) emission, (iii) Regulation of soil orgaic matter dynamics, (iv) Modification of soil physical structure, (v) Assistant to plant nutrient acquisition mineralization, fixation and mobilization of nutrients, and (vi) Enhancement of plant health, and biotic and abiotic stress tolerance

- Giving an excellent account of the functional and utilizational aspects of this wealth of ecosystem resource, 14 useful recommendations have been made. Highlighting some of the main points, it was noted that notwithstanding the congruence among BGBD and Above Ground Biodiversity (AGBD), the impact of climate change, and of intensive cropping systems such as rice-wheat in the Northwest and the Indo-Gangetic Plains (IGP), on the BGBD and its interaction with AGBD as reflected in yield growth, productivity, and sustainability should be critically analysed in terms of soil microbial constitution and functionality. A more coherent and directed effort is necessary to assess the indigenous diversity, especially of the growth promoting soil microorganisms. This will help in extending the advantages of the natural bio-resource base (BGBD) to intensive agriculture and maintenance of soil health

- Plant breeding has generally tended to ignore the functional contributions of microorganisms in soil and rhizosphere (e.g. agriculture microflora and rhizobium symbioses), and the plant genetic traits like enhanced association with and response to the beneficial microbial community groups in soil. Crop-genotype-specific differences in supporting soil biological processes can open a new area of plant breeding and biotechnology for exploiting soil biology for better production management of crops and cropping systems in a sustainable manner. The conventional and modern tools of plant breeding can be taken advantage of in breeding crop cultivars with enhanced response to the specific belowground communities. Such varieties shall be of greater advantage in case of alternative, low-input systems of production

- In context of transgenic crops , it is recommended that considering the steady increase in the exploitation of transgenic crops, it is important to take up, on priority, assessment of the ecological impact of their residues and rhizodeposits on BGBD structure and function; as for example, the overall impact of transgenes directed to suppress the insects or the nematodes, or the impact of crop genotypes modified in the pathway of recognition and defense to fungal pathogens or agriculture micro flora (AMF) colonization. This should also take care of the horizontal gene transfer from the transgenics to the microorganisms. This information, apart from putting transgenics use on sound ecological understanding, shall help in understanding the microbial gene expressions in soil.

- To meet the goals stated above, it is essential (a) to put in place a research initiative on long-term ecological research (LTER) for varied ecosystems to investigate the BGBD cropping or agro-ecosystem functional linkages, and to utilise the information for more balanced and productive cropping systems, and (b) to upgrade soil microbiology, including molecular biology research tools and methods. These efforts will not be successful without the well-trained and dedicated manpower in the fields of molecular and morphometric taxonomy, biosystematics, molecular ecology, and bioinformatics—BGBD-cropping system interaction research. This will require considerable investment for laboratory upgradation, introduction of teaching and training programmes, and adequate research support to the institutes and universities. Creation of Centres of Excellence around outstanding microbial ecologists will be a desirable step in this direction. The National Biodiversity Authority for implementing the Biodiversity Act (2002), should set up an expert group to develop guidelines for the conservation, and sustainable and equitable use of soil microflora and mesofauna

- Soil biodiversity is an abstract aggregated property of species in the context of communities or ecosystems. Functional diversity rather than taxonomic diversity or species richness per se is the major determinant of ecosystems functioning. Interdisciplinary dedicated team research is needed to understand interaction and integration of biological quality, below ground biodiversity, aerial ecosystem and above ground biological diversity, biotic/abiotic pressures, sustainability, productivity and the processes impacting goods and services. The NBA may give priority to this integrative research in its R&D priorities

- The NAAS may call a meeting of experts drawn from PPV&FR, NBA, NBPGR, Molecular Biology, Microbiology, Ecosystem and Ecology Biodiversity to reach at priority actions for Conservation, Utilization and Realization of Farmers Rights.

6.6 Global Commitment to Agro-Biodiversity and Farmers' Rights Management

Several national and international systems recognized the urgency of conservation and judicious utilization of the genetic resources and had initiated actions. Beyond the International Union for the Protection of New Varieties of Plants (UPOV, 1970) provisions, the Convention on Biological Diversity (CBD, 1995), Conference of Parties (COP III, 1997 Kyoto), Trade Related Aspects of Intellectual Property Rights (TRIPS, 1994), FAO Commission on Genetic Resources for Food and Agriculture (CGRFA, 1974), International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA, 2004), and Nagoya Protocol (2014) Agreements, not out underpinned the importance of conservation, evaluation, distribution, and utilization of genetic resources, but also recognized the Farmers' Rights and role of providing legal framework for fair and equitable sharing of benefits arising from the genetic resources, and from access to genetic resources.

The following table incorporates major agreements treaties and provision relating to Farmers' Rights and Benefit Sharing:

S. No.	Name of the Agreement	Provision relating to Farmers Rights and Benefit Sharing
1.	Convention of Biological Diversity (CBD)	➢ Recognizes farmers' rights and role of Farmers' communities in respect of conservation/ development of plant genetic resources.
2.	Trade Related Aspects of Intellectual Property Rights (TRIPS)	➢ Establishes rules regarding equitable benefit sharing, ➢ Protecting traditional knowledge of farmers and preserving local farmers' breeding system.

3.	International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA)	➢ Recognizes farmers' contribution in conservation and development of Plant Genetic Resources for Food and Agriculture ➢ Provides for promoting and supporting efforts of Farmers' local communities for on-farm/in –situ conservation of plant genetic resources.
4.	Nagoya Protocol	➢ Provides for a legal framework to ensure fair and equitable benefit sharing and access to genetic resources.
5.	International Union for the Protection of New Varieties of Plants (UPOV)	➢ Recognizes farmers' practice on production and of saving their own seeds.

The efforts were, consolidated by preparing the Global Strategic Plan for Biodiversity 2011-2020 through the Aichi Declaration 2010. The plan was geared towards: (a) halting biodiversity loss by mainstreaming biodiversity across government and society; b) reducing the direct pressures on biodiversity and promoting sustainable use; c) improving status of biodiversity by safeguarding ecosystems, species and genetic diversity; d) increasing benefits to all from biodiversity and ecosystem services; and e) enhancing implementation through participatory planning, knowledge management and capacity building.

The UN Sustainable Development Goals 2030, globally adopted in 2015, state "By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels and ensure access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed". This is one of the most profound globally endorsed agreement on conservation, sharing and use of genetic resources and provides for elaborate national and international cooperation and benefit sharing.

First International Agro-biodiversity Congress, held in New Delhi on November 6-9, 2016, inaugurated by Hon'ble Prime Minister of India, through Delhi Declaration, stated that "We recognize the importance of traditional knowledge on agro-biodiversity of farm men and women, pastoralists and other tribal and rural communities and their central role in its conservation and use for a food and climate resilient world. We, therefore, call upon countries to develop the necessary funding, legal and institutional mechanism to ensure and facilitate their continued active participation". The Congress provided opportunity for othe countries and concerned international organization to share the latest developments, including the commitment to the related SDGs (Paroda, 2016).

The Congress attended by 900 participants from 60 countries, after comprehensive deliberations on all concerned issues, unanimously adopted the following Declaration in its Concluding Session on November 9, 2016:

6.6.1 Declaration

1. We call upon nations to accord top priority to the agrobiodiversity conservation and their sustainable use towards achieving targets of SDGs relating to poverty alleviation, food and nutritional security, good health, gender equity and partnership

2. We recognize the importance of traditional knowledge on agrobiodiversity of farm men and women, pastoralists and other tribal and rural communities and their central role in its conservation and use for a food and climate resilient world. We, therefore, call upon countries to develop the necessary funding, legal and institutional mechanism to ensure and facilitate their continued active participation

3. We urge researchers and policy-makers to initiate, strengthen, and promote complementary conservation strategies to conserve and use agrobiodiversity including crop wild relatives in more dynamic way to ensure a continuum between ex situ, in situ and on farm conservation strategies to combat food and nutrition insecurity as well as adverse effects of climate change, land degradation and biodiversity loss

4. We invite researchers to employ modern technologies including, but not limited to, genomic, space, computational, and nano-technologies for characterization, evaluation and trait discovery using genetic resources. The aim should be to achieve efficiency, equality, economy and environmental security in agricultural production systems and landscapes

5. We reemphasize the necessity of global exchange of plant, animal, aquatic, microbial and insect genetic resources for food and agriculture to meet the ever-growing food and nutritional needs of each country. Nations also need to harmonize their multiple legal systems and prioritize the improvement of their phytosanitary capacities to facilitate safe transfer of genetic resources using latest technologies and trans-boundary partnerships

6. We strongly recommend that the governments and societies put greater emphasis on public awareness and capacity enhancement programs on agro-biodiversity conservation and use

7. We strongly suggest developing and implementing an agro-biodiversity index to help monitor conservation and use of agro-biodiversity

8. We urge public and private sector partnerships to actively invest in and incentivize the utilization of agro-biodiversity to address malnutrition, increase the resilience and productivity of farms, and enhance ecosystem services leading to equitable benefits and opportunities with particular emphasis on women and youth

9. The UN is urged to consider declaring soon a ‘Year of Agrobiodiversity’ to draw worldwide attention and to catalyze urgent action

10. We unanimously recommend that a congress focusing on agrobiodiversity be held each 3-5 years in order to maintain emphasis on this important area that we have realized in Delhi, for which a continuing committee be formed.

6.7 Perspectives of PGR Management in India

To meet the demands of increasing population and to ensure sustainability to agriculture of the country, management of Plant Genetic Resources (PGR), which are basic for developing new cultivars is key for meeting the challenges 21 Century. This has been debated both in national and international fora. In recent past, besides the technical issues, the debates have concentrated more on issues related to access, intellectual property rights (IPR) and commercialization, leading to the benefit sharing accrued out of their use, to individuals and communities. Thus, there is need for periodic review of the strategies of PGR management in relation to collection, acquisition, characterisation, evaluation, conservation, information documentation and dissemination, and distribution of germplasm facilitating use in crop improvement. The present scenario suggests that to ensure availability of broad-based germplasm with desirable genes (traits) for effective use, re-orientation of PGR activities is required.

- A significant progress was made in collection of germplasm during NATP project (1999-2004), however, they concentrated on major cereals accounting for around 50 per cent of total collections, neglecting other major and minor crops/groups. This situation needs to change with greater focus on minor crops and wild relatives (18.7 per cent of total). In this regard the strategy must change from general to pointed collection, searching for new genes and covering left agro-ecological zones. It would need creation of distribution maps of priority species, mapping of genetic diversity collected, using Geographical Information System (GIS), identification of gaps to facilitate pointed collection to capture desirable species/genetic diversity

- No country is self-sufficient in genetic resources; therefore, acquisition of diverse and elite germplasm from exotic sources is critical to crop improvement. After the enforcement of Convention on Biological Diversity (CBD) access to genetic resources have become difficult. Nevertheless, multilateral systems, such as ITPGRFA and Nagoya protocol have come into existence to facilitate the access to genetic resources either under Standard Material Transfer Agreement or Bilateral Agreement. They should be exploited vigorously to obtain germplasm from member countries, particularly, genetic stocks, cultivars, wild and weedy relatives with specific traits. Development of database for documentation and tracking of introductions would avoid repeat introductions and facilitate sharing at national level

- Collection and conservation have led to accumulation of huge collections in the gene banks, including duplicates. Lack of proper characterization and evaluation is perceived as a major limiting factor in their utilisation (FAO, 1998). Characterization involves recording of data on highly heritable oligogenic characters. However, these efforts have not been able to solve the problem of redundancy, reducing redundant genetic load carried by the gene banks. Therefore, for greater/better resolution of genetic constitution and conservation of distinct accessions, use of DNA molecular maker, identifying duplicates, weeding them out to conserve genetically distinct accessions is needed. This can be expedited by extracting DNA from seeds avoiding lengthy process of growing and environmental influence

- Evaluation of accessions against yield reducing constraints is complicated by (a) large number of collections, (b) no defined target environment or target group of traits, (c) highly heterogeneous nature (landraces, wild populations) of germplasm and (d) need for specialized laboratory/greenhouse facilities and screening techniques. It is further complicated by gene expression (activation/silencing), and needs to be done in appropriate environment, preferably place of origin/collection to ensure that the genetic identity and integrity of collections is maintained. In perennial crops, it is further complicated, which are not always planted in a specific experimental field design and characterization and evaluation is more skilled and expensive. These constraints can be overcome by molecular characterization and associating the molecular markers with specific traits/alleles to enable their use both in conventional breeding and molecular maker-assisted breeding. However, in this regard, choice of molecular marker is important, one would like to have a marker system that is 'truly' genomic in the sense, it covers both coding and non-coding sequences, unlike microsatellite or SSRs. Therefore, SNPs are the best. This would require a multidisciplinary team of scientists

- Regarding conservation of PGR, much is required on *in situ* conservation, where only 4.5 per cent area have come under protection. This would need inventorization of distribution of populations to identify the areas and population that are under various threats, specifically of crops' wild relatives. Efforts needs to be initiated for dynamic on-farm conservation of crop diversity in areas where traditional agriculture is prevalent and farmers and tribal communities have been conserving the genetic resources more as a compulsion for their sustenance/livelihood, it will enable harnessing the benefit of their interaction and evolution in response to changing climate. In these areas cultural diversity and rituals have contributed to evolution of genetic diversity and norms for conservation of specific plants or varieties. *Ex situ* seed conservation has been successfully exploited, but *in vitro* and cryopreservation approaches, need proper rationalization to support cost effective conservation and use particularly in horticultural crops. Nevertheless, for sustaining the *ex situ* conservation, there is a need to rationalize the standards on crop basis and the technique of ultra-desiccation and seed storage in the permafrost regions of Himalayas must be explored for cost-effective long-term conservation and safety duplication. In addition, strategies of core and mini-core collection must be explored, predominantly based on genetic diversity of traits breeding significance.To address the apprehension that the reserve collections are vulnerable, if neglected, conservation at DNA level through DNA libraries, gene constructs, promoters etc. should be explored as a backup mechanism.

- The value of all above knowledge about the accessions conserved will be of no use, if it is not documented and disseminated/shared nationally and internationally. Thus, for sustainable use and sharing of benefits accrued from the use, a user-friendly database needs to be developed on collections maintained and can be shared globally. This is recognized in the CBD (Articles 7d, 17), and the Global Plan of Action (priority activities 17 and 18). The global assessment indicates that many of the world's PGR are insufficiently and/or poorly documented (FAO, 1998). In this regard, the Indian PGR system also lags with poor documentation and retrieval system. There is need to update the data base with information, including non-coded information held by traditional farmers and indigenous people and technically with user-friendliness. It would help future planning; provide an early warning regarding genetic erosion, and desired information to breeders and researchers for use and establishing the linkages between *in situ* and *ex situ* conservation efforts. Further, it can provide leads for modern crop improvement with applications in pharmaceuticals, dietary supplements, other industrial uses, and for undertaking effective value addition. Use of appropriate legislations developed for various intellectual property rights regimes, benefit sharing with commensurate returns would ensure harnessing benefit for the nation and communities

- Another Access and Benefit System (ABS), the Nagoya Protocol is developed as supplementary agreement of CBD, applying to all biological/genetic resources, ensuring sharing of benefits arising from utilization. It was adopted on 29 October 2010 in Nagoya, Japan and came into effect from 12 October 2014 with 93 parties, including India. It also covers traditional knowledge (TK) associated with biological/genetic resources, ensuring access in accordance to Prior Informed Consent (PIC) and on mutually agreed terms, as required by Contracting Parties (CPs) for provisions of access and benefit-sharing compliance. National Biodiversity Authority (NBA), functions as national focal points (NFPs) and competent national authorities (CNAs) to serve as contact points for information, and to ensure access and benefit-sharing compliance

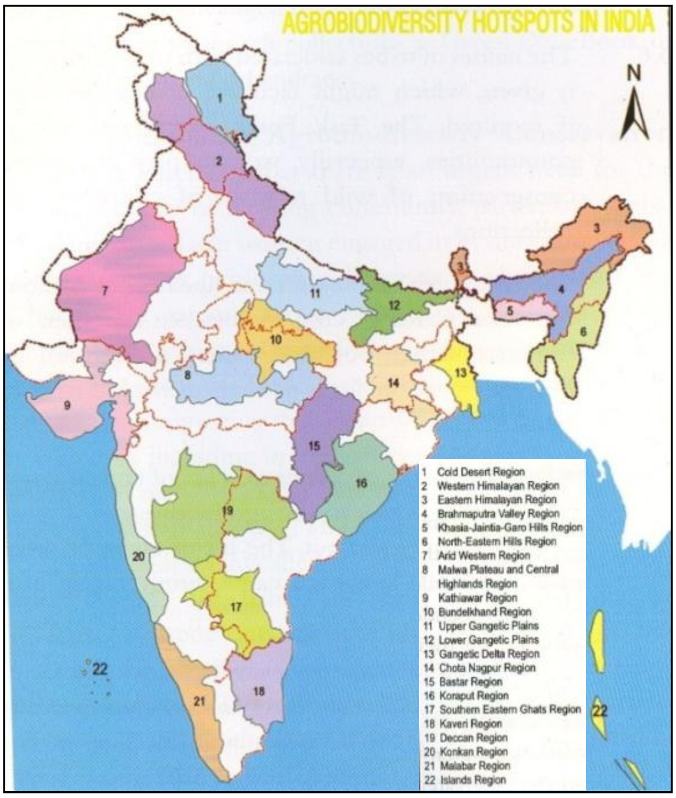
- The success of any PGR system is reflected by number of accessions distributed and used in research and crop improvement. In this regard India has followed a network approach with responsibility for distribution of germplasm for crop improvement and research with Active Germplasm Sites, while those for restoration for regeneration with NBPGR. No national database (except for exchange) is available on PGR distribution and use in crop improvement, justifying the efforts of PGR conservation. NBPGR needs to compile and establish a database on distribution and use of PGR. While, distribution of germplasm within country should be made free of red-tape, in the interest of nation and humanity at large.

6.8 India a World Leader in Farmers Rights Management

India is one of the world's 12 mega-centers of biodiversity comprising 7 climatic zones and 9 bio-geographic regions. Within the spectrum of crop species and wild relatives there are thousands of varieties, cultivars, land races and ecotypes which occur in India. It is known to have more than 18,000 species of higher plants including 160 major and minor crop species and 325 wild relatives. Around 1,500 wild edible plant species are widely exploited by native tribes. These include 145 species of roots and tubers, 521 of leafy vegetables/greens, 101 of buds and flowers, 647 of fruits and 118 of seeds and nuts. In addition, nearly 9,500 plant species of ethno-botanical uses have been reported from the country, of which around 7,500 are for ethno-medicinal purposes and 3,900 are multipurpose/edible species: Millets (51); legumes (31); fruits (109); spices and condiments (27); vegetables (54); fibre crops (24); oilseeds, tea, coffee, tobacco and Sugarcane (12) and medicinal plants (3000) (India's 4th National Report to *CBD, 2009*).

On the basis of richness of agro-biodiversity i.e. number of crop species, crop varieties, wild relatives of various crop species cultivated, social relevance and ancientness of the agriculture, wild relatives of crop species occurring in the region, number of species domesticated and the uniqueness of the agro-ecosystems, 22 agro-biodiversity hotspot regions have been identified in India(Figure 1). These are; 1.Cold Desert Region, 2.Western Himalayan Region, 3.Eastern Himalayan Region, 4.Brahmaputra Valley Region, 5.Khasia-Jaintia-Garo Hills Region, 6.North-eastern Hill Region, 7.Arid Western Region, 8. Malwa Plateau and Central Highlands Region, 9. Kathiawar Region, 10. Bundelkhand Region, 11. Upper Gangetic Plains Region, 12. Lower Gangetic Plains Region, 13. Gangetic Delta Region, 14. Chotanagpur Region, 15. Bastar Region, 16. Koraput Region, 17. Southern Eastern Ghats Region, 18. Kaveri Region, 19. Deccan Region, 20. Konkan Region, 21. Malabar Region and 22. Islands Region (Andaman & Nicobar Islands, Lakshadweep).

Figure. 1 India a Mega-centre of Biodiversity with 22 Agro-biodiversity hotspots



Farmers in these hotspots have a special responsibility to conserve and judiciously share and utilize the resources for sustainable development. Responding to Dr. B.P. Pal's call for 'Search for New Genes', 1937, the PGR drive of India was institutionalized through the Plant Introduction Centre, IARI (1946), Plant Introduction and Exploration Centre, IARI (1956), Division of Plant Introduction, IARI (1961), and National Bureau of Plant Genetic Resources / National Institute of Plant Genetic Resources, New Delhi (1977). Analogous progress occurred in other sub-sectors, resulting in the establishment of National Bureau of Animal Genetic Resources (1995), National Bureau of Microbial Genetic Resources (1983), and National Bureau of Fish Genetic Resources (1983).

India has been one of the first countries to develop and enact laws related to biodiversity, in response to the new regimes in international law concerning access, conservation and property rights on genetic resources. Obviously, these processes have not been easy. A formidable task was to maintain a balance between the new and traditional rights. Accordingly, three Acts were passed by the Indian Parliament in the beginning of current century in an attempt to protect the nation's biological diversity, IPRs, and the interests of researchers, be those plant breeders or the farmers/farming communities. These relevant Acts are:

i) The Protection of Plant Varieties and Farmers' Rights Act (PPVFRA), 2001

ii) The Biological Diversity Act (BDA), 2002, and

iii) The Geographical Indication of Goods (Registration and Protection) Act, 2000.

6.9 The Protection of Plant Varieties and Farmers Rights Acts (PPFRA)

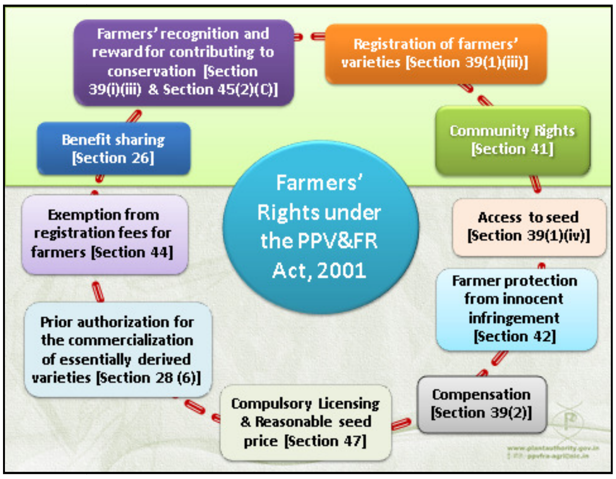
The PPVFRA is a unique act, being the first in the world, that provides rights to the farmers to produce, sell and use their own seeds, besides the typical rights to them equivalent to those of breeders and researchers for the valuable genetic resources conserved by them. Hence, the law aims to protect the plant varieties developed through public and private sector research as well as those developed and conserved by the farmers and farming communities. Accordingly, under the provisions of this Act, a PPVFRA Authority has been established that not only registers the new varieties developed by the breeders and farmers but also ensures fair and equitable benefit sharing through the provision of a national Gene Fund.

India is a signatory to both CBD and World Trade Organization (WTO) conventions. The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) is an International Agreement administered by the WTO that sets down minimum standards and regulations for many forms of intellectual property (IP) as applicable to WTO Member Nations. India opted for the *sui-generis* system for the plant varieties giving importance to farmers' rights compared to the provision of UPOV. With intensive and extensive national level consultations and dialogues, the Government of India enacted the "Protection of Plant Varieties and Farmers' Rights Act (PPV&FR Act)" in 2001. The PPV&FR Act recognizes the multiple roles of farmers with respect to their contributions made in conserving, improving and making available PGR for the development of new plant varieties and also evolvers of farmers' varieties.

India is the first country to provide substantial rights to farmers and registration of their varieties is one of them. The Act seeks to address the rights of plant breeders and farmers on equal footing. The other provisions related to farmers' rights are presented in Figure 2. The Indian PPV&FR Act is a model in protecting the interest of the farmers of the agro-biodiversity rich countries.

Beneficial provisions related to the farmers under the PPV&FR Act, 2001 are illustrated in Figure 2 and elucidated, as follows:

Figure 2. Provisions related to Farmers' Rights



a. **<u>Registration of Farmers' Variety</u>** [Section 39(1)(III)]

A farmer who has bred or developed a new variety shall be entitled for registration in the like manner as a breeder of a variety under the Act.

b. **<u>Community Rights</u>** [Section 41]

Any person on behalf of any village community can file any claim for compensation if the village or local community has contributed significantly to the evolution of the variety which has been registered under the PPV&FR Act, 2001. The Authority upon receiving objection from the registered breeder shall give an opportunity to breeder and determine the compensation which should be deposited in the Gene Fund within a period of two months.

c. **<u>Access to Seed</u>** [Section 39(1)(IV)]

➢ Farmers are entitled to save, use, sow, re-sow, exchange, share or sell their farm produce, including seed of protected varieties, in the same manner as they were entitled to before the coming into force of the PPV&FR Act

➢ However, farmers are entitled to sell unbranded seed of a variety protected under this Act. Farmers can use farm saved seed from a crop cultivated in their own field.

d. **Protection From Innocent Infringement** [Section 42]

If a farmer can prove before court that he or she was not aware of the existence of any rights at the time of an infringement on any such rights, as detailed in the PPV&FR Act, he or she will not be charged. This provision is made in consideration of the centuries-old unrestrained rights that the farmers had over the seed of all varieties, the novel nature of the PPV&FR Act and the poor legal literacy of farmers.

e. **Compensation** [Section 39(2)]

Registered seed must be sold with the full disclosure of their agronomic performance under recommended management conditions. When such seed is sold to farmers but fails to provide the expected performance under recommended management conditions, the farmer is eligible to claim compensation from the breeder through the intervention of the PPV&FR Authority.

f. **Compulsory Licensing and Reasonable Seed Price** [Section 47]

Farmers have the right to access seed of registered varieties at a reasonable and remunerative price. When this condition is not met, the breeder's exclusive right over the variety is suspended under the provision concerning compulsory licensing, and the breeder is obligated to license the seed production, distribution and sales of the variety to a competent legal entity.

g. **Prior Authorization for the Commercialization of Essentially Derived Varieties** [Section 28 (6)]

When farmers' varieties, whether extant or new, are used by a third party as source material for the development of an essentially derived variety, the farmers need to provide prior authorization for its commercialization. Such a process can allow farmers to negotiate the terms of authorization with the breeder, which may include royalties, benefit-sharing, etc.

h. **Exemption for Fees** [Section 44]

The farmers are exempted from payment of any fees in respect of any proceedings before the Registrar or Authority or Tribunal or High Court and they are also exempted from payment of any fee for inspection of any document or obtaining any decision or order or document under the Act or Rules.

i. **Benefit Sharing** [Section 26]

Plant breeders and legal entities including farmers who provide Plant Genetic Resources (PGR) to breeders for developing new varieties shall receive a fair share of benefit from the commercial gains of the registered varieties.
The PPVFRA is already playing on important role in the facilitation of farmers' rights through benefit sharing from the use of farmers' varieties in India, as elucidate below.

Each year between 50-120 campaigns have been conducted in all parts of the country among which at least five each year are for farmers from multi-states in a region, purely on letting the farmers know of their rights and claims to make on benefit sharing when they come to know about any of their conserved varieties of any crop being used in breeding programs by public or private sector, or whenever it comes to their notice if any specific trait which they know historically as occurring only in a traditional variety or species conserved by the community in any commercially sold variety by a public or private sector

Actual benefit transfer from use of farmers' varieties has already been initiated since 2018. Some examples are in improved or purified traditional varieties (land races included) under protection or in the process of registration (provisionally protected) of rice species:

Original Variety	**Registration No.**	**Improved or Purified Version**	**Breeders' Right Holder**	**Source Beneficiary of Farmers' Rights**	**Nature of benefit**
Mushkbudji	REG/2015/1163	Purified Mushkbudji	Farming Community of Sagam and Dhanwathpora, Anantnag J&K facilitated by SKUAST, Srinagar	Farming Community of Sagam and Dhanwathpora, Anantnag J&K	100% commercialization by the Community only (Supported in trade through GI registration also). Trade value enhanced from ` 5-20 lakhs per year to over `800 lakhs per year since 2018
Dubraj	REG/2016/1835	Dubraj Selection 1	IGKVV, Chattisgarh	Richharia Kisani Beej Samvardhan Samiti, Keregaon, Dhamtari; Dharohar Samiti, Golaband, Kondagon; Vananchal Krishak Samooh, Rajnandgaon; Kisan Vikas Samiti, Gotulmunda, Durgkondal, Kanker; Sangata Sahbhagi Vikas Sanstha, Ambikapur; Banshajhaal KrishakMahilaSamooh, Sarguja and Kishan Beej UtpadakSahkari Samiti, Risada, Bilaspur; Jai Durga Krishak Club, Janjgir-Champa; Adarsh	100% benefit transfer to the community by the University with authorisation for seed production and sale

				MahilaSwaSahaytaSamooh, Achanakpur, Durg.	
Badshabhog	REG/2016/1836	Badshah Bhog Selection 1	IGKVV, Chattisgarh	--- As above---	100% benefit transfer to the community by the University with authorisation for seed production and sale
Tarunbhog	REG/2016/1837	Tarunbhog Selection 1	IGKVV, Chattisgarh	--- As above---	100% benefit transfer to the community by the University with authorisation for seed production and sale
Vishnubhog	REG/2017/12	Vishnubhog Selection 1	IGKVV, Chattisgarh	--- As above---	100% benefit transfer to the community by the University with authorisation for seed production and sale
Mai Dubraj	REG/2015/469	Trombay Chattisgarh Dubraj Mutant 1	IGKVV, Chattisgarh& BARC, Trombay	Richaria Kisani Samvardhan Samiti, Koregaon, Dhamtari	100% benefit transfer to the community by the University with authorisation for seed production and sale

In a recent initiative under CORPORATE SOCIAL RESPONSIBILITY of Tata Group company Tata Chemicals Limited, an NGO has been established under the name Centre for Sustainable Agriculture and Farm Expertise (CSAFE) with whom the PPVFRA is negotiating to commercialize the following six traditional varieties of rice protected as Farmers' Varieties so that the benefit is transferred to the original farming communities by popularizing the traits which are unique in each variety having a consumer preference. The aim is for CSAFE to obtain under an Authorisation as provided in the Rights on the Registered Farmers' Varieties of the PPV&FR Act (2001), to get the seed multiplied, demonstrated with publicity of the value of the variety for generating due demand for appropriate price on the commodity which can compensate for the lower productivity so that the right holder communities.

Under negotiation for benefit transfer to original conserver community by the Centre for Sustainable Agriculture and Farm Excellence, Tata Chemicals Society for Sustainable Agriculture.

Name & Address of the Farmer/Community	**Registration Number**	**Registration Certificate issuing year**	**Name of the Landrace/ traditional variety**	**Indigenous Traditional Knowledge Proceeds to be shared with applicant farmer community**
Seed Care- An Association of Indigenous and Traditional Crop conservers of Malabar	REG/2009/504	05-04-2013	Chennellu	Tolerant to both pests and disease and posses medicinal value used for curing stomach ulcers, vomiting and blood purification
Secretary, Seed Care C/o MSSRF, Community Agrobiodiversity Centre Puthoorvayal P.O. Kalpetta Wayanad-673121	REG/2009/503	05-04-2013	Ghandhakasala	Scented rice, used for breakfast dishes. Preferred for payasam (sweet) also used in special dishes for serving distinguished guests.
Jogendra Sahu At- Jamujodi, Block-Harichandrapur, Harichandrapur	REG/2011/217	08-10-2013	Kalajira	Scented and suitable for **khir making**, resistant to disease & pest.

Mr. Dev Nath Verma, Swantarta Sainani, Jaivik Krishak Samiti, Village-Prem Nagar, Gadarpur Udham Singh Nagar-263152 Uttarakhand	REG/2007/126	21/12/2009	Tilak Chandan	Aromatic rice with aroma, resistance to brown spot and stem borer.
Basudha, Binodbati, P.O.-Layekbandh, Bankura-722157 West Bengal	REG/2011/229	20/11/2013	Kelas	Medicinal, Contains high level of Fe and Vitamin B1.
Basudha Binodbati, P.O.-Layekbandh, Bankura-722157 West Bengal	REG/2011/227	09/01/2014	Jugal	Double grain in 304% of spikelet's

PPV&FR Act, 2001 is the only Act which confers Intellectual Property Rights (IPR) to farmers who have bred plant varieties. Farmers are exempted for the payment of any fee for registration under PPV&FR Act, 2001. The application for registration of Farmers' Varieties is contained in 6th Schedule of PPV&FR Rules, 2003 and the said application format is very simple and contains no technical questions. Farmers' Varieties are tested to determine DUS criteria for one year at two locations. The DUS criteria for Farmers' Varieties are relaxed when compared to New Varieties and other Extant Varieties.

j. **<u>Plant Genome Saviour Farmers' Reward and Recognition</u>** [Section 39(i)(iii)]& 45(2)(c)]

- Farming communities engaged in conservation of genetic resources of economic plants and wild relatives of economic plants and their improvement through selection and preservation particularly in areas identified as agro-biodiversity hot spots (as per section 45 of the PPV&FR Act, 2001 and section 70(2)(a) of the PPV&FR Rules, 2003)

- A Farmer who is engaged in conservation of Genetic Resources of Land Races and Wild relatives of economic plants and their improvement through selection and preservation and that the material so selected and preserved has been used as donors of genes in varieties registerable under PPV&FR Act, 2001 (Section 39(1)(iii) of the protection of plant varieties and farmers' Right Act, 2001).

Farmers' varieties are outcome of century's efforts by the farmers / tribal communities, who selected the plants of economic importance from the wild species / relatives and landraces. Through continuous efforts, from the PGR available in particular agro-biodiversity hot spot regions, these varieties were selected and conserved dynamically and possess climate resilience traits which are the need of the hour. Some varieties in different crop species are tolerant to biotic and abiotic stresses besides their suitability to contingency planning in case of weather aberrations. Some of the varieties possess medicinal, neutraceutical, therapeutic and pesticidal values. Varieties such as "*Kasalath*" in rice possess a gene "*Pstol1*" which fixes phosphorus from phosphorous poor soils. These varieties are unique genetic stocks in developing improved varieties / germplasm. Under post WTO era, where restrictions on free exchange of PGR is imposed worldwide, the dynamic conservation, promotion and protection of PGR in the form of local / farmers' varieties, a great treasure and boon for the humanity at large, achieves greater importance.

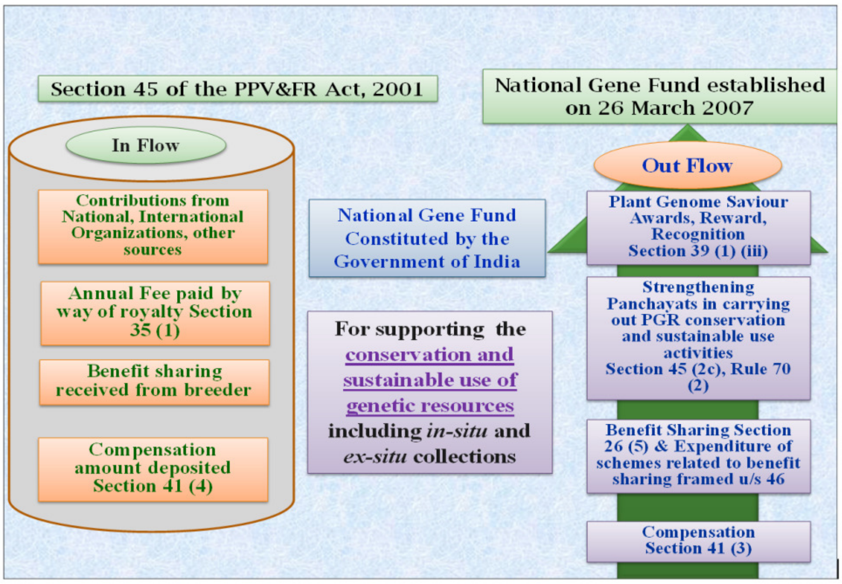
Farmers, who have been engaged in conservation and preservation of plant genetic resources (PGR) of land races and wild relatives of economic plants and their improvement through selection and preservation in these identified 22 agro-biodiversity hotspots, receive recognition and rewards from the National Gene Fund. This provision, when taken in conjunction with the provisions relating to the farmers' privilege, is similar to the concept of Farmers' Rights contained in the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA).

6.10 National Gene Fund

The National Gene Fund of India receives contributions from central government, national and international organizations and other sources. The gene fund also receives funds from benefit sharing from the breeder of the variety or an essentially derived variety registered under the Act or propagating material, of such variety or essentially derived variety as the case may be the compensations deposited and the annual fee payable to the Authority by way of royalty. The expenditures of the fund are earmarked for the payment of benefit sharing, compensation required for use of genetic material towards evolution of new and essentially derived variety, to meet expenditure incurred for conservation and sustainable use of genetic resources, and for framing of schemes related to benefit sharing. The gene fund is also used for capacity building on *ex situ* conservation at the level of local body, particularly in regions identified as agro-biodiversity hot spots and for supporting *in situ* conservation. Thus, in this way it can be considered to be a national equivalent to the global benefit sharing fund operating within the ITPGRFA.

Given the commonality of the objectives of the national and global gene funds, based on merit, the national programs can seek funds from the international gene funds, and, conversely, the globe systems, based on priority needs may proactively reach the national systems for promoting the cause for the welfare of the humanity at large.

Figure. 3 National Gene Fund



The Gene Fund, constituted by the Govt. of India, as depicted in Fig 3, is also utilized to support and reward farmers, particularly the tribal and rural communities engaged in conservation, improvement and preservation of genetic resources of economic plants and their wild relatives, particularly in areas identified as agro-biodiversity hotspots (22 Agro-biodiversity hotspots distributed over 7 agro-geographical zones).

6.10.1 Plant Genome Saviour Awards

Recognizing the important contribution of farmers and farming communities and their role in enhancement of quality in research and development in agriculture and to energize and implement Rule 70(2) (a) of PPV&FR Rules, 2003 and the provision of section 45 of PPV&FR Act, 2001, the PPV&FR Authority in consultation with the Govt. of India instituted the Plant Genome Saviour Community Awards (maximum of five awards per year consisting of a citation, a memento and cash of one million Rupees each). Since 2009-10 this award is being granted to 15 communities from different agro-biodiversity hot spot regions. Government of India has notified the Protection of Plant Varieties and Farmers' Rights (Recognition and Reward from the Gene Fund) Rules, 2012, whereby a farmer who is engaged in the conservation of genetic resources of landraces and wild relatives of economic plants and their improvement through selection and preservation and the material so selected and preserved has been used as donors of genes in varieties registerable under the PPV&FR Act, 2001 shall be entitled to Plant Genome Saviour Farmer Reward (maximum of 10 rewards per year comprising of a citation, memento and cash of Rupees one lakh fifty thousand each). The PPVFRA is the only body which confess 35 award to farmers, farming communities amouting to a total Rs. 85 lakh per year. Already twenty farmers have been awarded with Plant Genome Saviour Farmer Reward. Another award, namely, Plant Genome Saviour Farmer Recognition (maximum 20 recognitions per year consisting of a citation and memento and a cash of Rupees one lakh each) has been instituted. Nineteen eligible farmers have been recognized with this award for their PGR conservation efforts. During 2015 to

2018, 122 farmers or farmers communities have been awarded the above, amounting to Rs. 390 lakhs by the Authority. The awardees as such receive an identity and visibility in being able to enhance the trade value and reach of their varieties.

Notwithstanding the value of incentivizing the farmers' and communities efforts in conservation, it is essential to monitor and assess the impacts of these awards and the benefits accrued to the farmers and others at large and to the overall states of conservation and utilization of the resources.

6.10.2 Supporting Plant Genome Saviour Awardee Communities

PGR conservation, protection and promotion for sustainable use are being practiced by farmers and their families since ancient time. This has allowed them to cultivate a large number of different local varieties in different crop species of economic importance. This is how India has been regarded as one of the mega bio-diversity centres in the world. To support the activities of PGR, the Authority has selected the Genome Saviour Awardee Communities to support their efforts of saving local varieties and land races. As climate change has a significant impact on agricultural production, growing local varieties which have a high degree of genetic diversity is highly important because these varieties have the ability to better withstand and adapt to environmental stresses and change. Setting up community seed banks may help farmers to acquire varieties that are adapted to local conditions; these varieties may not be accessible through formal seed systems, may be costly or may suffer from erratic supplies. To make available the quality seeds of popular local varieties/planting material through informal seed chain, the Authority is promoting "Community Seed Bank Concept" for field crops and "Community Nursery Bank/Community Clonal Gene Bank" for vegetables, fruits and trees, medicinal and aromatic plants and fodder grasses at different Agro climatic bio diversity hotspots where improved varieties have not made impact on production and productivity. The Authority has identified regions in agro biodiversity hotspots and mainstreaming of farmers' varieties is being taken up by following unique maintenance breeding program for the supply of seed/planting material. Socio-economic and agro-ecological impacts of these initiatives should be dynamically analyzed and widely shared.

6.11 The Biological Diversity Act, 2002 and the National Biological Authority

India's fast growing bio-economy has crossed $35.1 billion in 2015; India has set an ambitious target of achieving a bio-economy of $ 100 billion by the year 2025. India comprises seven climate regions and also covers nine bio-geographic regions. Of the 34 hotspots of biodiversity identified all over the world, Eastern Himalaya, Indo-Burma region and the Western Ghats occur in Indian region and these regions have been the center of diversity for many cereals, legumes/pulses, vegetables, fruits, spices, condiments, and medicinal plants. Ever since the implementation of Seed Act (1966) from 1968, more than 3500 varieties have been notified and released for cultivation in different crops for different ecologies and production conditions by the Government of India, Ministry of Agriculture. In addition to these, the New Seed Policy of 1988 further facilitated development and marketing of varieties of different crops under self-certification of purity and viability parameters, without any regulatory certification. More than 5000 such varieties mostly bred or marketed by private seed companies exist in seed chain in the country.

The primary objective of the Biological Diversity Act, 2002, is to protect India's rich biodiversity and associated traditional knowledge against their use by others without sharing the benefits arising out of such use. It provides for the establishment of a National Biological Authority (NBA), State Biodiversity Boards and Biodiversity Management Committees with extensive powers to promote conservation, sustainable use and documentation of biological resources. Foreign organizations do require NBA approval in order to access biological resources. Provisions have also been made to set up biodiversity funds and management committees at the national, state and local levels".

As a signatory to UN Convention on Biological Diversity (CBD) 1992, India has enacted The Biological Diversity Act, 2002, as detailed below:

i. The Act inter alia provides for fair and equitable sharing of the benefits arising out of the use of biological resources

ii. The National Biodiversity Authority may constitute a committee to deal with agro biodiversity which includes biological diversity of agriculture related species and their wild relatives

iii. The Act provides for manner in which benefit can be shared from the grant of IPR to benefit claimers royalty

iv. Location of product research and development units in areas which may facilitate better living standards to benefit claimers

v. A National Biodiversity Fund to be created for monetary compensation and non-monetary benefits, for education and awareness raising activities, capacity building, technology transfer and product development. The fund will be used to channel benefits to benefit claimers

vi. Socio-economic Development of the area from where biological resources have been accessed. Emphasis on in-situ and ex-situ conservation of biological resources.

Notwithstanding the veritable efforts, progress has been rathers sketchy in terms of benefit sharing. Having taken the leadership in establishing the national PPV&FR authority and the National Biodiversity and the corresponding Acts, most of the developing world has been looking towards India for sustainable models for biodiversity conservation, management, use, and particularly realizing the Farmers Rights.

6.12 Harmonizing NBA and PPV&FRA for Realizing Farmers' Right While Ensuring Conservation

Several of the critical recommendations made in the 9 NAAS policy and strategy papers on this subject await implementation. But, in recent years some tangible progress has been made which need to be scaled-up and scaled-out. The purpose of the benefit sharing provision was to seek long term committed involvement of the masses in conserving the diversity in perpetuity without foregoing their own opportunity costs. Institutionalizing this mode of *in situ* conservation is the main purpose of PPV&FR as well as the NBA. Given India's initiative in this field, India has all the elements to emerge as a world leader in institutionalizing and implementing the PPV&FR and judiciously realizing the farmer's rights while ensuring conservation of the genetic diversity.

A critical report on the success story of each awardee in each category should be prepared. It should be clearly brought out as to how successful was the awarded story and what social, economic and ecological benefits. What were the areas and commodities covered? Sustainability of the approach, extent and prospects of its up-scaling and out-scaling should be assessed. Bottlenecks in the scaling-up, if any, should be identified. In the implementation pathway, responsibility and accountability of the partners and stakeholders and success and failure should be fixed. Future plans to remove the bottlenecks, and how to reach new heights and to achieve objectives and targets should be chalked out and closely monitored. All financial, governance, monitoring and accountability measures should be detailed out with clearly defined outcome targets.

Recently Agrawal and Prabhu (2019) have suggested way forward for creating harmony and balance among diverse regulatory bodies for efficient use and management of genetic resources in India. These suggestions should be duly internalized in the national programme. PPV&FRA and NBA have identified the following asymmetries between the two Acts and should be able to harmonize the two in consonance with the concerned national and international provisions. The NAAS proposed project on realization of Farmers' Rights should assist in harmonizing the two Acts.

6.12.1 Compensation under section 41 of PPV&FR Act, 2001 which deals with use of a community maintained material

It emerged that a fixed Percentage based on profits and royalty gained by the registered breeder may be fixed as the maximum limit for compensation under section 41(3) of PPV&FR Act, 2001. Under the Biological Diversity Act, there are no provisions or case laws to amplify the subject.

6.12.2 The varieties of PGSC Awardees/Plant Genome Saviour Farmer Reward/ Plant Genome Saviour Farmer Recognition must be entered in PBR

It was suggested that SBBs may be involved in the process of grant of awards to farmers and farming communities, so that the same may be entered in the PBR. It was also suggested that based on the proposal of PPV&FRA the NBA will issue one time advisory in this regard to SBBs.

6.12.3 Joint Awareness Programmes

It was informed by PPV&FRA that they are conducting awareness programmes with the support of KVKs, ICAR institutes, SAUs and other nodal agencies. The PPV&FRA targets to conduct about 200 awareness programmes a year at KVK level in addition to some national and state level programmes. These programmes are mainly to educate the farmers about the benefit of registration of their varieties under the PPV&FR Act, 2001, the various rights envisaged in the PPV&FR Act, 2001 and other relevant clauses which are directly related to the farmers. It shall be more beneficial if farmers are made aware of various provisions relating to access of their bio-resources by any person/ company/ public institute under Biological Diversity Act. The PPV&FR Authority will inform NBA the details of such programmes so that wherever possible NBA will instruct the related agencies like SBBs or nominee of Chairperson, NBA or relevant literature will be distributed in such awareness programmes.

6.12.4 BMCS Be Instructed By NBA To Forward Applications of Farmers' Varieties and Applications for PGSC Award /Reward / Recognition

BMC are one of the agencies notified in the official gazette to endorse and forward the farmers varieties applications and applications for PGSC Award/ Reward/ Recognition. But as of now, BMCs are not forwarding the same due to lack of awareness about such provisions. It was suggested that SBBs may be advised by NBA to instruct BMCs to identify registerable varieties and forward such applications for registration and also to identify the eligible farmers and farming communities for PGSC AWARD/ REWARD/RECOGNITION and forward the same to PPV&FR Authority.

6.12.5 PPV&FR Authority and NBA have to revise the agro-biodiversity hotspots with the technical collaboration with each other

The PPV&FR Authority identifies agro-biodiversity hotspots under Rule 70(2)(a) of PPV&FR Rules, 2003 to support and reward the farmers and farming communities in agro-biodiversity hotspots. The list of such hotspots was developed by the PPV&FR Authority before 2009 which requires extensive revision as the PPV&FR Authority feels that many areas needs to be covered under the same. As agro-biodiversity hotspot is not within the mandate of NBA, no technical inputs can be provided on the same. However the list of biodiversity heritage sites is available on the website of NBA and PPV&FR Authority can make use of the same.

6.12.6/7 Use of PBR For Documenting, Indexing and Cataloguing of Farmers Varieties and all Plant Varieties and Collecting Statistics with regard to Plant Varieties. - Collaboration with NBA in **Implementing Section 45(2)(C) of PPV&FR Act, 2001**

It was unanimously agreed that the soft copies of details of registration will be shared by PPV&FR Authority to NBA. The PPV&FR Authority can initiate the activities of such documentation with active SBBs in Kerala, Assam, West Bengal, Meghalaya and Tripura and co-ordinate with them for obtaining the details of PBR and use the same in documenting the plant varieties. NBA can issue an advisory in this regard to the respective SBBs.

With regard to utilisation of National Gene Fund for conservation purposes by BMCs it was appreciated by the Chairperson NBA that the PPV&FR Authority has genuine concern for the cause of conservation of plant genetic resources and NBA fully endorses the same and it was suggested that

a) PPV&FR Authority will provide a list of BMCs in this regard after consultation with respective SBB keeping in mind the agro-biodiversity rich areas.

b) BMCs can be funded through SBBs and utilisation certificate for the same will be submitted by BMCs through SBB.

c) PPV&FR Authority will develop a scheme in this regard and inform NBA in this regard which in turn will advise all BMCs through their respective SBBs for this purpose. The conservation activities set out in Section 45(2)(c) would be more effective if the documentation of the economically important plant species is catalogued and entered in PBR.

6.13 International Experience of Realizing Farmers' Rights

According to ITPGRFA the realization of farmers' rights has begun. Many countries have legislation pertaining to the protection of farmers' traditional knowledge against misappropriation, but relatively little is being done when it comes to implementation. There are many examples of indirect benefit sharing, normally non-monetary. Actual participation of farmers in decision-making processes seems to be marginal. The practice whereby farmers save, use, exchange and/or sell seed and propagating material from their own harvest is increasingly affected by regulations on plant breeders' rights and on the certification of seeds for sale.

The Bioversity International has listed examples for implementation of Farmers' Right Internationally and highlighted protection of traditional knowledge examples in countries like, Bolivia, India, Mali, Nepal, Peru and South Africa and Brazil, recognition of informal seed system in Uganda, benefit sharing project in China, under the "Diversity against Damage (DiAD)", community seed bank in South Africa and "Seeds for Needs" Project in India and elsewhere. It has also documented various projects including community seed banks in a number of African and Asian Countries.

6.14 A National Project on Realization of Farmers' Rights

6.14.1 *In situ, On Farm* Conservation of PGR

Agro-climatic zone wise planning and on-farm conservation need to be promoted across the agro-biodiversity rich areas covering vast stretches of land, cutting across state boundaries, habitation of different communities, ecological and climatic conditions. Farmers and farming communities have conserved, shared, and sustained these valuable resources at their own initiative for a larger cause and these biodiversity hotspots can be recognized and rewarded for better sustained protection and management by adopting the following measures:

- Incentives can be provided to the local communities for promoting diversified agro-ecological systems and designation of agricultural biodiversity conservation sites/agro biodiversity hotspots

- The PPV&FRA has already identified 22 agro biodiversity hotspots and these suggested BHSs can be designated as Biodiversity Heritage Sites (BHSs) by the concern States by involving local Biodiversity Management Committees (BMCs) and these hotspots can also be converted into agro-ecotourism spots to facilitate-agro-tourism

- For conserving these hot spots Gene Fund of the PPV&FRA, 2001 and the State Biodiversity Fund /Local Biodiversity Funds specified in the Biological Diversity Act, 2002, as well as International Gene Fund, can be explored.

6.14.2 Conservation of traditional seed varieties

The National Seeds Corporation (NSC) under the Ministry of Agriculture and Farmers Welfare is undertaking the production of certified seeds of nearly 600 varieties of 60 crops through its registered 8000 seed growers.

It is suggested to distribute 5 per cent of traditional seed varieties to the farmers with 100 per cent subsidies through NSC/SSC (rice, wheat, pulses, coarse cereals, oil seeds, vegetable and fruits) under the NFSC, NMOOP and MIDH schemes via seed mini kit distribution. The traditional seeds can be sourced from the PPV&FRA registered varieties and this can be promoted in the adopted organic villages.

❖ A national level database/mapping of traditional seed varieties need to be developed and documented

❖ To ensure adequate availability of traditional seeds, Community seed banks can be setup in each agro-climatic zones/village/block level

❖ Necessary assistance can be provided from NFSC, NMOOP and MIDH mission schemes for the supply of good quality seeds to the local farmers (CEBPOL 2017, NBA).

6.14.3 Realization of Farmers' Rights: The Project

As per ITPGRFA, farmers need to be awarded/rewarded for their "past, present and future" effort towards conservation of plant genetic resources. Seed industry exploited the genetic resources nurtured by the farmers, develop newer, improved varieties that provide food security. However, the communities of farmers, who actually conserved those PGR did not realize benefit sharing and it is a responsibility of the state to deliver a mechanism of Benefit Sharing.

The project should work with state governments in monitoring the value-chain and the net income and benefit flowing to the grower and other stakeholders. Value added to the entire chain by the gene/genes/genotypes conserved and used by the farmers/community and net gain in the farmers' income should be documented.

The ever-increasing availability of latest genomic tools and resources result in precision accelerated breeding inducing Next Generation Sequencing (NGS) through mass sequencing of genomics and CRISPR yielding rich genomic information. These allow discovery of new genes, regulatory sequences, large collections of molecular markers, resequencing of genomes and construction of high density genetic maps, rendering. Marker assisted selection, - "breeding by design", a routine practice, and allow understanding of "super domestication of crops and the genetic dissection and breeding for complexities. Most important, CRISPR gene editing – a miracle, offers unlimited opportunities for biological revolution to attain disruptive outcomes in the field of health, food, nutrition, energy, climate resilience etc. These latest developments have been discussed in chapter 15 leading to the formulation of new policy options and actions by the Academy.

6.14.3.1 Objectives

1. Spread awareness among farmers to maintain Conservation Continuum by conserving & developing PGR for food, nutrition and livelihood security and protection of environment and ecology
2. Spread awareness of protection of farmers' rights on landraces, conserved species, their developed varieties and benefit sharing
3. Promote traditional knowledge associated with genetic resources
4. Identify and remove local constraints which inhibit sustenance for *in-situ* and on-farm genetic resource collection and conservation
5. Identify strategies for creating convergence between various Missions and Programmes like National Food Security Mission (NFSM), Paramparagat Krishi Vikas Yojana (PKVY), Rastriya Krishi Vikas Yojana (RKVY), Organic Mission, National Horticulture Mission (NHM), Sustainable Development Mission and Climate Resilient Agriculture etc

6. Facilitate and technically backstop volume increase and multiplication of protected varieties and seeding materials among farmer communities along with standard maintenance practices of varieties

7. Promote establishment of Participatory Plant Breeding, Community Seed Banks and promote adaptive strategy e.g. Integrated Farming and Nutrient Management System

8. Generate IPR for plant varieties developed and conserved by traditional communities.

9. Develop mechanisms of benefit sharing for registered farmers' varieties being utilized by public/private seed industries

10. Give special recognition to the role of women as repository of traditional knowledge in conservation and utilization of genetic resources

11. Mobilise the financial mechanism through monetary and non-monetary sources to conserve the agro-biodiversity. The monetary mechanism includes: gene fund, biodiversity fund, green tax for organic products, visiting fee and the non monetary mechanism includes transfer of technology, establishing research and development, joint venture, venture capital fund and Corporate Social Responsibility.

6.14.3.2 Activities

- **Generation of awareness:** Undertake awareness programmes at grassroot level about Farmers' Rights and Benefit Sharing Programmes in collaboration with PPV & FRA, Biodiversity Authority, ICAR/KVKs and other Agencies
- **Capacity building:** Develop expertise to provide training and capacity building of farmers, farmer's groups like Agricultural Cooperatives, Farmers' Producer Organizations, Farmer's Clubs and Farm Women Groups. Build capacity to provide consultancy and advisory and customized services to farmers, groups, community and Panchayats to claim rights and benefits including Reward and Recognition and registration of varieties as per entitlements under various Laws and National and International Programmes
- **Survey, documentation, cataloguing of farmer's varieties**: Undertake survey and field research for farmers' varieties registered under PPV&FR Act, 2001; utilization and benefit sharing mechanism and generation of databases for farmers' varieties and contribution of any farmer/communities in the evolution and development of any plant variety
- **Farmer's portal and databases:** An interactive electronic platform should be created to address farmers' concern by subject matter specialists. Create a Data Bank and network of farmers with National Award and Recognition and of farmers at international level especially of SAARC, Africa, South America and Caribbean countries for mutual learning and experience sharing
- **Agri-Entrepreneurship promotion:** One of the main objectives is to mentor agri-enterpreneurs involved in participatory seed production/agri-input and deliver

innovative solutions pertaining to rural areas and to study experiences, methods and systems successful in promotion of traditional crops, value addition and marketing and promotion of organic farming

- **Linkages with various implementing agencies:** The programme shall establish linkages with all relevant stakeholders in public-private-peasants sectors.
- **Sustainability :** Promote crop diversity in farmer's field which is considered 'Global Life Insurance Policy'.

6.14.3.3 Expected outcomes (3 years)

- Awareness among traditional communities/farmers about the Farmers' Rights
- Conservation and utilization of plant genetic resources for food and agriculture promoted and scaled up especially in the hotspots
- Development of a mechanism of benefit sharing for utilization of registered farmers' varieties for development and commercialization of improved varieties by private/public seed sector. A lead 100 farmers community and 500 individual farmers would have received gene funds created for the purpose
- Promotion of Agri-enterpreneurship and delivery of innovative services towards integrated cropping and farming systems, resulting in additional income gains
- Documentation, indexing and cataloguing of farmers' varieties and sharing of success stories.

IP protection to biological inventions in India is granted under Patent (Amendments) Act 2005 and The Protection of Plant Variety and Farmers' Rights Act 2001 (PPV&FRA). Patents are granted on novel products and processes that meet the patentability criterion of novelty, inventive step and utility. The plants and animals other than microorganisms but including, varieties and species and essentially biological processes for production of plants and animals are non-patentable. The PPV&FRA provides for registration of new varieties after fulfilling the criteria of DUS- distinctiveness, utility and stability.

In case of transgenic seeds, which are made up of two components – a unique genotype and a transgene – PPVFRA does register transgenic seed a new varietal seed for its unique genotypic character and not the trangene, which is protected under the IPA, 2005? For registering varietal seeds containing transgenes, companies are required to obtain a no-objection certificate from the patent holder, which was recently disposed of in a meeting called after 'normal office hour' on the last day of the retirement of former chairperson of PPVFRA. Moreover, there is no technology developer cannot approach PPVFRA for registration of transgenic seeds, as they only own the transgene component of the transgenic seeds, which can only by protected under IPA, 2005.

Until now, the sui-generis system of IP system has worked very well in protecting plant varieties under the PPV&FRA 2001 and patenting of biological inventions under the Patent

Act 2005. However, there are some disputed areas including whether a microbial based biological patent gets invalidated when transferred into a higher organism for its end use? Neither the Patent Act nor the PPV&FRA prescribe any norms for establishing the value of an invention. How do we realistically account for development and marketing cost of an invention and the benefits it is likely to bring to the licensees and the ultimate consumers to estimate the fees to be paid to the inventors so that the latter are sufficiently encouraged to continue innovating? It is worth mentioning that the Protection of Plant Variety Authority has established mechanisms to repay the society whose bioresources are utilized for supporting the conservation and sustainable use of genetic resources and for strengthening the capability of the local population in carrying out such conservation and sustainable use.

Given the importance of intellectual property and the potential impact of its regulation on innovation efforts to meet the goal of food and nutritional security of the country, it is proposed to have a one-day stakeholder consultation on this important subject. Being organized jointly by Trust for Advancement of Agricultural Sciences (TAAS) and National Academy of Agricultural Sciences (NAAS), it is proposed to invite key participants from ICAR, Ministry of Agriculture, Protection of Plant Variety Authority, Office of Controller General of Patents, IP experts, lawyers, biotech scientists and breeders, industry leaders, representatives of associations, consumer society, and other opinion makers in agriculture to the consultation and debate on IPR protection mechanisms for agricultural innovations and the needed actions to benefits all the stakeholders from the innovations. The outputs of the discussion will be widely distributed among all the stakeholders including public and private sector agricultural, research innovation organizations, legal experts, consumers, media and others concerned with agricultural research, innovation and development.

- discuss and review the scope of IP protection of biological inventions under the Patent (Amendments) Act 2005 and plant varieties protection under the PPVFRA 2001
- identify and address grey/overlapping areas of IP protection of biological inventions and plant varieties protection under the PPVFRA
- recommend measures to enhance implementation and compliances with IPRs in agriculture and increase public participation and awareness about them.

Additional expected outcomes were:

- Clarity obtained regarding IP protection accorded by Patent Act and PPVFRA to biological inventions
- Overlapping areas and ambiguities in the two IP protection acts identified and remedial measures suggested.

PPVFRA and the Global Forum for Farmers jointly organized a ‘Dialogue on Realization of Farmers’ Rights and Benefit Sharing on 17th August 2018. The Chairman PPVFRA, Prof. Vinod Prabhu, in his address suggested the following options and pathways for realizing the

Farmers Rights and Benefit Sharing, which the Dialogue endorsed to be further developed and streamlined in the national system to the satisfaction of all stakeholders.

a. Connect through the RKVY the State Departments and SAUs to help in quantification of the contribution of a protected farmers' variety either in direct selling or in the development of new varieties by the formal sector (public or private)
b. Develop in local communities a voluntary set up at Panchayat level or KVK levels that is able to scrutinize the information put up for claims of benefit sharing by the PPVFRA for every new variety registered.
c. Develop in Panchayats involving the Biodiversity Management Committees (BMCs)facilitated by ATMA, a system for connecting the Plant Biodiversity Register (PBR) which is mandatory under NBA (2002) with potential gene carriers (donors), land races maintained by the community.
d. PPVFRA can support for maintenance of the local germplasm pool *in situ* or ex situ to ensure availability of pure seeds for verification of the claim of seeking benefit in a new variety registered under PPVFRA.
e. KVKs in association with their principal SAU/ICAR/NGO set up documenting the Panchayat owned or local farmer owned traditional variety/landrace in the PBR (official register) as required under NBA in order to authenticate the claim of the community on a new variety.
f. Organize capacity building process among the farmers on awareness of the benefits of the benefit sharing clause of PPVFRA, through trainings specifically carried out for making claims under Section 26
g. In the case of Hybrids, PPVFRA may organize focused awareness campaigns with training among farmers to help realize the benefits by being able to recognize the value of their conserved material in parental line development that resulted in the commercial value in the Hybrid registered.
h. The PPVFRA may train at H/Q all the PGS awardees to convert their conserved gene pool into bankable entities for commercial gains for the community
i. The dimension of negotiability value for the use of community conserved germplasm by characterization of the potential lines highlighting their commercial value in hybrids and varieties has to be integrated in ATMA project of the DAC&FW through KVKs within the PPVFRA framework.

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Chapter 7

Agri-Entrepreneurship for Employment and Economic Security

7.1 State of India's Agrarian Economy

Led by the Rainbow Revolution (Green, White, Yellow, and Blue Revolutions), India has attained unprecedented growth in agriculture-food system, attaining 4 to 10 times enhanced production in major commodities during the past five decades and has emerged as the second largest agrarian economy in the world. The transformation has rendered the country not only food self-sufficient but also a major exporter of agricultural products. The Revolution has greatly reduced the incidences of hunger, poverty, and malnutrition. Yet, we have miles to go. India is still home to nearly 200 million hungry, poor and undernourished people and about 35 per cent of the world's hungry children.

A series of programs and policies, research, science, technology, infrastructural, and institutional initiatives, as well as farmer-market linkages, pricing incentives, value-chain management, and risk management are being pursued to attain the SDGs -Agenda 2030, leading to a Zero Hunger India consistent with socio-economic and agro-ecological security.

Over 60 per cent of India still lives in villages, and majority of the rural people depend directly on agriculture for their livelihood. Of the over 138 million farm families, 67 per cent are in marginal (<1 ha) farm holding category, while 18 per cent are in smallholder (from 1 to 2 ha) category. The semi-medium (2 to 3.9 ha), medium (4 to 10 ha) and large (>10 ha) holders respectively account for 10, 4 and 0.7 per cent of the farm holdings. Thus, 85 per cent of the farm families comprising 600 million people, on an average, live on less than 1 ha cultivated area.

The situation is further aggravated as the overall contribution of agriculture to the total National GDP has declined to only 15 per cent, while about 50 per cent of the population is directly dependent on agriculture for its livelihood security. Thus, average income of a farmer is about one-fourth of that of a non-farmer, and these farm families are homes to high proportion of hungry, poor, and undernourished people and stunted and wasted children. With the increase in the population, the land fragmentation will go on unabated and it is projected that by 2030 the proportion of small and marginal farmers will swell to 91 per cent, thus, with business as usual, the ranks of the hungry and poor will further swell.

The Indian enigma of the coexistence of high overall economic growth rate and the entrenched high prevalence of hunger and poverty and veritable asymmetries can be attributed substantially to the neglect of agriculture and of the farmer in an agriculturally important country. The continued over-dependence on agriculture and serious income disparities between agriculturists and non-agriculturists are ascribed to the "stunted" structural change in Indian economy. Income in agriculture sector must increase for accelerated overall growth of the economy as it also creates demand for industrial and service sectors. In some of the states, where some structural changes have been adopted, the income disparities are narrowing.

Despite several social protection floors, the inequities remain wide and are proving serious deterrents to inclusive growth and have reduced the impact of growth on poverty. In this context, Nobel Laureate Amartya Sen had observed "I do not think there's enough clarity on economics here. I do not judge the performance of the Indian economy by growth alone. And the fact is that human capability expansion is also very critical for economic growth."

More recently, the GDP growth rate has come down to about 5 per cent. Further, the unemployment Percentage has increased to 6.1 per cent, highest in the last 45 years. Concerned with these trends, the Prime Minister began his second term by appointing two high level Cabinet Committees to look into the economy and unemployment issues.

Obviously, new approaches are called for accelerating the transformation process. Agri-entrepreneurship and development of related skills may be an effective complementary approach, and the two committees would be certainly examining the scope of entrepreneurship in resolving the issues.

7.2 Entrepreneurship in Farming is the Key to Agricultural Transformation

Entrepreneurship or Make-in-India (*Swadeshi* Movement) are not new to India. However, in post-independence era India did not promote entrepreneurship as means of self-employment, and entrepreneurship did not scale up until recently. The Montek Singh Ahluwalia's "Report of the Task Force on Employment Opportunities", July 2001 mentions "A large part of the employment generated by the economy will be self-employment in the informal sector. These self-employed entrepreneurs need training of the multi-skill variety, going beyond production skills to include marketing, finance and accounting and elementary management. Such skills cannot be developed through structured formal training but requires the guidance of "mentors" in actual business conditions".

To promote self-employment as a means of job-creation and to promote entrepreneurship for further job creation, the Micro, Small and Medium Enterprises (MSME) Act, 2006 was enacted to facilitate the promotion, development and enhancing the competitiveness of micro, small and medium enterprises. But even after the implementation of the MSME Act, 2006 the high proportion of unregistered MSME units outside the purview of the Act is a matter of concern. This was attributed to poor governance and regulatory hurdles.

Fortunately, as elucidated by Sanghi and Srija (2016), towards bridging the gap, the Ministry of MSME is implementing the entrepreneurship development and skill up-gradation schemes through appropriate training facilities. The Ministry has set up three national level Entrepreneurship Development Institutes. There is the scheme for providing support for "Entrepreneurial and Managerial Development of SMEs through Incubators" in implementation since 2008. A national award scheme has been initiated by MSME for outstanding performance in Entrepreneurship, Research and Development, Innovation, Lean Manufacturing Techniques, and Quality Products. Self Help Groups, including Women SHGs, have also emerged to promote entrepreneurship.

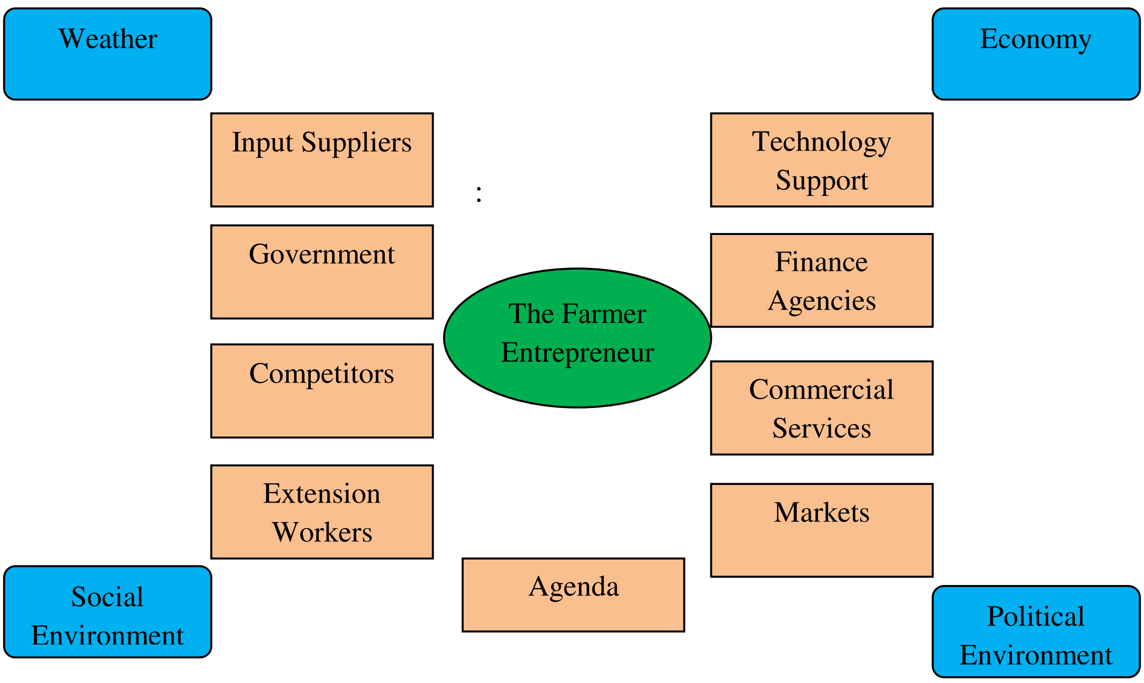
Despite the history and various schemes being in place, the country has generally not witnessed the natural gradation from self-employment to entrepreneurship as part of the growth process. To quote the National Knowledge Commission, "50 per cent of the entrepreneurs experienced difficulties while seeking statutory clearances and licences. Two-thirds faced hassles while filing taxes and 60 per cent claimed to have encountered corruption. Another hurdle was in accessing reliable information on registration procedures, finance and other schemes. 56 per cent claimed that the paucity of quality infrastructure – especially transport, power, and telecommunications – was a critical barrier."

In an agrarian economy of India's dimension, predominated by unemployed youth and smallholder farmers, entrepreneurship must be a key driver for agrarian transformation and socio-economic uplift of the majority youth and farmers who often operate on the edges of the economy in an ever-changing and increasingly complex and competitive global economy. Further agri-entrepreneurs will greatly strengthen employment security and help harness the huge demographic dividend.

7.3 Agri-entrepreneurs Characterized

Entrepreneurs are those who increasingly or primarily produce for the market and profits. They can be individual farmers, group of farmers, farmer's organization, cooperatives, and other related professional groups along the value chain *viz.,* suppliers, traders, transporters, and processers, many others who by themselves are also entrepreneurs. And, all must respect each other and work together. FAO (2012) had depicted the complex world of the farmer entrepreneur as below (Figure 1).

Figure 1. The world of the farmer-entrepreneur uncertainty



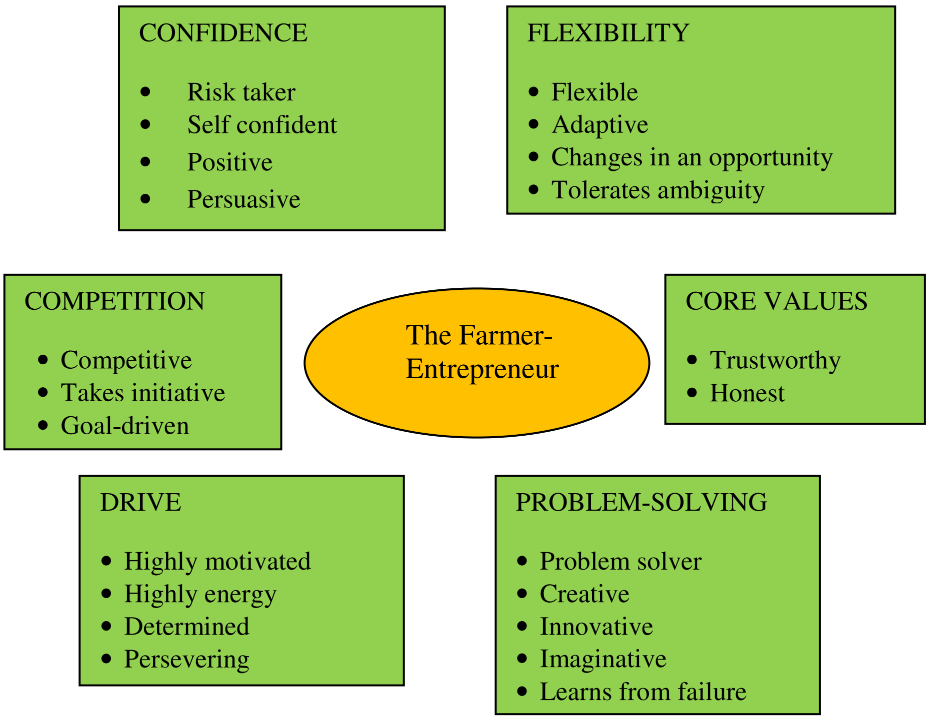
Source: FAO, 2012

As elucidated by FAO (2012), an entrepreneur is a determined, creative and committed leader always exploring opportunities to improve, expand, and diversify his business. He is supposed to be a bit imaginative, must be guided by technological possibilities and should have lots of patience. And, entrepreneur likes to take calculated risks, but need not be over ambitious, yet be able to gather courage and bring new approaches.

Entrepreneurs are also innovators and keep coming up with better and efficient ways to optimize their profits without jeopardizing their agro-ecological assests and sustainability. This is particularly important in this fast changing highly competitive and globalized world.

Entrepreneurship is a dynamic process of building enterprises of various sizes at different levels from establishment, survival, growth and maturity. A successful farmer entrepreneur who is mentally committed, technically sound, innovative and plans ahead can take his farm business to desired heights. However, in this journey he meets veritable barriers – social, economic, regulatory, information, weather aberrations, and access to finances. These barriers are not insurmountable, but the entrepreneur must have the necessary courage, conviction, confidence, skill, and patience to cope with and win over. As summed up by FAO (2012), some important characteristics of an entrepreneur are summarized below (Figure 2).

Figure 2. Some ‘typical’ characteristics of an entrepreneur



Source: FAO, 2012

There are nine key entrepreneurial competencies for a farmer-entrepreneur: initiative, ambition, focused problem-solving, creative thinking, taking risks, flexibility and adaptability, interpersonal abilities, networking and readiness to learn. With these competencies, farmers will be more able to compete in this new environment and make profits by taking advantage of new market opportunities. These competencies can be acquired through practice, experience and training. Further, these must be complemented with three technical competencies, namely, managing inputs, managing production, and managing marketing. And all these attributes must be combined in practice.

The entrepreneurial response to change comprises the following eight inter-dependent action points and attributes (FAO, 2012):

- Capturing value within the value chain by introducing value-adding enterprises
- Enhancing and managing efficiencies in production to cut input costs and to enhance productivity
- Promoting new technologies and innovations to adapt to changing economy and market and to enhance competitiveness
- Sustaining land management for evergreen economy – *swasth dhara to khet hara*
- Broadening management skill to meet the expanding demands and complexities to manage the synergies as well s asymmetries
- Trustworthiness and respect in business to ensure long-term success and continued quality technical input along the value chain
- Promoting group entrepreneurship, initially supported by the extension system, but ultimately the overall management to be the responsibility of the group
- Managing farm business according to a long term plan so that the business stays on course.

The above FAO thoughtful details constitute invaluable training material and should be used in our human resources development programmes.

7.4 Recent Entrepreneurship Initiatives

7.4.1 Startups

Some of the enterprising and determined entrepreneurs have taken to Start-ups. As revealed by Prime Minister Shri. Narendra Modi, the convergence of technology, integration across diverse fields, distributed architecture and people willing to back an idea, have opened a new world for enterprise. “I see Start-ups, technology and innovation as exciting and effective instruments for India’s transformation, and for creating jobs for our youth”. Among others, the government is vigorously promoting the Start-ups ecosystem, including adequate funds for startups to help them grow; to create an environment of ease of doing business; ready availability of essential services like office space, location, supplies telecom connectivity etc.; and mentors to provide strategic advice.

To give boost to the Make in India programme, the MSME Ministry had launched A Scheme for Promotion of Innovation, Rural Industry & Entrepreneurship (ASPIRE) in March 2015, aiming to set up a network of technology and incubation centers to accelerate entrepreneurship and also to promote start-ups for innovation and entrepreneurship in agro-industry. Further, to ease the credit availability requirements of startups the Government had announced the Micro Units Development & Refinancing Agency (MUDRA), operated by Small Industrial Development Bank of India (SIDBI) for providing refinance to micro units. This would improve the liquidity of the micro units who right now have to borrow from Non-Banking Finance Corporations (NBFCs) and moneylenders at high rates of interest.

Stand-Up India Scheme launched on 5 April 2016, gives new and promising entrepreneurs a chance at making it big. The scheme aims to provide a special thrust to entrepreneurship among women and scheduled castes and tribes. The scheme is anchored at the Department of Financial Services (DFS), Ministry of Finance, Government of India. Under the scheme, bank loans between Rs. 10 lakh to Rs. 1 crore are provided for setting up a green-field enterprise. This scheme is being made available to at least one Scheduled Caste (SC) or Scheduled Tribe (ST) borrower, and at least one women borrower, per bank branch. The objective of the scheme is to support SC, ST and women entrepreneurs, who face numerous challenges, in setting up enterprises, obtaining loans and other needs from time to time. The scheme therefore endeavors to create an ecosystem which facilitates and continues to foster a supportive environment for ease of doing business, thus greatly promoting entrepreneurship as well as equity.

7.4.2 Atal Innovation Mission (AIM)

This programme, operated from NITI Aayog, is about an Innovation Promotion Platform involving academics, entrepreneurs and researchers and draws upon national and international experiences to foster a culture of innovation, R&D and scientific research in India. The platform will promote a network of world-class innovation hubs and grand challenges for India. The overarching purpose of this mission is to promote a culture of entrepreneurship and innovation in India. The key objectives of the AIM are:

- To create an umbrella structure to oversee innovation eco-system of the country
- To provide platform and collaboration opportunities for different stakeholders
- To study and suggest best and novel practices to be adopted by different stakeholders in the innovation chain
- To provide policy inputs to NITI Aayog and various Government Departments and Organizations
- To create awareness and provide knowledge inputs in creating innovation challenges and funding mechanism to government
- To develop new programmes and policies for fostering innovation in different sectors of economy.

7.4.3 Self Employment and Talent Utilization (SETU)

It aims to bridge Techno-Financial, Incubation and Facilitation Programmes to support all aspects of startup businesses and other self-employment activities, particularly in technology driven areas operated from NITI Aayog.

7.4.4 Electronics Development Fund (EDF)

Launched by the Ministry of C&IT, it promotes innovation, research and development, and product development in the field of semiconductors, nano-electronics, IT and associated sectors by bringing in established companies and startups on board. The objective is to do research, design, and develop electronic products within the country for which the startup units would be provided supportive financial assistance from the EDF.

7.4.5 Digital India

It has been launched to provide broadband connectivity in rural and urban areas. Introduction of digital rural connectivity would give a big boost in developing traditional rural arts, crafts or other innovative ideas into business models.

7.4.6 Intellectual Property Rights (IPR)

IPR is being promoted to protect one's products from impersonators. The startups need to go for design patents, trademarks, copyright or trade secrets protection as the need maybe before marketing their product.

7.4.7 India Aspiration Fund

It was launched with Rs. 2000 crore by SIDBI in August 2015 to boost the startups fund of-funds ecosystem in the country. This fund would invest in various venture capital funds for meeting the equity requirement of MSME start-ups. A SIDBI Make in India Loan for Small Enterprises (SMILE) Scheme of Rs.10,000 crore has also been launched to catalyze tens of thousands of crores of equity investment in start-ups and MSMEs, creating employment for lakhs of persons, mostly educated youth over the next 4-5 years.

It is hoped that the recently established Cabinet Committees on Economy and on Employment and Skill Development should duly internalize the above moves and further strengthen them for entrepreneurship revolution for enhancing employment and income of the masses, especially smallholder farmers.

7.5 Research and Extension Support

Research works at the Indian Agricultural Research Institute (IARI), (Rashmi Sigh, M.S. Nain, J.P. Sharma, J.R. Mishra and others) on developing entrepreneurship for enhanced and sustained farm income in the NCR covering villages in Delhi, Rohtak, Hapur, Faridabad, and the surrounding have conducted several experiments and shown significant increase in profits, improved standard of living, sense of achievement, increased social interaction, improved decision making capacity, recognition of peer groups, and more investment in children's education. They have concluded that "agripreneurship development may be visualized as a process whereby individual's motivations and aspirations trigger it and their entrepreneurial competencies, adoption of best practices and facilitative socio-economic factors play sequential role in reaching agripreneurial success. It is the farmers' ability to rural environment which proves critical for achieving success. For developing agripreneurs, it is essential that an effective network is built consisting of various stakeholders like input suppliers, mentors, technical experts, marketing and supply chain agencies."

Of the 165 farmers trained by the group, 51 have launched their own rural agri-enterprises. Some of their main observations are as below:

- Youth are interested to take up agriculture if hi-tech agriculture options are available
- It is possible to train rural youth for uptake of agri-enterprises since they are inclined to take up enterprises based on agriculture which they are familiar with
- Training modules incorporating entrepreneurial behavioral aspects along with technological skills training are must to achieve desired success
- Farmer-led innovations are needed to be up-scaled and out scaled
- KVKs training modules must incorporate human domain as well as technology training
- Selection of potential agrientrepreneurs must be done utilizing standardized tools available to test their orientation for selection so as to ensure higher success rate of training interventions
- Convergence of efforts of all stakeholders involved results in higher success rate of entrepreneurship development in rural areas
- ETIPs- There is paucity of entrepreneurial information packages for potential entrepreneurs (from 1st stage to the end stage – planning, technical skills, methodology, marketing and finally economic analysis of technologies developed by research institute)
- Farmer Producer Organizations and Group Entrepreneurship (FIGs, SHGs) are essential for entrepreneurial efforts of small and marginal farmers, who are in majority.

The extension system should be competent to combine the special talents, behaviors, and skills to strengthen agri-entrepreneurship. Extension workers need to follow up formal training with guidance and support in taking actions on what has been learned. Training will be effective only if farmers have access to get the resources and services needed to establish and expand their farm businesses, such as finance and markets. Extension workers may also need to facilitate the establishment of producer organizations that can contribute to stimulating entrepreneurship, and to guide farmers through changes.

Further, extension workers have a responsibility to support farmers by facilitating links with financial institutions and advising them on the terms and conditions of loans. Similarly they have a role in providing information on market opportunities and facilitating links with buyers.

Moreover, extension workers have an important role to support entrepreneurial farmers by facilitating linkages and developing networks and partnerships along the value chain.

Finally, often a culture of entrepreneurship is needed for farmers to achieve their entrepreneurial vision. Extension workers can play a part by communicating a common vision to both farmers and other stakeholders in the value chain as well as the values needed to conduct business in an ethical way. Extension workers can support these farmers by reducing the risks for innovation.

7.6 Group Entrepreneurship in Farming – The Amul Model

Despite certain limitations, group entrepreneurship is a proven successful model of agri-business and farmers welfare. Its key advantages include:

- Greater power from pooled resources and scale of economy
- Internalizing shared multiple life/business experiences and promoting professionalism
- Protection from exploitative traders, markets and anti-social elements.

These approaches and experiences championed by the Small Farmer Agriculture Cooperative (SFAC), especially by Pravesh Sharma, Former Chairman, SFAC, in form of Farmer Producer Organizations (FPOs) particularly in Maharastha, Gujarat and Karnataka should be scaled-up and scaled-out.

Dr. Verghese Kurien had transformed India from a milk-deficit nation to the largest producer of milk in the world (current production nearly 170 mt, about eight fold increase during 1960-2017) and through his cooperatives movement had empowered millions of smallholder farmers to walk out of entrenched hunger and poverty – a huge change heralded as the White Revolution. The two Revolutions, Green and White, had saved millions of human lives and have been the backbone of national food security in India. Both the Revolutions were based on: (i) strong technological and innovation leadership, (ii) strong political will and support, (iii) strong farmer-market linkage, encompassing suitable price, market and services support, especially in case of the White Revolution, and (iv) farmers' enthusiasm, self-esteem and cooperative approach. Although the Green Revolution was more publicized, the White Revolution was equally effective but rather silent and more sustained.

The socio-economic face of the White Revolution has been shining green. In terms of value of product (VoP), milk equals rice plus wheat. Moreover, livestock distribution is highly egalitarian and growth in this sub sector has been highly pro-poor and pro-women. Recognizing that : (i) the livestock accounts for nearly 30 per cent of the Agricultural GDP and its contribution is accelerating at an average annual growth rate of 4 per cent and above, (ii) milk accounts for two-thirds of the total value of livestock, and (iii) the demand for milk continues to be high, the White Revolution must be extended and consolidated in all parts of the country not only for fighting the stubbornly high undernutrition, especially in children, but also for alleviating deep rooted poverty, livelihood insecurity, and inequity. Moreover, linkages between on- and off-farm employment fostered by dairy value chains and integrated farming systems offer unique entrepreneurial and youth employment opportunities in rural areas.

"The man who made the elephant dance", Dr. Kurien, from day one of his professional career starting in 1949 at the Kaira District Cooperative Milk Producers' Union Limited (KDCMPUL), Anand, had committed himself to galvanize the people's power - the millions of resource-poor milkmen, by creating cooperatives which empowered democracy at the grassroots level and brought about powerful social changes. Born out of a noncooperation movement led by none other than Sardar Vallabh Bhai Patel against the monopoly of Polson Dairy, KDCMPUL was established in 1946 to enable the producers to gain control over their resources they created. Under the patronage of Mr. Tribhuvan Das Patel, the founder of KDCMPUL, Dr. Kurien emerged as a marketing genius and transformed KDCMPUL into Amul Value Chain comprising milk producers – village-cooperatives – chiller unit – pasteurizer unit – cooling and packaging unit – wholesalers and distributers – retailers – customers. By the end of 1960, Amul Dairy with its most famous iconic brand Amul, marked the beginning of the White Revolution in India, and Anand – the seat of Amul, became the Milk Capital of India, and Dr. Kurien the "Milkman of India". Praising this effort, Borlaug had noted that "without effective methods of distribution, food has no way of reaching the tables of the world's population".

The white splash caught attention of the then most visionary and humanist Prime Minister Shri Lal Bahadur Shastri. In 1964 while inaugurating the new cattle-feed plant of Amul, the Prime Minister saw the success of milk co-operatives and asked Dr. Kurien to replicate the Amul pattern across the country. The vision and effort resulted in the creation of the National Dairy Development Board (NDDB). The World Bank provided unconditional loan for NDDB, which facilitated and triggered the replication of Amul model across India under the world famous programme called Operation Flood – christened so by Dr. Kurien himself, literally meaning flood of milk through increased milk production.

Charged with the dictums of India's great leaders, Sardar Patel and Prime Minister Shri Lal Bahadur Shastri, Kurien strategically implemented the Operation Flood in three phases. In Phase I, 1970-80, four Mother Dairies linked to 18 of India's premier milksheds were established which greatly increased both production and procurement. In Phase II, 1981-85, 136 milksheds, 296 urban markets, 43,000 village cooperatives with 4.25 m milk producers were added which boosted direct marketing by producers. In Phase III, 1985-96, volumes of milk produced and procured increased dramatically. Animal, health, feed and artificial insemination (AI) services were strengthened; Members education was intensified, 30,000 cooperatives were added, milksheds peaked to 173, women members and women cooperatives increased rapidly. Most significantly, emphasis on research & development in animal health, nutrition, technologies adoption, quality products and human resource development were enhanced.

The White Revolution thus created and nurtured by Dr. Kurien is rooted in the over 1,45,000 village level dairy cooperatives and over 15 million farmers, mostly smallholders and landless farmers. Building on Kurien's legacy and further strengthening the growth trajectory, projected milk production and demand in 2021-22 is about 200 million tonnes, 50 per cent of which will be realized in the organized sector. The anticipated size of the dairy industry market will be about US$ 150 billion. In order to materialize the projected growth, India will need a six- to seven-fold increase in its strength of dairy technocrats, graduates and diploma holders.

The White Revolution must be rendered still more greener. The future efforts must focus on increasing milk productivity through genetic conservation and improvement, increased feed and fodder security and health care and augmenting the value chain – processing, quality control and efficient distribution. Currently, hardly 5 per cent of public spending in agriculture goes to the livestock sector, and the share to Dairy Development has been dropping. Moreover, institutional credit to livestock sector is only about 3 per cent of total agricultural credit. Further, despite numbering 1.5 lakh, dairy cooperatives procure less than 10 per cent of the total milk produced in the country. These veritable gaps must be abridged toward rendering the White Revolution evergreen.

It is gratifying that the Government of India has initiated an Intensive Dairy Development Programme, and its National Dairy Plan, Phase I, comprises productivity enhancement, augmenting village level infrastructure for linking producers with market, improving genetic potential of bovines and adopting adequate biosecurity measures. The other components include: Strengthening infrastructure for quality and clean milk production and distribution, assistance to cooperative and dairy entrepreneurship development scheme, and the Livestock Development Board.

The NAAS and the entire scientific community see the White Revolution as a national movement served by hubs of knowledge, technology, skill and leadership, and must commit themselves to sustain and render it ever greener. In this context, partnerships among public, private, industry, farmers, consumers and civil society nurtured by built-in mechanisms of priority and targets settings, feedback, problem identification, and strategic implementation are a must. As envisioned by Dr. Verghese Kurien, dynamic agro-ecologically differentiated national dairy research, technology, education, skill development and technology transfer systems must be institutionalized towards sociologically, economically, and environmentally sustainable developments.

Despite outstanding success of the Amul model of cooperative entrepreneurship, the model has not been adopted in many regions even in the dairy sector, what to say of other sectors. The research behind the non-adoption should be critically examined, and solutions should be found to judiciously adopt the model to harness the entrepreneur potential of the agriculture sector.

7.6 Transforming Agricultural Education to Harness the Entrepreneurial Attributes

Continued learning as per the business life cycle is essential for success. Both formal and non-formal education (learning) alongwith learning by doing are essential for building the needed capacity and skill. Besides extension systems and corporate sector, public sector institutions, State Agricultural Universities, ICAR institutes, especially National Institute of Agricultural Extension Management (MANAGE), other universities and public sector institutions *viz.* CSIR, should play active role in building the trained and skilled human resources in agri-entrepreneurship.

The Fifth Deans' Committee of the ICAR has updated the curricula of agricultural universities in line with the national initiatives entitled "Rural and Entrepreneurship Awareness Development Yojana" (READY) and "Attracting and Retaining Youth in Agriculture" (ARYA). The student READY program aims to reorient graduates for ensuring and assuring employability and develop entrepreneurs for emerging knowledge intensive agriculture. The component envisages the introduction of the programme in all the Agricultural Universities as an essential prerequisite for the award of degree to ensure hands on experience and practical training. It comprises three components: (i) Experiential Learning (ii) Rural Agriculture Work Experience (iii) In Plant Training/Industrial attachment.

The above three components, as briefly described below, are interactive and are conceptualized for building skills in project development and execution, decision-making, individual and team coordination, approach to problem solving, accounting, quality control, marketing and resolving conflicts, etc. with end to end approach.

- Experimental Learning helps the student to develop competence, capability, capacity building, acquiring skills, expertise, and confidence to start their own enterprise and turn job creators instead of job seekers
- Rural Agriculture Work Experience also enables the students to gain hands-on experience giving them confidence and enhancing on-farm problem-solving abilities in real life situations
- In-Plant Training for a short period of time in relevant industry to gain the knowledge and experience of the work culture. In-Plant Training by reputed organizations provides industrial exposures to the students as well as to develop their career in the high tech industrial requirements.

Towards training agricultural graduates to be an entrepreneur the Vth Deans' Committee has made the following recommendations:

- Education for Agriculture in the 21st Century should have the goal that every becomes an entrepreneur. Thus, Business Management should be mainstreamed in all applied courses, e.g. Seed Technology and Business, besides establishing new faculties or Departments of Agricultural Business Management. Private companies and cooperatives, manufacturing and distributing agricultural inputs and related products should, other things being equal, give preference to such agricultural graduates for employment and granting licenses and dealerships

- Like the IITs, Centers of Excellence in form of Agricultural IITs and Agricultural IIMs should be created to ensure availability of quality human resources in agriculture-led development. A new Government programme on ‘Youth for Leadership in Farming’ should be launched
- The University curricula must capture the latest trends and their impact in the next 10 to 15 years and train the graduates accordingly. For instance, increasing role of livestock, horticulture and fisheries in meeting the socio-economic goals are evident. Our curricula should emphasize that the White and Blue Revolutions in India are fairly green and inclusive, and drivers of protein and overall nutritional security
- Keeping in mind India’s commitment to climate justice, our curricula should underpin that livestock impact climate change and get impacted by it substantially, and is increasingly obliged to mitigate its own GHG emissions. Thus, there is an urgent need to reorient livestock education and research and assess the genetic potential of indigenous breeds. Students should be trained in the frontier areas to establish their own unique enterprises, such as multi-antibody vaccine production based on indigenous cattle, under the Make-in-India and Start-up-India initiatives
- While maintaining desired national level uniformity in designing agricultural courses and curricula, adequate flexibility should be provided to meet the agro-ecologically differentiated challenges and opportunities, *viz* hill agriculture, coastal agriculture, dryland agriculture etc.
- Agriculture curricula in the past had little coverage of indigenous knowledge and innovations. In the contemporary agriculture, we need innovations more than ever before. The observance of this decade as the ‘Decade of Innovation in India’ is a recognition of this reality. Importance of cost effective, location-specific and affordable farm Innovations emphasizing value chain management, new extension systems promotion of agri-business models and entrepreneurship should be highlighted in curricula
- Agricultural education, research and extension institutions are increasingly challenged to transform to produce newer technologies, create comprehensive knowledge pool and strengthen trained, skilled and retooled human resources to meet the challenges and new opportunities unleashed by technological revolutions and the fast changing world. Our universities must occupy respectable places in the world ranking. In this context, we must ask ourselves the following questions as we move forward to transform our agriculture and allied sectors towards reshaping India
- We have generally failed both at national and international levels to suitably and adequately communicate the outstanding achievements to the veritable stakeholders – political leaders, policy makers, scientists, development partners, farmers, consumers, and the civil society. The Proposed curriculum attempts to strengthen communication

science and technology capacities to ensure effective and timely communication of actual and potential impacts of the products and outcomes.

7.8 Every Agriculture Graduate to be fully Equipped to be an Agri-entrepreneur

The need for attracting and retaining intellect, especially the youth, in agriculture must be a high priority as the complexities of challenges and opportunities are intensifying. Mentoring all stakeholders, from the ground to the top level, by experienced and successful mentors should become a part of the teaching-learning process in the NARES, as being practiced in the Ministry of Human Resources Development (MHRD), and common in western countries. The Department of Science and Technology (DST) is already mentoring students through its Innovation in Science Pursuit for Inspired Research (INSPIRE) program and MHRD is funding such incentives under the program called Global Initiatives of Academic Network (GIAN). The Handbook of Mentoring and Performance Audit prepared by the DST and MHRD could be used as a starting template for the agricultural system. The Department of Agricultural Research and Education (DARE), ICAR and NAAS may institutionalize implementation of the roadmap prepared by the Academy. Willing NAAS Fellows may participate in the initiative to encourage younger colleagues for excellence in agricultural sciences.

India is joining the Big Data Management. In a country of India's size and magnitude with varying agro-climatic situations, we need a centralized agriculture data base on a variety of issues that are of interest to scientists, students, farmers and industry. Through such an arrangement, in line with the Big Data movement, the data can be easily accessed by one and all. It is extremely important to use modern information and communication systems for marketing, sales and pricing activities to move with the time. This is a bright option for the graduating youths as well as for the e-market platform recently launched by the Prime Minister. These developments have been seeded in the curricula, and should figure more prominently as the necessary facilities and faculties mentors are in place.

With the current thrust on Make-in-India, Start-up-India, Skill India, Digital India etc. we need to evolve agricultural education system that is harmonized with job markets and entrepreneurship and also meets the changing needs of agriculture and rural sectors. Special capacities are thus required to be built in education system for nurturing the students. These include creativity and innovation, use of high technology, and entrepreneurial and moral leadership. India is already a knowledge power and must become the leader in the knowledge revolution. And, this will also help the universities to occupy respectable places in the world ranking.

Several of the ICAR initiatives, such as the Rural Entrepreneurship and Awareness Development Yojana (READY), encompassing Experiential Learning Programme (ELP) and Rural Agricultural Work Experience (RAWE) and in-plant/industrial attachment are highly relevant. The Council has stepped up efforts to attract talented students and young faculty, such as the Agricultural Science Pursuit for Inspired Research Excellence (ASPIRE) programme. Along with READY, Attracting and Retaining Youth in Agriculture (ARYA) programme, is most timely, and could mutually reinforce the Farmer First campaign of ICAR. These various initiatives should be congrued and regularly monitored for their implementation and impact assessment.

A few projects, such as the Bill and Melinda Gates Foundation (BMGF) initiatives, are innovating in the areas of social engineering and humanity towards enhancing and stabilizing livelihood security of resource-poor and vulnerable farmers. BMGF being a telecommunication giant, the Foundation may establish model Innovation Centres at selected SAU campuses to link farmers, agriculture, agribusiness and digital communication in a real-world situation to trigger new exciting opportunities, particularly for the young innovators and entrepreneurs in harnessing best of the science and technology in serving farmers to save and transform farming, leading to accelerated economic growth and employment.

Incubation centres should be created in research university campuses. Such settings become incubators for new ideas and stimulate and trigger young minds to innovate. Several of such innovations find practical applications and synergise the university-industry linkage including joint appointments, and enrich the research and academic stream. With such a setup, a good number of students shall be working as interns with the companies, thus gaining invaluable hands-on experience that will jump start their careers. The incubators for start-up companies will help convert innovations into commercial businesses thus boosting the Startup India initiative.

Education for Agriculture in the 21st Century and the Third Generation Universities should have the goal that every agricultural graduate becomes an entrepreneur. Thus, as suggested by the Committee, business management should be mainstreamed in major applied courses, e.g. Seed Technology, Dairy Technology, Fish Technology, Food Processing etc., besides establishing new Faculties or Departments of Agricultural Business Management. Private companies and cooperatives, manufacturing and distributing agricultural inputs and related products should, other things being equal, give preference to such agricultural graduates for employment and granting licenses and dealerships.

The proposed curricula and quality measures should render agriculture as an intellectually more stimulating discipline and an economically rewarding profession to attract talent and investment. An academic legitimacy has been provided to contemporary challenges and opportunities for greater understanding in the classrooms as well as by our policy makers. The efforts should revitalize the youth to find agriculture, agribusiness, agriculture related service sector, and the pursuit of agricultural science and technology generation as an attractive vocation, career and profession. In this context, new trans-disciplinary areas and entrepreneurship have been proposed as new subjects of formal study and informal learning to harness demographic dividends.

Given the comprehensive leadership of the ICAR and the commitment of the NARES, Judicious implementation of the recommendations of this committee will go to a longway in transforming Indian Agricultural Education to reshape India is the fast changing demographics, socio-economic, ecological and environmental regimes of the world.

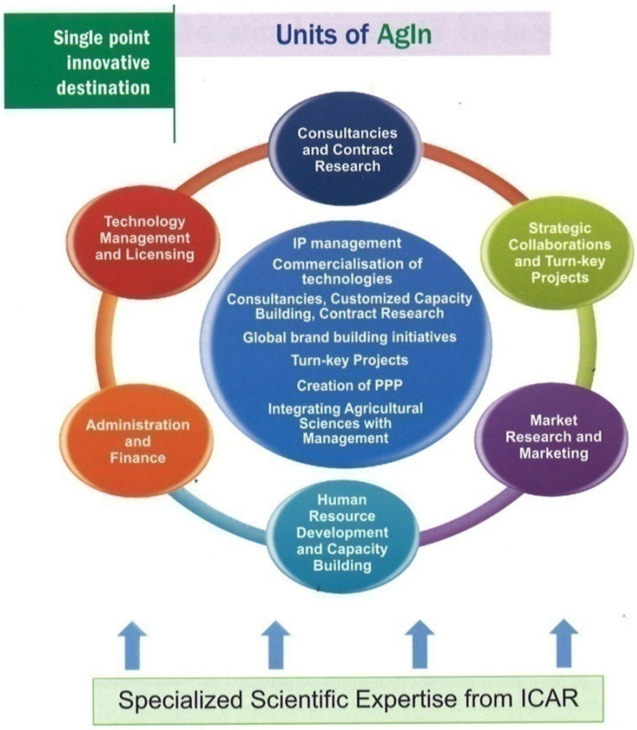
7.9 Leveraging Agritech Startups in Indian Agriculture

With the growing agriculture-dependent economy, the ICAR is now giving greater importance to commercialization of potential technologies enabling agrientrepreneurs to take up agri-startups and has established AgrInnovate (AgIn) India to promote income, employment and livelihood security. The Department of Agricultural Research and Education (DARE) established AgrInnovate India Limited in 2011. Its vision is to stimulate, foster, enhance and catalyse innovation and capacity driven agricultural development through partnerships. Its mission to enhance pace of agricultural development through efficient use of innovations, human resource and capabilities of National Agricultural Research System (NARS).

Main objectives of AgIn are:

- Protection, management, commercialization and distribution of Intellectual Property for public benefit
- Production, marketing and popularization of ICAR's products, processes and technologies in agriculture and allied sectors such as seed, planting material, vaccines, diagnostics, biotechnological products, other value-added inputs and products and farm implements and machinery
- Providing consultancies, contract research, contract services, customized capacity building
- Setting up of research and production farms outside India and undertaking global brand building initiatives
- Providing technical support for turn key projects on production and processing plants in agriculture and allied sectors
- Creation of Public-Private Partnership in research, education and other capacity building endeavors in agriculture and allied sectors
- Carrying out activities to integrate proficiencies in agricultural sciences with management, such as market intelligence, pricing and valuation issues, to nurture demand-driven research.

To this 'one stop shop' for all the stakeholders, ICAR provides the necessary Specialized Scientific Expertise as depicted below:



Source: AgrInnovate India Ltd and ICAR, New Delhi

AgIn offers the following services:

- One stop shop for market ready agri technologies
- Facilitates strategic collaborations & turnkey projects (domestic & foreign)
- Capacity building on Intellectual Property & Technology Management
- Impact assessment
- Technology valuation & pricing.

The current areas of focus of the company are:

- Seed & planting material (field crops, horticulture)
- Bio based agri inputs (bio pesticides, bio fertilizers, nano inputs with regulatory compliance)
- Animal husbandry, dairy & fisheries (diagnostics, vaccines, feed & nutritional products)
- Post-harvest value added products (horticulture, meat, dairy & fisheries)
- Small & marginal farmer friendly agricultural tools, implements & machinery
- Biotechnological products (protocols, GMO detection, molecular markets).

The future thrust area of AgIn are:

- A marketplace for agri technologies
- Streamlined process for technology commercialization
- Technology validation & upscaling for ICAR & other institutions
- Branding & evaluation
- Technology pricing and valuation.

The Department of Agriculture, Cooperation & Farmers and Welfare, Department of Agricultural Research and Education (DARE), and the ICAR of the MoA&FW, respectively through the National Institute of Agricultural Extension Management (MANAGE), Directorate of Agricultural Knowledge Management (DKMA), and IPR management unit, substantially, contribute to the GoI's initiatives for agribusiness and agri-entripreneurial development. For instance, the Agri-Clinics and Agri-Business Centers Scheme (AC & ABC) of the Ministry organizes through MANGE two-month residential certificate training in Agri-entrepreneurship development for eligible candidates across the country using Nodal Training Institutes (NTIs). Presently 131 NTIs are implementing the training program. After the training, one-year handholding support is given by the NTIs to the trained candidates for establishing agri-ventures. The trained entrepreneurs are also assisted through start-up loan and credit. Since inception, a total of 65,790 candidates have been trained and 28,131 ventures established (agripreneur e-bulletin volume 11, 2019). The key output of this program is an agripreneur with qualified knowledge along with entrepreneurial skills.

Prof. Raghunath Mashelkar, Former Secretary to the GoI and Director-General, CSIR, in his Dr. A.B. Joshi Memorial Lecture "Leveraging Agritech Startups in Indian Agriculture Innovation Ecosystem" at the recently held XIV Agricultural Science Congress highlighted that In India, we have daunting challenges in our agriculture system. They range from the need for substantial enhancement of our productivity to dealing with over dependency on monsoons, to managing dry land farming as also the small and fragmented land holdings to rapid elimination of poverty and malnourishment. Climate change poses some daunting challenges too. To deal with all these, India needs to take recourse to not only innovation but 'disruptive game changing innovation'.

He suggested that in building the new National Agricultural Innovation System, one of the important measures is to fully develop and use `collective intelligence' that involves several stakeholders. Amongst this should be innovative youth, but not at the periphery but at the core. Recalling the various initiatives of the government, namely, Make-in-India, Skill India, Start-up-India, e-NAM, etc, he reiterated that assured success in innovation would come from an ASSURED Innovation matrix: A (Affordable), S (Scalable), S (Sustainable), U (Universal), R (Rapid), E (Excellent), and D (Distinctive). He concluded that Young Indian Agritech Startups are emerging, but somewhat slowly. If the current Agriculture Innovation Ecosystem can leverage the Agritech startups by bringing them from periphery to the core then not only we provide an opportunity for the youth to contribute to the greatest public good, namely agriculture, but we can also accelerate the disruptive innovation led agriculture based inclusive growth, which can be achieved within a decade.

Prof. Mashelkar referred to the new developments in digital platforms, rural agriculture to urban agriculture, precision agriculture for input and water use optimization, gene-editing for multi-trait improvements, biological based crop protection, micronutrients for soil management, microbiome technologies to enhance crop resilience, agriculture robots, which cut down on operation costs and accomplish more with small workforce, CRISPR, a bold new technology used now by scientists that can create drought tolerant, disease proof, ultra high yields crops, and disruptive technologies such lab grown meat alternatives that test identical to the real thing, but does not require cultivation/slaughter of livestock. These innovations provide new opportunities to produce More from Less for More.

The startup India initiative, launched by Prime Minister Shri Modi is expected to have 100,000 startups with 3.25 million employees, with a market value of USD 500 billion dollars by 2025. Youth are playing a major role in this start-up movement. Beside the Fund of Funds, Government of India is catalysing agri- entrepreneurship with programmes like the Agri-Udaan Accelerator and the Agri Grand Challenge. Government-backed funding agencies like the Credit Guarantee Fund Trust for Micro and Small Enterprises (CGTMSE) is incentivizing banks to lend at highly affordable rates to start-ups.

Prof. Mashelkar emphasized that patents are valuable for startups. The 2008 Berkeley Study titled ‘Patenting by Entrepreneurship: An Empirical Study’ found that 67 per cent of venture backed start-ups reported that patents had been vital for them in securing investment. While 40 per cent of all the start-ups held patents, 80 per cent of those receiving venture capital investments owned patents. Patents not only ensure a startup’s freedom to operate, but can also help startups form joint ventures and R&D partnerships. According to a 2014 National Science Foundation backed study, 49 per cent of manufacturing and service firms used inventions obtained from external sources to develop their most important new products and services.

7.10 Policy Directive

Promotion of export of agriculture processed commodities is essential for expansion of agriprienurship. Thus Indian agriculture will have to be highly efficient competitive and knowledge-based to capture foreign markets. A stable and proactive trade policy must be formulated to ensure trade sustainability and enhanced net trade. We must be able to critically analyze the global situation and position ourselves to develop our own market and promote niche commodities. Needless to assert, quality and food safety aspects must be the highest considerations.

While we must empathize the farmers and rural poor, we must not build their homes on sand. The routine “hand outs”, loan waivers, and free electricity and water will not strengthen them sustainably, rather will erode their dignity, pride and confidence. Notwithstanding the necessity of smart stress relief measures and risk management provisions, we must empower and skill the farmers and rural youth to become entrepreneurs by ensuring their access to appropriate technologies, mentorship, markets, remunerative price realization, timely services and input support, communication, knowledge platforms, and infrastructure. With such empowerment they would themselves be able to feed their aspirations, and build the necessary self-confidence, and will generate wealth not only for themselves, but would also create new employments. Thus, agri-entrepreneurship should become a treasured possession of a good number of farmers and other stakeholders along the value-chain to synergistically accelerate economic growth and employment security towards building New India.

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Chapter 8

Water Security*

8.1 NAAS's Work on Water Security

The National Academy of Agricultural Sciences (NAAS) has always maintained that agri-food system security is synonymous to water security. Thus it is not a surprise that the very first Policy Paper brought out by the Academy in 1995 was on National Water Policy. India has the very formidable and challenging task of feeding 17.5 per cent of the world's human population from a meagre 2.4 per cent of land, further, constrained by the fact that the country has only 4 per cent of the global water resources at its disposal. In addition to the second largest human population, which will soon become the largest, the country has to also provide feed and fodder to 11.5 per cent of the world's livestock population from the same quantum of land and water resources.

In view of the vital importance of water for human and animal life, for maintaining ecological balance and for economic and developmental activities of all kinds, and considering its increasing scarcity, the planning and management of this resource and its optimal, economical and equitable use has become a matter of utmost urgency. The success of the national water policy will depend entirely on the development and maintenance of a national consensus and commitment to its underlying principles and objectives. Research is needed to develop site-specific management strategies for sustainable agriculture under such situations.

Agriculture, being the major user sector using almost 80 per cent of available water resource potential, the National Academy of Agricultural Sciences (NAAS) is concerned about its use and consequences. In order to critically analyze and deliberate different water related issues pertaining to improving water productivity, suitable technologies, and water use potential of the country, the NAAS organized brainstorming sessions from time to time and brought out water related policy papers on (i) Agricultural scientists' perceptions on national water policy, (ii) Harnessing and management of water resources for enhancing agricultural production in the eastern region, (iii) Drought preparedness and mitigation, and (iv) Water use potential of flood-affected and drought-prone areas of eastern India. The NAAS has also brought out a publication on 'The State of Indian Agriculture: Water' highlighting the various issues of water and agriculture like (i) technology frontiers for 'more crop per drop of water', (ii) water productivity in crop, livestock, fisheries and aquaculture sectors, (iii) water pollution in relation to agriculture, (iv) impacts of climate change on water and various mitigation and adaptation options, and (v) use of poor quality water in agriculture. This document also vividly reviewed the National Water Policy - 2012 of the country.

All indicators point to the fact that the availability of water is declining day by day, while on the other hand, there is no dearth of field-tested efficient water conservation and management

* *Substantial input of Dr. Anil Kumar Singh, Secretary NAAS, in preparing this chapter is gratefully acknowledged*

technologies developed by the national agricultural research system. There is also a large untapped potential of waste waters being generated by the domestic and industrial sectors which can be scientifically and judiciously utilized for irrigation particularly in the peri-urban areas. There is, therefore, an urgent need to fast track dissemination of these technologies supported by appropriate institutional mechanisms and policy decisions so that food and nutritional security can be ensured to the nation.

8.2 Global Water Scenario

FAO in 2017 launched at COP 2022 a detailed plan on "Coping with Water Scarcity in Agriculture: A global framework for action in changing climate". It had also authored Water for Sustainable Food and Agriculture – a report produced for the G-20 presidency of Germany. "Water is at the core of 2030 Agenda, with a dedicated Goal (SDG6) and many linkages to health, food security, climate change, resiliency to disasters and ecosystems, among many others. Reaching its ambitious objectives demands that we address access to water and sanitation alongwith issues of water quality and supply, in tandem with improved water management to protect ecosystems and build resilience", had emphasized FAO.

The G20 water report had underpinned some of the following water facts:

- Water is essential for every form of life, for all aspects of socio-economic development, and for the maintenance of healthy ecosystem
- Agriculture accounts for 70% of global fresh water withdrawals
- World contains 1400 million cubic km of water, of which only 0.003% or 45,000 cubic km are fresh water resources
- It takes 1 to 3 tonnes of water to grow 1 kg of cereals. 1 kg of beef takes upto 15 tonnes. Between 2000 and 5000 liters of water are needed to produce one person's daily food.

While thinking of water in agriculture, the following three challenges faced by agriculture should be kept in mind: (i) Increased production & productivity, (ii) Increase job, income security, reduce hunger & poverty, and (iii) Sustainable management of natural resources and adaptation to and mitigation of climate change.

With the above backdrop, the G20 Report identified the following critical issues affecting global outlook for water & food security:

1. Growing demand
2. Intersectoral competition
3. Water scarcity
4. Climate change
5. Access to water
6. Water quality and pollution
7. The water-food-energy nexus.

To resolve the above issues the following recommendations were made for policy makers.

(A) Under agriculture domain (primarily for enhancing irrigated infrastructure and management and increasing irrigation efficiency and access)

a. Modernise irrigation scheme
b. Improve agricultural water supply systems
c. Improve productivity and sustainability of water
d. Reduce food losses and waste
e. Strengthen international disciplines on all forms of import and export restrictions, and reduce distorting domestic support.

(B) Under the water domain

f. Improve water governance, make institutions adaptive and capable of cross-sectoral coordination
g. Support water data and information systems, develop effective water accounting and auditing systems
h. Communicating scarcity conditions – water pricing
i. Effectively engage in dialogue & support international fora and initiatives.

"Water is universal, it crosses borders and nourishes all life – water is a human right", said FAO DDG Maria Semedo at the 1st International Forum on Water Scarcity in Agriculture (WASAG) held on March 19-22, 2019 in Cabo Verde, West Africa celebrating World Water Day. Citing the World Water Development Report 2019, she highlighted that more than 2 billion people are currently living in countries with high water distress, and by 2050, water demand will increase by 20 to 30 per cent while supply will dwindle rapidly. Further, climate change is adversely impacting water regimes, and drier areas are experiencing more frequent and severe drought.

The Forum had focused on the following areas: (1) Water and Migration; (2) Drought Preparedness; (3) Financing Mechanisms for Sustainable Management of Water Resources; (4) Water and Nutrition; (5) Sustainable Agricultural Water Use; and (6) Saline Agriculture. The main objectives of the Forum are as below:

- Raise awareness
- Identify the specific needs and agree on priority actions
- Share experiences
- Establish collaboration
- Mobilise resources.

The expected outcomes of the Forum are:

- Sustainable and effective management of water for agriculture declared as a global priority
- Applicable solutions identified & tailored
- New and strengthened collaboration between partners & stakeholders
- Sustainable investments committed.

8.3 Status of Water Resources

Water is a finite resource the availability of which is declining each passing day. If the international yardstick of 1700 cu. m per capita availability per annum of water is taken as a criterion, then the whole country became "Water Stressed" in the year 2006 with per capita water availability declining to <1700 cu. m from 5200 cu. m in 1951 (Fig. 1). It is estimated that the per capita availability of water is likely to reach a level of around 1100 cu. m in 2050 but in reality we may reach this threshold much earlier considering the wasteful ways of water usage. It may be noted that per capita availability of <1000 cu. m indicates "Water Scarcity". If the per capita availability is scrutinized basin-wise, a significant number of basins in the country were either in the "water scarcity zone" or worse in 2010 (Fig. 2). The statistics related to the per capita storage or the days of average flows are equally disturbing. The data available indicate that the per capita storage in India at 220 cu. m is one fifth that of China (1110 cu. m).

Figure 1. Per capita water availability (m^3/year) in India

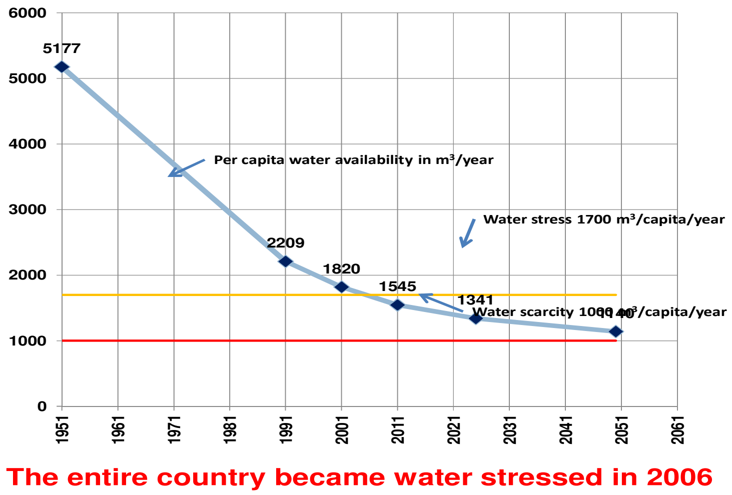
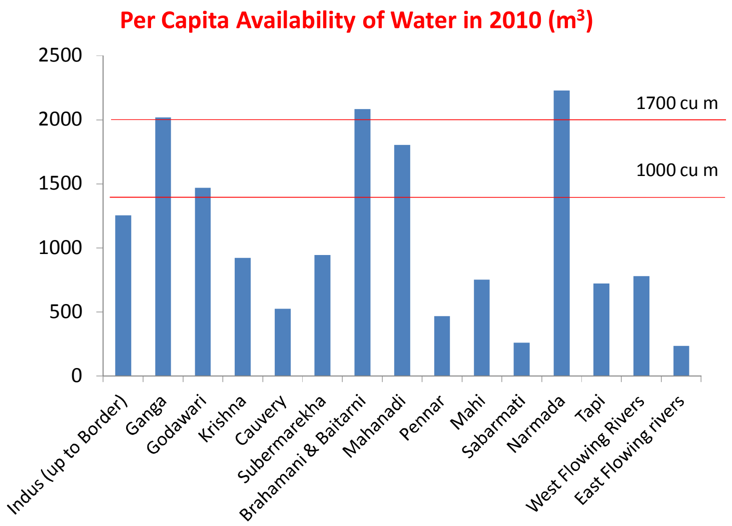


Figure 2. Basin-wise per capita water availability in India in 2010



It is worth stating that India has developed one of the largest irrigation infra-structure in the world which today stands at more than 68 m ha of net irrigated area. It is second only to China. It is no doubt that irrigation development played a very crucial role in ensuring food security to the huge population. However, the productivity of the irrigated production system (occupying 48 per cent area) at around 3 t/ha is considerably lower than the existing potential.

The Govt. of India initiated the Accelerated Irrigation Benefit Project (AIBP) in 1996-97 with a special emphasis on accelerating the rate of creation of additional irrigation potential in the Major and Medium Irrigation sector. In the spirit of Har Khet Ko Paani, the Government has aimed to complete 99 major and medium projects by December 2019. It is contemplated to take up remaining additional 50 long pending projects under Long Term Irrigation Fund (LTIF). The NITI Aayog, exploring funding through MGNREGA has planned one million small water storage/diversion weirs/ water harvesting structure per annum. The target for the area to be covered under AIBP was 15.13 mha but up to March 2016 only 8.79 mha had been created. A study completed in late 2011 revealed that the gap between the irrigation potential created and utilized in these projects is substantial and growing. It is not only the demand – supply mismatch in the major and medium irrigation projects but also the fact that the gap between the irrigation potential created and utilized has been widening continuously and today it stands at more than 25 mha (Fig. 3). Top most priority should be given to bridge this gap considering the fact that the Government of India invests a huge amount on this sector. Major reasons are low water discharge, insufficient water distribution mechanism, unequal water distribution across farmers located at different points, loss of water during distribution, incorrect recording of irrigated area and diversion of cultivable land to other purposes within the command area. The conclusions of a study carried out on 35 major/medium irrigation projects in the country have indicated that the overall water use efficiency was 36 per cent with the conveyance efficiency pegged at 69 per cent and on farm application efficiency at 55 per cent (Table 1). The overall efficiency of surface irrigation systems (around 36 per cent) implies that more than 60 per cent of the water supplied is being lost at various stages in the system resulting in several environmental issues including converting prime agricultural land into non-productive areas. However, one very heartening feature of the study is that there are major and medium projects which have shown conveyance efficiency higher than 85 per cent, on farm application efficiency >75 per cent with overall water use efficiency of 60 per cent. If these efficiency levels are replicated in the inefficiently run projects, the availability of water would not be an issue at all. It all boils down to awareness, implementation and governance.

Figure 3. Plan - wise irrigation potential created and utilized

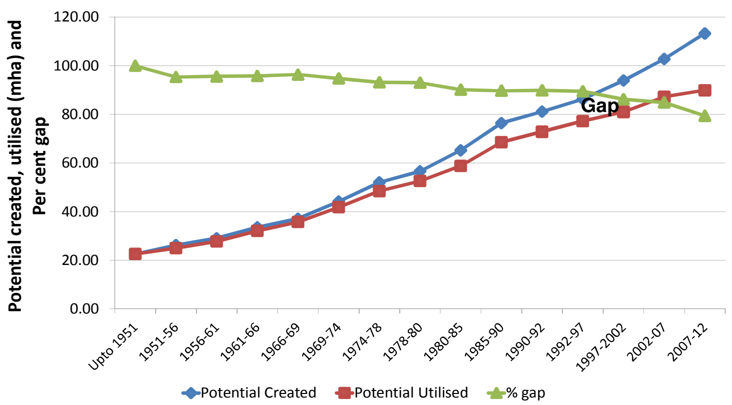


Table 1: Water use efficiency of completed Major/Medium Irrigation Projects

Conveyance Efficiency	**69**
Major	**91**
Medium	**86**
On Farm Application Efficiency	**55**
Major	**80**
Medium	**75**
Overall Water Use Efficiency	**36**
Major	**62**
Medium	**58**
Lowest CE:47, OFAE: 27, OWUE:13	

Source: (CWC 2016)

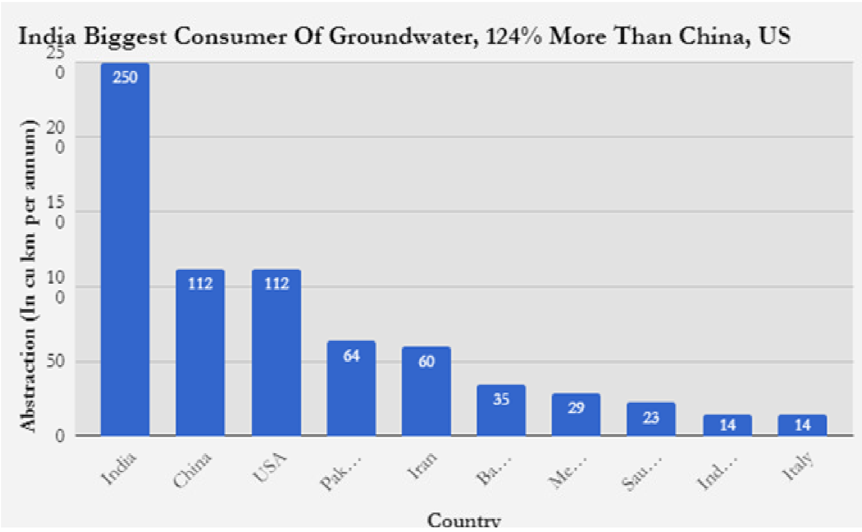
8.3.1 Ground water development

Development of ground water resources which was a low key affair in the earlier stages, is now contributing to more than 60 per cent of the irrigation demand and playing a critical role in ensuring food security to the millions in the country. However, its over exploitation has now become a very serious cause of concern and the potential of judicious exploitation of ground water resources is now confined only to some states in the eastern part of the country. Out of the 6607 assessed blocks, 4530 are safe while the rest in the semi-critical (697), critical (217) and a large number of over exploited (1071) blocks. India has the dubious distinction of having the highest ground water abstraction (Fig. 4). In fact, India is abstracting more water than USA and China put together. The overall ground water development in the country is 62 per cent only but the variability within the states is very high. In states like Delhi, Haryana, Punjab, Rajasthan etc, the ground water development is more than 100 per cent. But in states of eastern India and North-East, the ground water development is at a low level. Considering this fact, GoI has rightly decided to focus on Eastern India and has implemented a programme aptly titled "Bringing Green Revolution to Eastern India" (BGREI). In view of the seriousness of the problem, the Government is, therefore, putting a lot of emphasis on artificial recharge of ground water. A project for setting up 225 thousand recharge structures at an estimated cost of approximately Rs. 20,000 crores was launched with this objective and a clear defined goal that it has to be implemented in a participatory mode with involvement of local communities, locally elected bodies like *Panchayats,* and Non Government Organizations (NGOs). By 2025, an estimated 60 per cent of India's groundwater blocks will be in a critical/semi critical/ over exploited conditions, almost 54 per cent of the groundwater blocks in Gujarat, Haryana, Maharashtra, Punjab, Rajasthan, and Tamil Nadu are likely to fall in these categories if the present rate of decline trend continues. The challenges facing ground water management are as follows:

- Uncontrolled Groundwater exploitation both in hard rocks and alluvial areas is threatening sustainability of this resource, mostly in the states of Rajasthan, Gujarat, Tamil Nadu, Punjab, Delhi and Haryana

- Dependence on groundwater for irrigation will increase due to global warming. Quality issues will increase.
- Excessive withdrawal of ground water is worsened further due to free/subsidized power in some States (Water-Energy nexus)
- Groundwater pollution due to excess application of fertilizers and pesticides, indiscriminate disposal of effluents from industries and urban sewerage
- Arsenic, Fluoride and Iron in groundwater in excess of permissible limits in several states of India prohibits its use for drinking purposes
- Seawater Ingress in Coastal Aquifers- Groundwater in coastal aquifers exists in a fragile dynamic equilibrium with seawater. Indiscriminate exploitation of ground water from such aquifers leads to seawater intrusion into the fresh water aquifers.

Figure 4. Ground water abstraction in some countries



8.3.2 Physical and Financial Sustainability

In general, providing water at subsidized rates for irrigation has remained a vital policy issue for ensuring food production. Currently, irrigation accounts for more than 1/3rd of states' revenue deficits. In many states, O&M expenditure is adequate for staff salaries only and no funds for works. Low water charges and poor cost recovery therefore, results in a decline in funding for maintaining water infrastructure, inefficient water allocation and increasing conflicts over water sharing in many regions. Current status of O&M expenditure and cost recovery (≈25 per cent) in some major states, viewed in conjunction with the physical condition of the irrigation system, points towards an unsustainable scenario evolving in water sector, both physically and financially.

8.4 Rainfed Agriculture

Although India has the largest irrigated area in the world, it has a very sizeable area under rainfed agriculture (nearly 75 mha) which caters largely to pulses, oilseeds, minor millets, cotton and even rice (~45 per cent) but the productivity of which is very low (~1 t/ha). The average annual rainfall in India is 117 cm which is higher than the global average of 110 cm but there is a wide spatial and temporal variation in its distribution and intensity. The ratio of the minimum, average and maximum is of the order of 1:10:100 with the maximum being around 11000 mm in Cherrapunji (Meghalaya) to 100 mm in the Thar Desert. The number of rainy days can vary from 4 days to over 300 days a year and the intensity can vary anywhere from <1 cm/hr up to 15 cm/hr. It has also been estimated that almost 80 per cent of the rain occurs in only 100 hr in a year. Soil and nutrients loss due to run off is of the order of 5.34 billion tonnes and 6 million tonnes, respectively, resulting in production losses in excess of Rs. 115 billion.

A comprehensive assessment of district level water harvesting potential had revealed that the potential to realize the rainfed agriculture lies in the harvest of small part of available surplus runoff and reutilize it for supplemental irrigation at critical crop growth stages. The study identified about 28.5 M ha of potential rainfed area covering large number of districts in Central and eastern India that can generate sufficient runoff (114 BCM) for harvesting and reutilization. It is possible to raise the rainfed crop production by a total of 28-36 m tonnes from an area of 20-25 M ha during normal monsoon years which accounts for about 12 per cent increase over the present productiion level. With adoption of improved technologies (the possibility of which increases once 'critical water requirements' are assured) the benefits could be still higher. Extensive area coverage rather than intensive irrigation, needs to be followed in regions with higher than 750 mm/annum rainfall, since there is larger possibility of alleviating the in-season drought spells and ensuring a second crop with limited water application. This component may be made an integral component of the ongoing and new development schemes in the identified rural districts.

An evaluation of 636 watersheds has clearly brought out that watershed programs have impacted the rain-fed areas with a mean benefit-cost ratio of 1:2.03. The results have indicated that even in such fragile eco systems, these programs generated benefits which were more than double of their cost. About 18 per cent watersheds generated benefit-cost ratios above 3. However, 68 per cent of watersheds performed had a below average B:C ratio of 1:2.03 which indicated that there exists a large scope for proper watershed management. Only 0.6 per cent of the watersheds studied failed to commensurate with cost of the project. The mean internal rate return of 27.43 per cent was significantly high and comparable with any successful government programs. The internal rates of return in 41 per cent watersheds were in the range of 20 to 30 per cent whereas about 27 per cent watersheds yielded IRR of 30 to 50 per cent. The watersheds with IRR below 10 per cent were only 1.9 per cent.

Another important purpose of the watershed programs is to generate employment opportunities to address the equity concerns of landless labourers and marginal and small farmers. The results of meta-analysis have clearly established that watershed programs resulted in generating substantial employment opportunities in the watershed areas. The mean additional annual employment generation was about 154 person-days/ha/year. This also implies that the investment in watershed development programs can be considered as poverty alleviation program in those areas.

Focus on rain water harvesting is important because global warming is likely to result in a decrease in the number of rainy days and a consequent increase in intensity considering the prediction of GCM's that rainfall will either increase or remain constant over the Indian subcontinent. Historical data analysis has also indicated that the low intensity rainfall events have decreased while the medium and high intensify rainfall events have increased over the past fifty years, a trend which is likely to intensify as a consequence of climate change. As stated earlier, it is also a fact that even when all the water resources for irrigation have been developed, almost 45 per cent would still be rainfed. There is a possibility of easily enhancing the productivity of these areas by a minimum of 50 per cent through rain water harvesting and supplemental irrigation. The reality is that:

- Only 29 per cent of the 400 million ha of annual rainfall (117 cm) is harnessed
- 80 per cent rain falls in 100 days of the monsoon season but actually the rainy days are 45. This leads to water shortages during rainy season also
- Most of the total rainfall occurs in 100 hours out of 8760 hours in a year. This often leads to floods/droughts
- 1/3rd water is locked in north-east region
- About 215 million ha of rainfall can be stored in the underground aquifers.

8.5 Wastewater utilization for irrigation

With the projected scenarios of water availability compounded by global warming, increasing urbanization (circa 55 per cent of India's estimated 1.6 billion would be urban by 2050) and industrialization, huge volumes of waste waters will be generated. These waste waters would be of varying qualities depending upon the source. In developing countries like India, the problems associated with wastewater reuse arise from its lack of treatment. On the whole, only 60 per cent of industrial water and 26 per cent of domestic water is treated in India. Waste waters are being used indiscriminately particularly in peri-urban agriculture. Considering the size and vast population of the country and various sectoral demands, India is a growing market for water and waste water treatment. It includes both sewage treatment and effluent treatment. Industrial and municipal sectors account for almost 90 per cent of the estimated US$ 2000-2100 million water treatment market in India. Currently, 75 per cent of the rural population and 85 per cent of the urban population have access to public water supply. However, municipal agencies in many Indian towns and cities are unable to increase their water supply capacities to match population growth, especially in the urban areas. The challenge, thus, is to find low-cost, low-tech, user friendly methods, which on one hand avoid threatening our substantial wastewater dependent livelihoods and on the other hand protect degradation of our valuable natural resources.

In fact, domestic wastewater should be considered as a "*resource for irrigation*" as the cost of treating these waters for making them suitable for irrigation is significantly less than for potable water and they are rich in nutrients.

8.6 Precision Farming: Use of modern tools in water management

The stupendous progress in information technology coupled with the rapid advancements made in Geographical Information Systems (GIS), simulation tools, sensors, precision farming and remote sensing have opened up new vistas for water resources development and management. These tools should be an integral system of scientific management of irrigation networks, water distribution, crop planning and related operational activities as they will enable the system managers to take correct and timely decisions. These tools can be equally, if not more effective, in assessment and monitoring of watershed related development studies. Decision Support Systems (DSS) for real time monitoring and decision making with inputs from remote sensing and ground based inputs can contribute significantly in improving water use efficiencies in large irrigation projects and integrated watershed management schemes.

Developments in biotechnology have reached a level where gene flow has no boundary. Marker assisted selection (MAS), gene pyramiding etc. can enable identification as well as introduction of genes (single/multiple) that can enhance water use efficiency as well as increase tolerance to water logging, soil salinity or heavy metal toxicity. The potential of this technology needs to be utilized fully.

8.7 Efficient water management technologies

The National Agricultural Research System (NARS) through the vast network of State Agricultural Universities (SAUs), Indian Council of Agricultural Research (ICAR) institutions and All India Coordinated Research Projects (AICRPs) have developed a plethora of technologies focusing on water harvesting, conservation and management and use. There benefits are described below. The water savings associated with the various interventions developed and summarized below:

Proper scheduling of canals (matching supply with demand):	40-60 per cent
Precision leveling through laser levelers:	15-20 per cent
Scientifically designed check basins/border strips:	10-30 per cent
Zero tillage:	20-30 per cent
Adoption of Pressurized Irrigation Systems:	40-70 per cent
Land configuration changes-Ridge/furrow or raised/sunken beds:	20-25 per cent
Use of tissue cultured eucalyptus, banana, sugarcane, papaya	30 per cent

Simple measures like banning transplanting of paddy before second week of June in Haryana and Punjab have made a significant impact on the ground water extraction in the two states.

Such policy decisions can convey a message that unnecessary and wasteful use of water is a non-sustainable and non-negotiable issue.

The National Water Policy had stated that the water use efficiency of surface water has to be enhanced to 60 per cent and ground water usage to 75 per cent to enable meeting the production targets with the current quantum of water resources available. If attention is paid to adoption and upscaling of the technologies available today, whether it is irrigated or rainfed regions, with a focus on its use efficiency, it is possible to meet the country's water demand.

8.8 New Initiatives by the Government

Water is a resource which does not recognize geographical or sectoral boundaries when it flows or is utilized. But separate ministries/departments exist which looked at this resource from the developmental and utilization aspects. A typical example is that although agriculture sector is the major consumer of water (~80 per cent), its development and utilization was the responsibility of the Ministry of Water Resources. Likewise, the Central Ground Water Board dealt with ground water development and the Ministry of Water Resources (Department of Land Resources) and National Rainfed Area Authority (NRAA) dealt with watershed development i.e. rainfed areas, although the precipitation (rainfall), surface water and groundwater are all part of the Water Cycle. This silo-type of functioning obviously had inherent limitations.

The Government of India on July 01, 2015 accorded approval to the Pradhan Mantri Krishi Sinichai Yojana (PMKSY) to address the shortcomings in implementation in a holistic manner.

The major objective of PMKSY is to bring convergence of investments in irrigation at the field level, expand cultivable area under assured irrigation, improve on-farm water use efficiency to reduce wastage of water, enhance the adoption of precision-irrigation and other water saving technologies per drop more crop, enhance recharge of aquifers and introduce sustainable water conservation practices by exploring the feasibility of reusing treated municipal waste water for peri-urban agriculture and attract greater private investment in precision irrigation system.

For promoting 'per drop more crop' NITI Aayog has suggested the following actions:

i. Operation and Maintenance (O & M) of the distribution system is below standard, causing water leakage and wastage. This needs to improve, and involvement of people through 'Participatory Irrigation Management (PIM)' would be useful. Promote large number of Water Users Associations (WUAs) and Paani Panchayats

ii. Precision agriculture by way of micro-irrigation (drip and sprinkler); and sensor-drone big data analytics based technology is important. Micro-irrigation (MI) must become a compulsory agenda in all forms of irrigation – flow, lift, small sources

(WHS/DW/Ponds etc.). In all command areas of minor/medium/major irrigation projects, micro irrigation system should be compulsorily adopted

As of date, only about 10 million ha. of the total of 63 mha. of irrigated area is covered under micro irrigation. An annual coverage of a minimum of 2.5 mha. is necessary to quickly achieve water use efficiency and narrow the gap between IPC and IPU. Under 'Krishi Bhagaya' programme of Karnataka, small irrigation ponds dug in rainfed areas have proved very useful in protecting a standing crop from monsoon vagaries, when connected with steel pipe conveyor and MI system. This programme deserves to be scaled up in a major way across the rainfed areas of the country

iii. Crop alignment and Conservation agriculture must be strictly practised in all command areas for optimal water use efficiency.

PMKSY has been conceived amalgamating ongoing schemes viz. Accelerated Irrigation Benefit Programme (AIBP) of the Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR), Integrated Watershed Management Programme (IWMP) of Department of Land Resources (DoLR) and the On Farm Water Management (OFWM) of Department of Agriculture and Cooperation (DAC). The scheme will be implemented by Ministries of Agriculture, Water Resources and Rural Development. Ministry of Rural Development is to mainly undertake rain water conservation, construction of farm pond, water harvesting structures, small check dams and contour bunding etc. MoWR, RD &GR, is to undertake various measures for creation of assured irrigation source, construction of diversion canals, field channels, water diversion/lift irrigation, including development of water distribution systems. Ministry of Agriculture will promote efficient water conveyance and precision water application devices like drips, sprinklers, pivots, rain-guns in the farm "(Jal Sinchan)", construction of micro-irrigation structures to supplement source creation activities, extension activities for promotion of scientific moisture conservation and agronomic measures.

Programme architecture of PMKSY is to adopt a 'decentralized State level planning and projected execution' structure that will allow States to draw up their own irrigation development plans based on District Irrigation Plan (DIP) and State Irrigation Plan (SIP). It will be operative as convergence platform for all water sector activities including drinking water & sanitation, MGNREGA, application of science & technology etc. through comprehensive plan. State Level Sanctioning Committee (SLSC) chaired by the Chief Secretary of the State will be vested with the authority to oversee its implementation and sanction projects.

The programme will be supervised and monitored by an Inter-Ministerial National Steering Committee (NSC) will be constituted under the Chairmanship of Prime Minister with Union Ministers from concerned Ministries. A National Executive Committee (NEC) will be constituted under the Chairmanship of Vice Chairman, NITI Aayog to oversee programme implementation, allocation of resources, inter-ministerial coordination, monitoring & performance assessment, addressing administrative issues etc.

District Irrigation Plans (DIPs) are the cornerstone for planning and implementation of PMKSY. DIPs will identify the gaps in irrigation infrastructure after taking into consideration the District Agriculture Plans (DAPs) already prepared for Rashtriya Krishi Vikas Yojana (RKVY) vis-à-vis irrigation infrastructure currently available and resources that would be added during XII Plan from other ongoing schemes (both State and Central), like Mahatma Gandhi National Rural Employment Guarantee Scheme(MGNREGS), Rashtriya Krishi Vikash Yojana (RKVY), Rural Infrastructure Development Fund (RIDF), Member of Parliament Local Area Development (MPLAD) Scheme, Member of Legislative Assembly Local Area Development (MLALAD) Scheme, Local body funds etc. The gaps indentified under Strategic Research & Extension Plan (SREGP) will be made use in preparation of DIP.

DIPs will present holistic irrigation development perspective of the district outlining medium to long term development plans integrating three components viz. water sources, distribution network and water use applications incorporating all usage of water like drinking & domestic use, irrigation and industry. Preparation of DIP will be taken up as joint exercise of all participating departments. DIP will form the compendium of all existing and proposed water resource network system in the district.

The DIPs will be prepared at two levels, the block and the district. Keeping in view the convenience of map preparation and data collection, the work would be primarily done at block level. Block wise irrigation plan is to be prepared depending on the available and potential water resources and water requirement for agriculture sector prioritizing the activities based on socio-economic and location specific requirement. In case of planning is made based on basin/sub basin level, the comprehensive irrigation plan may cover more than one district. The activities identified in the basin/sub-basin plan can be further segregated into district/block level action plans. Use of satellite imagery, topo sheets and available database may be appropriately utilized for developing irrigation plans at least on pilot basis to begin with and subsequently may be extended to all projects.

PMKSY – implemented in letter and spirit would certainly make a sea change at the ground level.

8.9 Composite Water Management Index (CWMI)

NITI Aayog (2018) has developed an index, CWMI, to quantify how the various states are managing their water resources in a holistic manner. Their performance is quantified based on the following indicators:

1. Source augmentation and restoration of water bodies
2. Source augmentation (Groundwater)
3. Major and medium irrigation-Supply side management

4. Watershed development-Supply side management,
5. Participatory irrigation practices-Demand side management
6. Sustainable on-farm water use practices-Demand side management
7. Rural drinking water
8. Urban water supply and sanitation, and
9. Policy and governance.

8.9.1 States' performance across critical indicator themes.

Most of the states have done well in the infrastructure-heavy themes of 'Major and medium irrigation' and 'Watershed development' and have also enacted policies corresponding to the recommendations within the 'Policy and governance' theme.

However, the critical themes of 'Source augmentation (Groundwater), 'Sustainable on-farm water use practices', and 'Rural drinking water' are lagging behind. Most states have achieved less than 50 per cent of the total score in the augmentation of groundwater resources, highlighting the growing national crisis.

54 per cent of India's groundwater well levels are declining, and 21 major cities are expected to run out of groundwater as soon as 2020, affecting ~100 million.

70 per cent of states have also achieved scores of less than 50 per cent on managing on-farm water effectively.

Given the fact that agriculture accounts for 80 per cent of all water use, this underperformance, as discussed in the analysis of low performers above, poses significant water and food security risks for the country.

Finally, states have also performed averagely on providing safe drinking water to rural areas. With 800 million people, or ~70 per cent of the country's population, living in rural areas, and about two lakh people in the country dying each year due to a lack of access to safe water, this is one of the most critical service delivery challenges in the world.

CWMI is certainly a step in the right direction. States should be asked to develop a strategy to recover the operation and maintenance cost of the irrigation projects as the first step and gradually move to charging for water use on volumetric basis, provide incentives to farmers who adopt water efficient technologies and factor in the role of water as a provider of ecosystem services.

8.10 Nature Based Solutions for Water

The indiscriminate use of water resources, in general, and the multi-faceted demands of this precious resource for meeting the diverse demands of the continuously increasing population and the adverse impact of climate change are challenging the water security like never before.

To ensure the sustainable use of this finite resource, there is need to change our approach towards its conservation, management and reuse. We must look towards nature based solutions (NBS) that work in harmony with nature because it is nature which regulates the various elements that constitute the water cycle (WWAP. 2018).

As a consequence of increasing population, economic development and diversifying consumption patterns, the demand of water globally is increasing at a rate of about 1 per cent per year and likely to continue at this rate in the future also. Climate change associated global warming is impacting both the quantity and quality of water. Water pollution is escalating and is threatening not only human health but also environment and sustainable development. It is also projected that the population at risk from floods is going to increase to 1.6 billion in 2050 representing 20 per cent of population from the current 1.2 billion. Additionally, land degradation/desertification/droughts are currently affecting 1.8 billion at the global level.

Water resources are generally perceived as an input for enhancing productivity in agriculture. It varies from the individual's daily requirement to landscape level applications. Apart from the role of water in providing provisioning service like production of food, fodder, fiber, fuel as well as agriculture, domestic & industrial uses. It plays a critical role in regulatory services like water flow, erosion control, GHG emission, and even pollution. It also provides supporting ecosystem services like nutrient cycling, soil formation, ecosystem resilience, mitigation of climate change as well as cultural services related to heritage, livestock assets and tourism. Water resources management for agro-ecosystem with a focus on ecosystem services will lead to environmental sustainability and resilience to climate change. Unfortunately, the eco-system services that water provides are generally over looked. An institutional mechanism needs to be put in place for Payment of Ecosystem Services (PES) so that their sustainable management in guaranteed.

NBS can serve the triple goals of augmenting water availability, improving water quality and also reduce the risks related to water. Nature based solutions are also central to achieving the UN defined 2030 SDGs and resilience because they lead to social, economic and environmental benefits inclusive of human health and livelihoods, food and energy security, sustainable growth, healthy ecosystem and biodiversity (Singh, 2019).

8.11 Issues

- Water use efficiency for surface water is low (30-40 per cent)
- The gap between the irrigation potential created and utilized is substantial (currently around 25 per cent) and widening
- Irrigation systems are supply driven and canal schedules rigid
- Supply/distribution of water is insufficient and unequal
- There is diversion of cultivable land for other purposes within the command area
- Poor O&M cost recovery

- Lack of adoption of water efficient technologies
- Inefficient use of water leading to water logging and secondary salinization
- Over exploitation of ground water
- Poor quality of ground water
- Sea water intrusion in coastal areas
- Climate extremes analysis including intra-seasonal rainfall variability and development of management practices
- Surface and sub-surface water management including customized solutions for rainwater management
- Innovations in upscaling in-situ soil and water management practices through convergence like MGNREGA
- Farm mechanization for coping with labour shortage
- Development of DSS for national and state level drought monitoring, agro-advisories and contingency planning.

8.12 Strategies

- There is need to close the gap between the Irrigation Potential Created and Utilized which now stands at more than 20 M ha
- The irrigation systems should be demand driven and not supply driven
- Emphasis should be on integrated and conjunctive use of rain, surface and ground waters
- Development of cost effective and ecofriendly technologies for sustainable high production of agricultural produce of competitive quality should receive top priority
- The extension agencies should be geared up for speedy transfer of improved technologies
- Incentives may be provided to the farmers for adopting efficient water use technologies
- Awareness has to be created among farmers about the value and scarcity of resources and negative fallouts of improper use
- Fine tuning of Furrow based irrigation systems (Raised beds) for different crops and soils
- Development of low cost pressurized irrigation systems. In spite of so much push by the GoI, the area under micro-irrigation was 8.63 mha as on 25.12.2016. Need to identify areas most suitable for micro-irrigation in the country
- Use of agrochemicals which enhance water (and nutrient) use efficiency

- Development of a regulatory mechanism for ground water resource development and utilization
- Use of modern tools for developing cultivars of higher water productivity and their applications for precision farming
- Institutional mechanism for full recovery of Operation & Maintenance costs through realistic pricing of water for different stakeholders. Water pricing should be managed scientifically. Water pricing should mean communicating water scarcity. In Australia,, price signals and effective water markets are seen as an essential part of improving the economic efficiency of water use and encouraging water users to adjust to changing climate conditions
- Multi disciplinary Participatory Management Approach for surface/ground water irrigated and rainfed areas
- Focus on multiple use of water through identification of cropping /farming systems which can enhance water productivity
- Planned waste water reuse with emphasis on peri-urban water use
- Focus on Bioremediation of waste waters
- Use of renewable energy eg. solar energy, for agricultural purposes
- Development of user-friendly Decision Support Systems (DSS) for real time decision making
- Public-Private-Partnership: For extending the watershed approach for development of natural resources in the drought prone areas by supporting the programme in scaling it up quickly as the complete coverage of the area by public funds may take considerable time; for investments in on-farm water harvesting; and in ICT which will enable small and marginal farmers to accesses weather based agro-advisories and market information through village kiosks
- Private sector can also help small and marginal farmers by bearing the part cost of the premium for weather insurance as well as providing support for establishment of community seed and fodder banks which help the farmers during natural calamities. This can be done in case of millets, pulses and other dryland crops where the private sector is not interested for supply of seeds because of low profitability.

UNESCO International Water Conference - 13 and 14 May 2019 on Leveraging the trans-sectoral management of water resources for sustainable water security and peace has the following objectivities:

- Bringing everyone around the table to discuss trans-sectoral approaches to the governance and management of water resources
- Launching a Call for Action to foster, embrace, and adopt trans-sectoral water management

- Sharing good practices enabling participation, transparency and information-sharing
- Evidencing of the importance of interdisciplinarity and the integration of sciences to support Member States in reaching the goals of the water-related international agendas.

8.13 Ministry of Jal Shakti

India took note of the global alarm bell on water security, and in its present term 2019-2024, the Government's spotlight is on water. It launched Jal Shakti Abhiyan – an intensive water conservation campaign built on citizens' participation. The focus is on integrated demand and supply-side management of water at local level – *viz* rainwater harvesting, ground water recharge, and management of household waste water for reuse.

The Government has further launched Jal Jeevan Mission, assuring piped water supply to all rural households by 2024. The current priority concerns are:

- Waste water
- Prevention of groundwater extraction
- Aquifer mapping program critical to raise groundwater levels
- Perennial rivers turning seasonal – a disturbing trend
- Ganga needs more than just cleaning
- Chennai water crisis: A wake up call for Indian cities.

Mission, Vision, and Functions of the newly formed Ministry of Jal Shakti, are as below:

8.13.1 Vision

Optimal sustainable development, maintenance of quality and efficient use of water resources to match with the growing demands on this precious natural resource of the country.

8.13.2 Mission

India is endowed with a rich and vast diversity of natural resources, water being one of them. Its development and management plays a vital role in agriculture production. Integrated water management is vital for poverty reduction, environmental sustenance and sustainable economic development. National Water Policy envisages that the water resources of the country should be developed and managed in an integrated manner.

8.13.3 Function

The Ministry of Water Resources is responsible for laying down policy guidelines and programmes for the development and regulation of country's water resources. The Ministry has been allocated the following functions:-

- Overall planning, policy formulation, coordination and guidance in the water resources sector.

- Technical guidance, scrutiny, clearance and monitoring of the irrigation, flood control and multi-purpose projects (major/medium)

- General infrastructural, technical and research support for development

- Providing special Central Financial Assistance for specific projects and assistance in obtaining External Finance from World Bank and other agencies

- Overall policy formulation, planning and guidance in respect of Minor Irrigation and Command Area Development, administration and monitoring of the Centrally Sponsored Schemes and promotion of Participatory Irrigation Management

- Overall planning for the development of Ground Water Resources, establishment of utilizable resources and formulation of policies for exploitation, overseeing of and support to State level activities in ground water development

- Formulation of national water development perspective and the determination of the water balance of different basins/sub-basins for consideration of possibilities of inter-basin transfers

- Coordination, mediation and facilitation in regard to the resolution of differences or disputes relating to Inter-State Rivers and in some instances overseeing of implementation of inter-state projects

- Operation of the central network for flood forecasting and warning on inter-state rivers, provision of central assistance for some State Schemes in special cases and preparation of flood control master plans for rivers Ganga and Brahmaputra

- Talks and negotiations with neighboring countries, with regard to river waters, water resources development projects and the operation of the Indus Water Treaty

- Ensure effective abatement of pollution and rejuvenation of the river Ganga by adopting a river basin approach to promote inter-sectoral co-ordination for comprehensive planning and management.

The Ministry of Jal Shakti being a multidepartmental and multidisciplinary Ministry is ideally suited to address multidirectional aspects of water, *viz.* Water as a major source of soil erosion and ecologically sustainable drainage of excessive water. The NAAS had brainstormed on “Mitigating Land Degradation due to Water Erosion” and “Biodrainage: An Eco-friendly Tool for Combating Waterlogging”. Soil erosion by water results in loss of 5.37 to 8.4 mt nutrients, reduction in crops productivity, occurrence of floods and drought, reduction in reservoirs capacity, and loss of biodiversity. Soil and Water conservation being inseparably linked, policies for mutually reinforcing these basic resources should be developed.

Towards meeting the above challenges, the NAAS had recommended that the catchment areas of our river basins urgently need integrated soil and water conservation measures following watershed approach by identifying site-specific best management practices to prevent irreversible loss of soil to oceans. Further, it had suggested that to economically justify the huge expenditure on soil conservation and watershed development programmes by Central and State Governments and to ensure greater accountability and transparency towards public investments, a clearly defined set of indicators is needed. Implementation of these indicators should be made mandatory as an integral component of Common Guidelines for Watershed Development Projects by Govt. of India.

While irrigation plays on important role in increasing agricultural productivity, introduction of canal irrigation in arid and semi-arid regions without provision of adequate drainage causes rise in water-table leading to waterlogging and secondary salinization. Though the problems of waterlogging and salinity can be effectively tackled by conventional engineering approaches like surface and sub-surface drainage (both horizontal and vertical), which have been standardized to rehabilitate the saline waterlogged lands, but their adoption on large scale is being hindered by very high capital investment, associated operational and maintenance problems in addition to suitable alternatives for disposing drainage waters. As an alternative the use of vegetation for managing waterlogging and salinity, often referred to as biodrainage, has been advocated. The biodrainage system consists of fast growing tree species, which absorb water from the capillary fringe located above the ground watertable.

This ecofriendly attractive approach of water drainage as suggested by NAAS, should be further researched to fill the following information gaps: evapo-transpiration capacity under varying subsoil water salinities; salt removal from the soil profile for reducing salinity of cropland, field crop and tree competition for water when watertable falls below safe limits creating additional demand for water in arid irrigated regions having overall water scarcity; competition between crop and trees for nutrients along the tree strips.

While the information gaps are filled, Agencies may be identified and entrusted with the task of undertaking biodrainage programmes at pilot scale at suitable sites as per guidelines, for demonstration, extension and acceptance among farmers.

Government intervention may be required in popularizing biodraining trees in and around the fields in canal command areas by way of providing quality planting materials, capacity building and minimal maintenance cost. In specific situations biodrainage may be integrated with traditional practices. Regular sensitization programs on biodrainage may be organized for creating awareness amongst the field functionaries of Departments of Irrigation, Forest, Water Resources, Agriculture, Command Area Development Programs, Water Management Institutions and Water User's Associations.

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Chapter 9
Soil Health and Nutrient Management*

9.1 Background

With an increased understanding of the fragility of natural resources and their inevitable role in meeting United Nation's Sustainable Development Goals (SDGs) and overall societal wellbeing, there is an increase in global concern on rejuvenation and improvement of the health of these invaluable resources. The health of Indian soils got deteriorated over the years due to depletion of organic matter levels, widespread multi-nutrient deficiencies, mining of native soil reserves owing to non-judicious fertilizer use, wide gap between nutrient demand and supply, lowering of factor productivity, and deterioration of soil physical and biological health. Besides, acidification, salinization, alkalization and waterlogging have also been contributing to deterioration of soil health. The challenge is much bigger in India, as it supports about 17 per cent of the global population through only 2 per cent of the world's geographical area and 2.4 per cent of the world's geographical arable land. The per capita land availability (land: man ratio) continuously decreased from 0.34 ha in 1951-52, to 0.14 ha in 2012-13, which is likely to come down further with the passage of time. About 86 per cent of the operational holdings belong to marginal and small categories with holding size <2 ha, and 67 per cent of the holdings are below 1 ha. As the need for marketable surplus is greater at smaller farms to get cash income, it would be imperative to enhance the productivity of marginal and small farmers through judicious soil management to enhance overall resource use efficiency. National Commission on Farmers in its Report mentioned *inter alia* that improving small farm productivity as a single development strategy can make a greater contribution to the elimination of hunger and poverty, and recognized soil health enhancement as a key to raising small farm productivity.

The National Academy of Agricultural Sciences (NAAS) has been organizing brainstorming sessions (BSS) from time to time on various issues pertaining to soil health and its management, and coming out with valuable recommendations. The key recommendations on different aspects, published by the Academy as Policy Papers/Strategy Papers/Policy Briefs and their implementation status are presented hereunder:

9.2 Residue Management

9.2.1 Recommendations

9.2.1.1 Crop residue management

Crop residue (CR) management remained a major problem for Indian farmers, especially in the cereal growing belts of Indo-Gangetic Plains (IGP). Out of various crops grown, CR burning is practiced in rice, wheat and sugarcane. A state-wise reliable estimate of CR burning should be made annually using the remote sensing techniques, to assess the loss of

* *Substantial input of Dr. B.S. Dwivedi in preparing this chapter is gratefully acknowledged*

quality residue and its impact on environment. Legislation should be developed on prevention and monitoring of on-farm CR burning through incentives and punishment. High capacity efficient machines for harvesting, baling, combining of straw, densification/compacting, handling and transport of CRs should be introduced and popularized. Based on the benefit: cost analysis, socio-economic and technical feasibility of recycling on-farm and off-farm CRs has to be worked out. The permissible quantity of residues of different crops should be quantified which can be incorporated/retained depending on cropping systems, soil and climate without creating operational problems.

9.2.1.2 Conservation agriculture

Conservation agriculture (CA) technologies need to be popularized through *Krishi Vigyan Kendras* (KVKs) and state departments of agriculture for creating awareness and dissemination at village level. Unemployed village youth should be encouraged to take-up operation of CA machinery as profession. Machinery for CA (Turbo Seeder, Happy Seeder *etc*.) should be supplied on subsidized rates, promoting custom hiring systems and providing soft loans for purchase of implements. Attachment of Super SMS (straw management systems) needs to be made mandatory for registration of all new combine harvesters. Since most farmers are small and marginal, purchase and owning Turbo/Happy Seeder and Super SMS by individual farmers is neither feasible nor desirable. There is a need to promote ‘Turbo Happy Seeder Technology Package’ led self-sustaining business models through cooperatives (agriculture service centres), private service providers, farmer groups, young entrepreneurs *etc*. Suitable policy environment needs to be devised to facilitate the agriculture service centers. Provision of carbon-credit to the farmers practicing CA should be introduced for effective carbon sequestration and greenhouse gas mitigation.

9.2.1.3 Utilization of biomass for energy generation

Procurement and custom operation of biomass management equipment should be promoted through financial incentives and training to the unemployed educated rural youth. Surplus crop and agro-processing residues should be stored for domestic and industrial uses for thermal application and generation of power. Vegetable market wastes should be used for biogas and FYM production, and also for domestic and industrial fuel. Biomass-based pilot plants should be established for decentralized power generation in the catchments to meet the power needs of agricultural fields and rural households. Mechanized composting should be promoted. Standards for good quality compost need to be formulated and popularized. Briquetting of crop and agro-processing wastes should be promoted in rural areas. Use of these briquettes as domestic fuels should be promoted to curb down the requirement of firewood and minimize felling of trees.

9.2.2 Implementation Status

In order to prevent CR burning, Government invoked Section 144 of the Civil Procedure Code (CPC), but it could hardly be implemented, and there is petite effort to sensitize farmers on the concern. A National Policy for Management of Crop Residue (NPMCR) has also been formulated and disseminated to all the States for implementation to ensure prevention of CR burning by providing incentives on the purchase of modern machinery to minimize leftover CR in the field, multiple uses of CR and preparation of fodder pellets and briquettes for gasification. The following legal frameworks are there to regulate the pollution: (i) Air Prevention and Control of Pollution Act, 1981; (ii) Environment Protection Act, 1986; (iii) Environment (Protection) Rules, 1986; (iv) National Environment Tribunal Act, 1995; and (v) National Environment Appellate Authority Act, 1997.

Conservation agriculture is a production system involving minimum soil disturbance, soil cover through crop residues or other cover crops and crop rotations for achieving high productivity with most efficient resource use. Globally CA is estimated to be practiced over an area of 124.8 mha, of which India contributes about 1.5 mha only. Crop residues have been effectively and meaningfully utilized in CA. Use of residues in CA has potential to enhance soil quality through improvement in SOC content and other soil parameters.

To subsidize machinery required for *in situ* management of CR, a new Central Sector Scheme on 'Promotion of Agricultural Mechanization for *in situ* Management of Crop Residue in the States of Punjab, Haryana, Uttar Pradesh and NCT of Delhi' for the period from 2018-19 to 2019-20 has been approved with the following objectives:

(i) Protecting environment from air pollution and preventing loss of nutrients and soil micro-organisms caused by burning of CR

(ii) Promoting *in situ* management of CR by retention and incorporation into the soil through the use of appropriate mechanization inputs

(iii) Promoting Farm Machinery Banks for custom hiring of *in situ* CR management machinery to offset the adverse economies of scale arising due to small landholding and high cost of individual ownership

(iv) Creating awareness among stakeholders through demonstration, capacity building activities and differentiated information, education and communication strategies for effective utilization and management of CR.

Most importantly, it is the self-realization of the communities and people to protect the environment for their own protection and healthy living. Despite the various measures and restrictions imposed, Times of India, October 26, 2019 reported in bold lines "Crack Down on Farm Fires in next 3 Weeks: PMO to States – Focus to be on 13 Hotspots of Stubble Burning" (identified through satellite images in Punjab & Haryana). The states have been asked to take all possible measures to reduce stubble burning. Between October 1 and 24, the trend was similar to that during 2018. On October 23, as per NASA data, in Punjab 919 fire counts were detected.

National Centre of Organic Farming (NCOF) developed a 'Waste Decomposer' for quick composting of organic waste, soil health improvement and as plant protection agent. This microbial consortium comprises microbial strains isolated from dung of indigenous cow. The

Waste Decomposer is sold to the farmers directly through NCOF and Regional Organic Farming Centres (RCOF). ICAR-IARI and several other R&D institutions also brought out microbial formulations to facilitate faster decomposition of CRs and biodegradable wastes and produce quality compost.

9.3 Reclamation of Degraded and Polluted Soils

9.3.1 Recommendations

9.3.1.1 Management of problem soils

Different technological options available for amelioration of problem soils must be inter-woven. Improved and economical technologies have to be developed for reclamation of waterlogged sodic soils. A National Acid Soil Management Authority needs to be established for implementation of different acid soil management programs across the country in a coordinated manner. Extent and severity of sub-soil acidity should be delineated across the country and suitable corrective measures should be taken-up. The harmonized district-wise database on types and degree of soil acidity and acreage available with NARS should be used by State Governments for planning amelioration strategies. Research emphasis needs to be given on efficient phosphate management and breeding programmes to modify root characteristics for mitigating the problem of Al-toxicity and nutrient deficiencies in acid soils. Physiological and molecular interventions should be made to develop high tolerance of plants towards Al-toxicity. Also, there is need to explore and utilize microbial diversity in acid soils. Conservation irrigation needs to be promoted for enhancement of water and nutrient use efficiencies in these soils. A supply chain should be developed to ensure availability of phosphate rock and low cost liming materials in these regions. Policy needs to be framed for judicious utilization of large lime reserves in NEH states. Strategies and policies are required to encourage the use of soil amendments like gypsum, lime and other alternative sources to ameliorate and enhance the productivity of problem soils. The critical aspects such as transport facility and incentives for use of these amendments need special attention.

As nearly one-third of the land area is under degraded and wasteland categories, there is a need for a precise and periodic assessment of the nature, magnitude and extent of soil and land degradation through rapid inventory using appropriate tools and techniques involving agencies like National Remote Sensing Centre (NRSC), ICAR, national and state soil survey organizations, with particular reference to cultivated lands for their effective rehabilitation and updated every three to five years.

9.3.1.2 Soil conservation

In order to protect the top soil, there should be minimum migration of soil out of a given field/catchment area. Universal Soil Loss Equation models have to be used to assess the extent of soil erosion, soil and water resource conservation and non-point source pollution assessments. Use of satellite data and fuzzy logic models are also useful in diagnosing and controlling erosion and related soil degradation processes. Emphasis is needed on rain water management focusing on maximum water retention in the soil profile, groundwater recharge, and water harvesting by controlling run-off water along with appropriate drainage.

Inclusion of water harvesting along with specific amendment materials has the great potential of reclaiming problem soils. Implementation of technologies to arrest water and wind erosion developed by the ICAR Institutes and State Agricultural Universities may be reviewed and strengthened. Special package involving multi-sectoral interventions may be implemented for minimizing degradation and rejuvenation of ravine, waterlogged, coastal saline, riverine *diara* lands and mining areas. The Himalayan region needs greater attention, as the loss of soil, water, property, human and animal wealth is now taking place at an accelerated pace in this ecologically fragile region. It is essential to ensure minimal landform/landscape disturbance to reduce land degradation in this region. In areas where *jhum* cultivation is prevalent, alternate models of land ownership at community level and integrated models of land use as evolved and demonstrated by ICAR may be encouraged, with suitable incentives, for their adoption at community level to ensure livelihood security and sustainability of the fragile ecosystem.

9.3.1.3 Soil pollution and risk assessment

Thorough diagnosis and detailed risk assessment should be performed for the sites contaminated with toxic heavy metals, inorganic compounds and persistent organic pollutants. Based on risk review, integrated soil management options can be developed for minimizing threat to soil quality and to human and animals. Research on soil-plant-animal/human continuum in different agro-climatic zones with reference to heavy metals and other pollutants needs to be strengthened to assess the extent of pollution and for safeguarding the animal and human health. In fact, a national-level Soil Protection Policy may be formulated to regulate the entry of pollutants to soil. The policy framework regulations must be binding to all enterprises and government agencies engaged in the professions and the services affecting soil environment. Safe disposal of municipal wastes and industrial effluents should strictly be followed.

9.3.1.4 Protecting prime agricultural lands

It is high time that land use policy be framed to save productive lands being transferred for purposes other than agriculture. There is need to earmark areas not suitable for farming, so as to facilitate their utilization as agroforestry/forestry/range lands. Inter-ministerial dialogue at central level is needed to devise effective policy guidelines regarding use of fertile lands. A Land Reclamation Board may be set-up to facilitate monitoring of programmes related to reclamation of degraded soils by mobilizing necessary resources and agencies. The Board may also initiate proactive measures from preventing risks from pollution. Clear demarcation of biosphere reserves, production forests, community lands, urban green belt and special agricultural zones/ potentially efficient crop zones must be made using geo-spatial techniques. The land use survey organization should use district or even taluka level geo-spatial data to suggest most appropriate land use and allocation. Prime agricultural lands with high carrying capacity, perennial orchards/plantations, parks and similar green spaces within urban limits may be demarcated and regulated against diversion. Further, incentivizing policies for setting up industries in marginal lands will be helpful to achieve the above objective, as strongly emphasized by the National Commission on Farmers (2004 to 2006).

9.3.2 Implementation Status

The estimates of area under degraded lands as given by different agencies have been harmonized, and acceptable statistics of 120.72 mha is provided. Subsequently, ICAR institutes namely CSSRI, Karnal, IISWC, Dehradun and CAZRI, Jodhpur developed large number of technologies to curb/manage soil degradation and improve productivity of degraded soils.

The erstwhile Planning Commission constituted a Working Group of Sub-Committee of the National Development Council (NDC) on agriculture and related issues on dryland/ rainfed farming system including regeneration of degraded waste land, watershed development programme under the Chairmanship of Chief Minister, Government of Gujarat to suggest various steps to be taken for effective utilization of natural resources especially in rainfed areas including measures/programmes for land resource development, requirement of funds and also the area to be covered under the programmes of various Ministries/Departments as well as the State Governments. The Committee in its report recommended for formulation of a Centrally Sponsored Scheme for Reclamation of Problem Soils during XI Plan with enhanced unit costs and Government of India's assistance. For acid soils, periodic liming at 2-4 t/ha has been considered effective in ameliorating acidity. Subsequent studies, however, revealed the superiority of furrow applications of liming materials over broadcasting. Thus, furrow placement of lime at the rate of 10 per cent to 20 per cent of lime requirement (LR), which amounts to around 200 to 500 kg ha^{-1} to each crop, is as effective as one-time application of entire LR.

It is interesting to note that the area under non-agricultural uses increased by about 10 mha since 1970-71, whereas that under barren and uncultivated lands declined by about 10 mha during this period. The often overlooked fact behind almost stagnant net-cultivated area (~140 mha) is significant diversion of prime agricultural lands for non-agricultural purposes and simultaneous induction of barren and uncultivable lands. As these new lands being inducted to croplands are extremely poor in terms of fertility status and overall health, a careful monitoring and management is obviously needed to make them productive and economically remunaretive. At the same time, we must desist from divering price agricultural land to non-agricultural uses.

9.4 Monitoring Soil Health

9.4.1 Recommendation

9.4.1.1 Soil quality assessment

Soil quality should be assessed, along with development of soil quality index and periodic monitoring through identification of minimum data set under different agro-ecosystems and models be developed for predicting the impact of management practices on soil quality under different climate change scenarios. A real-time dynamic national database centre, may be created to enable access to soil health data by the stakeholders. This centre may be linked to all research institutions and soil testing laboratories. Requisite search engines and robust online platform for data acquisition, storage and retrieval may be in-built within this architecture. A web portal for National NRM Systems has been operationalized by Indian Space Research Organization. It must become a one stop-shop for all information.

9.4.1.2 Revamping soil testing services

In order to maintain the quality and authenticity of soil test reports, there has to be a strong monitoring mechanism for cross- checking or referencing of soil test data so as to enhance their worth and acceptability. For this some reference laboratories need to be identified and strengthened. All soil testing laboratories (STL) especially district and regional laboratories in the country should be well-equipped for the analysis of available macro and micronutrients and quality of irrigation water – the foremost recommendation in the NAAS Policy Paper 35, 2006. Soil testing should include plant tissue testing also to provide advisory service for general as well as for specialized farming including horticulture, floriculture and plantation crops. Qualified and trained staff should be appointed in STL. Training and updating of the staff of STL should be a regular feature. It is vital to ensure that the information contained in Soil Health Card is not only conveyed to the farmers appropriately but also put into practice. A national roadmap needs to be framed for revamping the existing STLs, including mobile laboratories for efficient, rapid and reliable soil quality assessment. Sub-soil contributes considerably towards meeting nutrient needs of plants. However, soil testing is done only for surface soils. It is suggested that the nutrient resources in soil profile up to a depth of 1.5 m should be monitored periodically and their share in meeting the nutrient needs of a crop be determined.

9.4.1.3 Monitoring SOC changes and GHG emission

The "4‰ (4 per 1000) initiative" launched in 2015 during the 21st Conference of the Parties (COP21, Paris) to the United Nations Framework Convention on Climate Change (UNFCCC) aims to increase SOC by 0.4 per cent per year in the top 30-40 cm of agricultural soils. With this initiative, agriculture takes centre stage in combating climate change. This small increase in SOC of only 4‰ can totally nullify the ever-increasing CO_2 emissions, besides improving soil health and contributing to food security.

There is need to generate verifiable soil baseline data for SOC under agroforestry, grass-lands and arable agriculture. Government may provide proper financial and infrastructure facility to generate, document and store data on carbon stocks. A national network for resourcing organic residues such as CRs, various forms of composts, urban wastes *etc*. may be created. A 'National Mission on Soil Carbon Improvement' should be launched in order to improve organic carbon status of soils, and for adaptation/mitigation of climate change. In view of India's climate pledge (COP 21, Paris, 2015), GHG emission intensity has to be reduced by 33-35 per cent of 2005 level by 2030. This demands creation of additional carbon sink of 2.5-3 billion tonnes of CO_2 equivalent by 2030. Hence, particular emphasis be given to programmes related to agro-forestry, efficient recycling of CRs and CA supported by desired mechanization and community-based mechanized composting. There is need to have an institutional mechanism in place for Payment of Ecosystem Services (PES) that soil provides through adoption of BMPs.

9.4.2 Implementation Status

The National Commission of Farmers laid great emphasis on strengthening soil testing services, suggesting need to establish at least 1000 STLs. The STL network, therefore, expanded over the years and currently therefore some 1586 STLs (1232 static labs + 354 mobile labs) exist in different parts of the country. Besides, a large number of digital soil testing kits, called minilabs, have also been added to support the soil testing service. Many of the state STLs are equipped with micronutrient analysis facility.

In recent years, the biggest initiative by the Government so far with respect to soil health assessment and maintenance is the Soil Health Card (SHC) Scheme launched during 2015. The Scheme envisages to issue to the farmers SHCs, which provides crop-wise fertilizer recommendations for individual farms, besides soil test results, to improve crop productivity through judicious use of inputs. Under this Scheme, geo-referenced soil samples are to be collected at a uniform grid of 2.5 ha in irrigated areas and 10 ha in rainfed areas. The SHC would include analysis of 12 soil parameters *viz*., pH, EC, SOC, available primary nutrients (N, P, K), available S, and available micronutrients (Zn, Fe, Cu, Mn, B). The SHCs are to be provided to farmers at an interval of two years. First cycle of issuing the SHCs has already been completed, and the second one is continuing.The efficacy of the SHCs has so far been unsatisfactory and the process needs revamping and effective monitoring and evaluation.

9.5 Nutrient Management

9.5.1 Recommendations

9.5.1.1 Balanced fertilization

Site-specific fertilizer application practices (SSFAP) based on soil-test recommendations and integrated plant nutrient supply (IPNS), involving FYM, compost, vermicompost, green manures, dual purpose legumes (e.g. summer mung in rice-wheat cropping system) and biofertilizers, need to be developed for various crops and cropping systems including agroforestry systems, integrated farming, orchards and peri-urban-agricultural systems in different agro-ecological zones of the country. The current gap between annual drain of nutrients from the soil and inputs from external sources is 10 million tonnes, which has to be bridged as far as possible to minimize nutrient mining from soil reserves. Availability of fertilizers on time still remains a problem in several parts of the country, which necessitates a relook at existing mechanism of fertilizer distribution. Studies suggested the possibility of curtailing fertilizer N and P application rates in wheat under permanent raised-bed (PRB) planting compared with conventional flat-bed planting owing to greater nutrient use efficiency (NUE) and better crop establishment in the former case. Thus, fertilizer prescriptions for PRB planting and other CA-based systems need to be developed through systematically planned multi-location studies.

9.5.1.2 Organic manure and biofertilizers

Technologies need to be refined and popularized for enrichment of bulky organic sources. Intensive research using biotechnology and other emerging frontier sciences is needed to develop more efficient biofertilizers. Isolation of effective strains tolerant to high temperature, drought, acidity and other abiotic stresses is of high priority. Emphasis is needed on development of newer formulations of biofertilizers, microbial consortia, improvement of inoculant quality and devising effective delivery systems are crucial. Greater emphasis is needed to improve field level efficiency of PSB, VAM *etc*. particularly in soils of different pH. Creating awareness and doorstep availability of quality biofertilizers at an affordable price would popularize their use. Location-specific technologies and strategies need to be developed for different agro-ecologies for growing of green manure crops depending on availability of water, labour, seed and time available in the cropping systems.

Efficient utilization of organic manures, integration of crop and livestock-production systems, promotion of biogas plants and improving their efficiency, and enriched composting may receive greater attention of R&D institutions and concerned Government departments. Fertilizer equivalents of different manures need to be worked out based on crop response to organics *vis-a-vis* fertilizers, so as to suggest more rational IPNS packages for crops and cropping systems.

9.5.1.3 Nutrient-water interactions

Considerable amounts of plant nutrients (N, K and S) may be added through irrigation water, especially groundwater. Estimates of such amounts of plant nutrients will not only help in determining more realistic balance sheets but also in curtailing fertilizer input through increasing the efficiency of plant nutrients. For high yields, water and nutrient use efficiency, attempts should be made to optimize fertilizer rates in relation to the quality and quantity of irrigation water.

9.5.1.4 N management

Excessive use of N fertilizers is a serious concern in many high productivity zones practicing rice-based systems. Efficient N management can contribute to curtailing the leakages of N to the environment and at the same time make fertilizer N application more cost-effective. Precision N management approaches using tools like leaf color chart, which rationalize fertilizer use, must be standardized and adopted on large scale. Also, N management protocols should be developed for CA-based cropping systems. Use of urea super granules (USG) and nitrification inhibitors based on neem products which improve N use efficiency, needs to be popularized. Possibilities of inclusion of legumes in cropping systems need to be explored to tap the benefits of biological nitrogen fixation (BNF). The vast potential of BNF has remained unrealized at the farmers' level due to many reasons and needs to be looked into holistically in agricultural production systems. Development of N-efficient cultivars could help decrease fertilizer N inputs and minimize reactive N losses to the environment.

9.5.1.5 P management

The P use efficiency (PUE) continues to be extremely low (15-20 per cent). A continuous build-up in soil P status has been recorded in intensively cropped areas, owing to regular use of P fertilizers to all crops irrespective of soil test values. These P-rich soils can possibly be "mined" through biological P mobilization. Accounts of residual P in cropping systems should be studied extensively, especially in the long-term, and recommendations be evolved for biological mobilization of sparingly soluble P accumulated in the rhizosphere. Application of P on the basis of cropping sequence instead of individual crop needs to be considered for improving PUE. Developing precision P placement techniques, heavy initial application of rock phosphates (RPs), use of nano-RP, state-of-art controlled release P fertilizers and breeding P-efficient cultivars would go a long way to enhance PUE. Also there is need to develop suitable strategies for P management in rainfed crops, for basal application of P fertilizers in these regions are often risky owing to failure of crops at later stages on account of long dry spells. Role of chemically and biologically synthesized nano-P for better mobilization of native soil P and higher PUE needs to be studied. The P inputs to surface water have increased because of intensive livestock grazing and the combined manure and fertilizer inputs in excess of crop requirement that led to a build-up of soil P levels. Threshold soil P levels that guide manure applications should be linked with site vulnerability to P loss.

To use low grade rock-phosphates, a new policy is required for the direct use of indigenous reactive rock phosphates under certain soil and crop conditions. Availability of modified RP products *viz*., acidulated RPs, SSP-RP mixture, Pyrite-RP mixtures, PSB-RP mixtures, compacted RPs *etc*. should be enhanced in Indian market, and subsequently popularized among farmers. There is an urgent need to popularize phospho-composting technology. Making low grade RPs available to the composting units and to the farmers at cheaper price is the need of the hour. There should be a technical discussion within the researcher - fertilizer industry- policy makers-extension agency interface, so that bottlenecks of non-availability of RP in the market could be discussed.

9.5.1.6 K and other nutrients

The present method of determining available K in soils is not adequate to predict K supplying capacity of soil. It is, therefore, desirable to have an estimate of non-exchangeable K (NEK) in a soil. There is a gap between the 'K-release threshold level' and 'K-fixation threshold level' in soil, the latter being generally higher. A judicious K management practice should maintain the exchangeable K level in soil at an optimum intermediate between these two thresholds. Farmers' fertilizer use is often skewed towards N and P ignoring K. As a result, constant K mining even started exhibiting distortion of soil clay mineralogical make-up, which is quite disturbing and irreversible deterioration of soil health. In order to minimize S mining from soil, use of S fertilizers and industrial by-products such as phosphogypsum and press mud need to be encouraged and incentivized. The micronutrient deficiency has grown rapidly over the years both in extent and intensity, although reliable statistics on the amount of micronutrients being used in different states is lacking. Whereas efforts are needed to make available reliable data about micronutrient requirement and use, equally important is to ensure timely availability of necessary micronutrient fertilizers at farmers' doorstep.

9.5.1.7 Enhancing farmers' awareness

Extension machinery needs to be geared-up and rejuvenated for popularizing soil-test based fertilizer recommendations, time and method of fertilizer application, role of secondary and micronutrients in human and animal health, importance of organic manures, biofertilizers, IPNS *etc*. Farmers' awareness on K fertilization should, therefore, be imposed through potential programmes in mass media and popular literature. There is still a larger exploitable yield gap in most of the crops as evidenced by nationwide frontline demonstrations. Greater efforts on bridging this gap with Best Management Practices (BMPs) and their effective transfer to farmers are critical to achieve the production targets in the wake of shrinking land and water resources.

9.5.2 Implementation Status

The National Mission for Sustainable Agriculture (NMSA) has been implemented with the objectives to make agriculture more productive, sustainable and climate resilient; to conserve natural resources; to adopt comprehensive soil health management practices; to optimize utilization of water resources; etc. 'Soil Health Management (SHM)' remained one of the most important interventions under NMSA. It aims at promoting IPNS through judicious use of fertilizers including secondary and micronutrients in conjunction with organic manures and biofertilizers for improving soil health and productivity.

Analysis of soil samples collected from agriculturally-important agro-ecological sub-regions (AESRs) indicated widespread multi-nutrient deficiency involving 2 to 6 nutrients *viz*, NK, NKS, NKB, NPKS, NKSZn and NPKSZnB. Recently AICRP on Secondary and Micronutrients and Pollutant Elements brought out an e-Atlas containing taluka-wise maps on micronutrient status in soils using geo-referenced data generated under the AICRP and other projects to improve understanding regarding micronutrient problems in the country and help devising appropriate options for amelioration of the deficient soils. Incidence and expansion of such multi-nutrient deficiencies in Indian soils owing to inadequate and unbalanced nutrient input through fertilizers is considered one of the major constraints in enhancing and sustaining crop productivity.

Long-term studies undertaken in different soil-crop environments established the benefits of IPNS involving use of organic and biological resources along with fertilizers. The integrated use of green manures, organic manures and fertilizers under pre-dominant cropping systems showed great potential to curtail fertilizer requirements, achieve maximum economic yields and sustain crop productivity on long-term basis. Adoption of IPNS either helped curtailing fertilizer rates or enhanced productivity levels at recommended fertilizer input. Unfortunately, IPNS studies are often restricted to measurement of yield, nutrient uptake/NUE and soil parameters, ignoring economic impact. Nonetheless, sporadic studies involving computation of economic returns gave mixed results, rather than suggesting superiority of IPNS over sole fertilizer application in terms of net income and B:C ratio in different cropping systems.

Multi-location studies with intensive cropping systems *viz*., rice-wheat, rice-maize, pearl millet-wheat, pearl millet-mustard, and sugarcane-based systems underlined the superiority of site-specific nutrient management (SSNM) as against general fertilizer recommendations or farmers' fertilizer practice (FFP). The SSNM improved nutrient use efficiency and economic returns over FFP. In rice-wheat cropping system, it was possible to attain 14-16 t ha^{-1} annual grain productivity along with significantly greater economic returns with the adoption of SSNM *vis-à-vis* other options at different locations.

9.6 Fertilizer Policies

9.6.1 Recommendations

The process of approving, pricing and incorporation in Fertilizer (Control) Order by Govt. of India for Value Added Fertilizers (VAF) needs to be accelerated. An All-India Centre for R&D on fertilizer materials may be established without any further delay, which would be responsible for development, testing, quality control, and advisory services. Fertilizer policies need to be oriented towards ensuring balanced nutrition to major crops through nutrient-based subsidy (NBS), micro-nutrient-fortified fertilizers and soil test-based SSNM. Reforms in NBS policy is needed to correct highly skewed the N: P: K consumption ratio in some states with emphasis to narrow down N: P: K ratio to 4:2:1. A research cess on fertilizers could be levied, and funds thus generated be utilized for R&D in the area of enhancing fertilizer use efficiency.

There is need to strengthen fertilizer-product research. Low-cost indigenous nitrification inhibitors and nano-VAFs should be developed. Incentives may be provided to the fertilizer manufacturers opting for the manufacture of VAFs such as neem-coated urea, sulphur coated urea, *etc*. Collaboration should be strengthened between the fertilizer industry and National Institutes engaged in developing soil test-based and site-specific nutrient recommendations to develop soil and crop-specific quality fertilizers. Customized fertilizer grades based on soil-test-crop response studies for different crops and regions are to be developed and promoted. Equally important is a focused R&D. Research is needed on the use of water soluble and liquid fertilizers especially in horticultural crops.

Urea constitutes about 82 per cent of the fertilizer N used in India. Neem-oil when applied as nitrification inhibitor along with urea reduces loss of applied N, thereby increasing N use efficiency and controlling N_2O emission. In early 1970s, investigations at Indian Agricultural Research Institute (IARI) suggested the technology of neem-oil coating of urea for slowing down nitrification rate and thus curtailing the losses of applied N fron soil.

9.6.2 Implementation Status

At present, India is the 2nd largest consumer and producer of fertilizers in the world. Chemical fertilizers have been one of the key inputs responsible for enhancing crop productivity and driving the country towards self-sufficiency in food production. Despite tremendous growth in fertilizer consumption in recent past, the nutrient demand of crops could not be met through fertilizers alone. In fact, an annual demand-supply gap of about 10 Mt persists, suggesting excessive mining of soils' native reserves. The pace of nutrient mining from soil gets further aggravated due to imbalanced use of fertilizers as the fertilizer consumption is skewed towards N and P. With the fractured implementation of NBS during 2010 (keeping urea out of ambit of NBS), the P and K fertilizers became costlier rendering their decreased consumption. As a result, fertilizer consumption ratio (N: P_2O_5: K_2O) widened from 4:3.2:1 (2009-10) to 7.2: 2.9: 1 (2015-16).

In response to the commendable initiative of Hon'ble Prime Minister for mass adoption of the neem-oil coating technology, Government of India brought a fertilizer policy in 2015 wherein entire urea (domestic as well as imported) has to be essentially coated with neem-oil. Implementation of this policy not only helped curtailing its' usage due to higher use efficiency but also controlled diversion of urea (highly subsidized for farmers) to the non-agricultural purposes. According to Fertilizer Control Order (2017), minimum coating of 350 mg neem-oil kg^{-1} urea should be there for commercial production of neem-oil coated urea (NOCU). However, efficacy of such a low concentration of neem-oil coating for enhancing N use efficiency and curtailing N_2O emission needs to be studied extensively under diverse farming situations.

Prime Minister made a call to curtail the use of urea to one-half by 2022. Serious R&D efforts along with apt policy framework are needed to meet this target, through appropriate substitutes as well as novel products without hurting the much needed TFP growth. Bringing urea under NBS may help to discourage its over-use by farmers in some intensive cropping systems.

The deficiency of secondary and micronutrients can be overcome to a great extent by fortification of the presently manufactured N/P/NP/NPK fertilizers. Use of micronutrients at recommended rates and quality of micronutrient fertilizers has to be ensured.

9.7 Organic Farming

9.7.1 Recommendations

Organic farming is a market demand-driven agriculture, aimed to cater to the foreign export and affluent section of the society in the country. However, in order to make a dent in the export market, there is need to develop high-tech organic farming technology with strict quality control, meeting international quality standards. Niche areas and crops for organic farming need to be identified, although the real niches will be determined by the market infrastructure and international linkages/demands. The practice of organic farming considered for lesser endowed regions rather than intensively cropped regions which serve as the backbone of the country's food security. Thus, farming along the entire value chain may be strengthened and promoted in rainfed and hilly tracts, tribal areas, and north-eastern region with low productivity and low/negligible usage of agro-chemicals, for chosen crops and commodities where the country has comparative market advantage. There is need to promote strong research back-up to develop national standards for organic certifications coherent with international protocols.

Organic farming should not be confined to the age old practice of using cattle dung, and other inputs of organic/biological origin, but an emphasis needs to be laid on the soil and crop management practices that enhance the population and efficiency of below-ground soil biodiversity to improve nutrient availability. Performance of cultural techniques for weed control and that of biopesticides for pest management need to be evaluated under field conditions, preferably under cultivators' management conditions. Besides the identification of regions suitable for the adoption of organic farming, the crops and their products should also be identified which are amenable for production through organic ways and have the potential to fetch a premium price in the international organic market.

Region-specific resource inventory, including animal wealth, farm residues/by-products and their competitive uses, non-conventional nutrient sources of organic/biological origin *etc*., needs to be prepared for development of rational technology packages of organic farming. A strong technological back-up by scientific community should be provided in order to verify, confirm and further refine some selected ITKs (like Agnihotra, Panchgavya *etc*.) pertaining to organic farming. Crop-specific and farming situation-specific package of practices for organic cultivation should be developed and after thorough on-farm validation, recommended for adoption. Such proven technology packages need to be documented in regional languages.

9.7.2 Implementation Status

At present, the total area under organic farming in India is estimated at 2.6 mha. The compound growth rate (CGR) of organic farming area remained 11.5 per cent, of which wild collection was 12.6 per cent and remaining area 7.45 per cent during 2005-2013. The CGR of export of organic products was 51.5 per cent and export value 11.8 per cent during 2002-03 to 2013-14. The prices of organic products are often greater than the conventional products in domestic markets. India exports around 135 organic products. The share of oil crops in total organic export quantity was highest (26.7 per cent) followed by cotton (24.5 per cent), and basmati rice (11.8 per cent) during 2013-14. India exports organic products to all the continents, though the largest share goes to EU (44.1 per cent), followed by USA (19.2 per cent).

The Government has been promoting organic farming in a big way through two centrally sponsored Schemes namely '*Paramparagat Krishi Vikas Yojona* (PKVY)' and 'Mission on Value Chain Development for North Eastern Region (MOVCDNER)'. Whereas, PKVY envisages establishment of organic farming clusters of 50 acres each in different states, MOVCDNER takes care of developing entire value chain of organic production in the NE region, involving input supply, production, aggregation of produce, packaging, branding and marketing. Under PKVY, an indigenous organic certification protocol named 'Participatory Guarantee Scheme (PGS)' has been developed and adopted for domestic certification.

The above notwithstanding, the current status of Organic Agriculture in Sikkim, the first state in India to become totally organic in 2016, while was also declared by UN as the world's first 100 per cent Organic State is not as rosy. The Sunday Guradian, 24-30, June 2018 article "Sikkim Organic Farming Delusions" by Ganeshan and Nair give a different story. They have reported that the staple that in the last 20 years, the staple food productions declined by 60 per cent while the population increased from 4 lakhs to 6.5 lakhs during this period. This excludes the tourist flow which has its own food requirement. Data also indicates that Sikkim produced 5,400 tonnes of cardamom in 2004 which reduced to 4,000 tonnes in 2015. In 2016-17 India imported 3,120 tonnes of this commodity from Nepal. The data presented above should be an eye opener to all stakeholders who are concerned with India's food security which was attained with a sound scientific and technological approach rather than anything else.

9.8 Zero Budget Natural Farming (ZBNF)

Experimented developed and advocated by Mr. Palekar in Karnataka during late 1990s to 2010, ZBNF is described as a farming system based only on Nature with no purchased inputs, no loans, no credit, and without chemicals. This cow-based natural farming practice has been institutionalized in Andhra Pradesh – APZBNF, and is based on four pillars Bijamrita (seed treatment using local cowdung and cow urine), Jiwamrita (applying inoculation made of local cowdung and cow urine without any fertilizers and pesticides), Mulching (activities to ensure favorable microclimate in the soil), and Waaphasa (soil aeration, soil enrichment, soil water retention). This process and social movement is seen as an agro-ecological movement, and the farmer field school system of extension, training and technology transfer was followed, and the technology was to be adopted in a progressive manner. AP data showed that ZBNF had enhanced cotton yield by 11 per cent, paddy yield by 12 per cent, groundnut yield by 23 per cent, and chilli yield by 34 per cent, reduced (more than halved) cost of inputs and greater efficiency of production had significantly increased farmers' income, besides the ecological ecosystem improvement. On the other hand, several reviews conclude that the claims of ZBNF are questionable and need scientific validation. It is, therefore, premature to recommend its wide-spread adoption which may lead to massive damage to the hard-earned knowledge and benefits of agricultural R&D over the last 70 years.

As such, without consultation with ICAR and the Department of Agriculture, NITI Aayog is promoting ZBNF, and the approach was mentioned even in the 2019 Budget speech/document stating that “steps such as this can help in doubling farmers’ income” The move to turn Andhra Pradesh into world’s 1st natural farming state is estimated to cost rupees 17,000 crores (equivalent to 2.3 billion US $) and is to be raised as loan based on state guarantee. ‘Azim Premji Philanthropic Initiative’ has already extended a rupees 100 crore grant for this purpose.

NAAS must critically examine the scientific legitimacy and authenticity of the movement and provide scientifically evidenced guidance and way forward. To begin with, the NAAS chapter in Hyderabad in close collaboration with Hyderabad – based ICAR institutions – NAARM, MANAGE, CRIDA, Rice Project, SAUs and others, must undertake transparent analyses and come up with solidly researched facts and scope of adoption of ZBNF.

While ICAR has already initiated experiments and is further moving towards studying the impact of ZBNF, there has been no hard evidence from the ground suggesting the efficacy of the techniques. In fact, the results of the first year experiments undertaken by the Farming Systems Institute, Modipuram, Meerut were all negative. All case studies are self-reported and there have been no scientific tests of the products as well. It would be a more effective move to have ICAR scientifically assess the model before the renewed and announced focus on the methodology. Regarding wide adoption of ZBNF, Prof. Ramesh Chand, Member NITI Aayog has said “There is no scientific evidence till now on the results of zero budget farming. We will first assess the report, which ICAR will be submitting, before reaching to any conclusion,” But, the NITI Aayog seems to be in a hurry to nationally adopt ZBNF. Hopefully the Member will prevail over the system to accept only scientifically proven approaches.

9.9 NAAS Policy Brief 3 – Soil Health: New Policy Initiatives for Farmers’ Welfare

This recent, 2018, NAAS Policy Brief lists implementable new policy recommendations, suggesting possible solutions to several of the above issues, as reproduced below:

1. Implementation of technologies to arrest water and wind erosion developed by the ICAR Institutes and State Agricultural Universities may be reviewed and strengthened. Focused attention has to be given to the Himalayan region where loss of soil, water, property, human and animal wealth is now taking place at an alarming and accelerated rate

2. It is high time that land use policy in the country is framed to save productive lands being transferred for purposes other than agriculture. The farmers then will have the option to decide crops and cropping patterns keeping in mind the safe water availability, land capability, resources available with him, socio-economic conditions and demand driven

market to avoid gluts and sudden fall in prices. This may also eliminate the practice of fixing minimum support price (MSP) of the commodity by the government

3. Soil Health Mission introduced by Govt. of India to provide soil health card to each and every farmer is a timely and welcome step. The Govt. of India has invested heavily in its Soil Health Mission and it is estimated that 120 million Soil Health Cards have been distributed. The most important aspect is that it would be a continued exercise repeated every two years. In order to maintain the quality and authenticity of soil test values, there has to be a strong monitoring mechanism for cross- checking or referencing of soil testing data so as to make the programme viable. For this some reference laboratories need to be identified and strengthened. All soil testing laboratories (STL's) especially district and regional laboratories in the country should be well equipped for the analysis of available macro and micronutrients and quality of irrigation water. Soil testing should include plant tissue testing also to provide advisory service for general as well as for specialized farming including horticulture, floriculture and plantation crops. Qualified and trained staff should be appointed in STL's with some incentives. Training and updating of the staff of STL's should be a regular feature. It is vital to ensure that the information contained in Soil Health Card is not only conveyed to the farmers appropriately but also put into practice

4. Biofertilizers (BF) along with organics has to be an integral part of nutrient management. Deployment of new microorganism or consortia of microorganisms and quality control of biofertilizer packets supplied at farmer's doorstep should be of paramount importance. Newer formulations of mixed biofertilizers and devising effective delivery systems are crucial for making further progress in taking the BF technology to farmers' fields. Efficient utilization of organic manures, integration of crop and livestock-production systems, promotion of biogas plants and improving their efficiency; training and incentives for better manure management; improved and enriched compost preparation is desired/to be ensured. Washing of cow dung and urine to nallas, canals and streams from the dairy farms established in the peri-urban areas should be strictly banned

5. The Nutrient Based Subsidy (NBS) policy encourages use of more urea which has highly skewed the N: P: K use ratio in some states. Reforms in NBS policy are required to correct this aberration. The subsidies on fertilizer should be rationalized so that there is parity in nutrient pricing to promote balanced fertilizer use. A research cess on fertilizers can be levied which can thus be utilized to funding research for developing efficient use of nitrogenous fertilizers. Blending or coating of N fertilizers with nitrification inhibitors to increase N use efficiency is one of many options for developing more efficient N-fertilizers. Incentives may be provided to the fertilizer manufacturers opting for the manufacture of value-added fertilizers such as neem-coated urea, sulphur coated urea, etc

6. There is need to develop new products and popularize more efficient methods of nutrient application. Fertigation is one means which can effectively enhance the nutrient use efficiency considerably. The Hon'ble Prime Minister has made a call to halve the use of urea by 2022. Serious R&D efforts are needed to meet the target in time, through appropriate substitutes as well as novel products

7. The deficiency of secondary and micronutrients can be overcome to a great extent by fortification of the presently manufactured N/P/NP/NPK fertilisers ensuring supply of micro-and secondary nutrients. Since deficiencies of micro- and secondary nutrients are

affecting the quality and productivity in all commodities of soil – plant – animal - human chain, promotion of use of micronutrients at recommended rates and quality maintenance of micronutrient fertilizers through regulation has to be ensured

8. Safe disposal of municipal wastes and industrial effluents should strictly be followed. A simple policy change may be urgently introduced in government campaign in areas having high nitrates in potable waters and phosphates in surface waters. Policies designed to promote greater N-use efficiency in agriculture should emphasize incentives to farmers rather than punitive regulations, so as to avoid export of crop and livestock production to areas with less stringent environmental guidelines

9. The process of approving, pricing and incorporation in Fertilizer Control Order by Govt. of India for Value Added Fertilizers (VAF) needs to be accelerated. A special committee consisting of senior representatives of the Ministry of Agriculture & Farmer Welfare, Ministry of Fertilizers & Chemicals, ICAR and the fertilizer industry be constituted to examine various issues pertaining to VAF and make appropriate recommendations to the Government of India

10. Conservation agriculture has emerged as an alternative to residue burning, where residue is managed in-situ thereby improving soil organic carbon for sustainable soil health. Availability of appropriate machinery that does no-till, fertilizer placement, seeding, chopping and spreading of standing crop residues in one-go should be ensured. Heavy machinery for land shaping, construction of raised and sunken beds, ponds etc. may be ensured through rural cooperative societies by custom hiring. Technical help should be provided to achieve such special tasks

11. Use of alternate energy sources such as solar and wind energy in on-farm agricultural operations should be encouraged

12. Introducing and providing carbon-credit or incentives to the farmers practicing conservation agriculture for carbon sequestration and greenhouse gas mitigation may be a good option

13. In view of the 3 related SDGs (2, 13, 15), "4 per 1000" as well as India's Climate Pledge stated earlier, extra emphasis has to be laid on carbon sequestration in soils. Since Organic Carbon Content is an easily measurable parameter, monitoring and incentivizing the farmers through payment of ecosystem services, would go a long way in achieving these targets.

9.10 Important Policy Issues-Way Forward

From the above it is obvious that several of the recommendations under each issue have been implemented. The gaps in efficiency of implementation have also been identified for necessary action.

There are a number of areas pertaining to scientific management and restoration of soil health that need policy support and prioritized R&D. Supplementing the NAAS Policy Brief recommendations, some important areas are listed below:

- A Land Development Department needs to be created under the Ministry of Agriculture and Farmers Welfare. This Department will be the apex body for all Land Care Policies and Programmes and their implementation. All the activities related to land *viz*., digital land records, conservation, reclamation of degraded and waste lands, rejuvenation of fallow lands and their development should be planned, implemented and monitored by this Department in collaboration with R&D organizations and the State Governments. The National and State Land Use Boards may be revived and strengthened with representations from all the concerned stakeholders including farmers

- A 'National Mission on Soil Carbon Improvement' should be launched in order to improve SOC content and sequestration, and for adaptation/mitigation of climate change. Emphasis needs to be given on (i) study of mechanisms and assessment of the potential for carbon storage in soils across regions and systems; (ii) performance evaluation of best farming practices for enhancement of SOC and their impact on GHG emission; (iii) monitoring and estimating variations in SOC stock, especially at farmers' level; and (iv) innovative models for incentivizing those (farmers/communities/FPOs) adopting low C footprint farming and allied practices

- Despite large network of STLs and personnel engaged therein, the service could not gain desired mass acceptability. As a result, the demand for soil testing is low, as even innovative and resource-rich farmers are seldom enthusiastic to get their soil tested for fertilizer use decisions. This soil testing service, therefore needs revamping. Instead of expansion of the service by way of establishing several small STLs every year, it would be better to establish duly-accredited high output STLs under public sector or in a PPP mode, initially on a pilot scale (may be one STL in each state). Depending on their success, establishment of such STLs at divisional level in each state could be thought of. Proliferation of small STLs in the name of strengthening soil testing service is not a professional approach, and should no longer be continued. As mentioned earlier (in chapter 3, section 3.4), had the very first recommendation of Policy Paper 35, 2006 entitled " Low and Declining Response to Fertilizers" been judiciously implemented, this unsatisfactory situation would have not arisen

- In order to hire trained human resource and ensure their retention in the soil testing service, creation of a state level dedicated service cadre named 'Soil Health Monitoring Service' appears an innovative option. These officers should be exposed to advanced level professional trainings and orientation courses at a regular interval. At present, the officers are frequently transferred from/to STLs, and they hardly own the service. Even a training imparted to such officers ultimately proves wasteful. Creation of a separate cadre would also enhance self-esteem of the officers, who will work had to complete and rise within the cadre

- To enhance the large scale adoption and acceptability of SHCs, geo-referenced soil samples be collected from individual farm holdings instead of grid–based sampling, and apart from the existing 12 soil parameters, soil depth, texture and irrigation water quality may also be included. This improved SHC be better designated as "Soil Health Management Pass

Book" which should be updated every three years. This pass book may also contain the information on best management practices (BMPs) for the crops of a given area. The SHC data may also be used for preparation of digitized soil fertility maps for promoting balanced fertilization. Periodic submission of soil health status report to the Parliament/State Assemblies be made mandatory

- Peri-urban Agriculture is evolving as a new sector. Scientific policies and practices for promoting peri-urban agriculture are crucial for environmental safety. Recycling and reuse of treated sewage and effluent water for irrigation and mechanized composting of urban solid wastes as source of plant nutrients may be promoted as integral components of peri-urban agriculture. In this regard, compliance of pollution and health standard protocols must be ensured for their utilization. This will help in reducing use of fertilizers and promote IPNS for improved soil health

- A series of ecosystem services are provisioned by soil which impact food and nutritional security (Lal, 2013). These include crop yield and quality, animal production, climate change mitigation, water quality improvement, and biodiversity enhancement. And, these services are strongly interconnected, promoting the "One Health" concept – indivisibility of soil – plant – animal – human health. This integrated outlook should guide our policy options and actions to attain the SDGs, especially the SDG1 (poverty alleviation), and SDG2 (Zero Hunger)

- Region-specific Integrated Farming System (IFS) models developed by NARS and NGOs be promoted, particularly in case of small and marginal farmers for harnessing supplementary and complementary relationships among different farm enterprises to achieve greater productivity, sustainability and climate resilience leading to better income generation and livelihood opportunities

- As the fragile coastal eco-system is affected by cyclonic storms and sea erosion, policy interventions are required in the form of restricting indiscriminate expansion of coastal aquaculture, with due recognition of user rights of the traditional fishermen. Similarly, inland water bodies need to be protected and optimally utilized for aquaculture offering first rights to traditional fishers. The coastal lands must be protected against sea water ingression by cyclonic storms and sea erosion by regulated groundwater usage, embankments and bio-shields. Therefore, it is necessary to effectively enforce the provisions of Coastal Regulation Zone Act

- So far, innovation in fertilizer products has not been a priority area of research in India. As a result, 3 or 4 conventional fertilizers rule the market, despite their low use efficiencies. However, development of sustained release fertilizers using nano-formulations and other novel approaches would be important to enhance nutrient use efficiency and minimize losses to the environment. Adequate public investment is needed to encourage research in this important area. Also, the fertilizer industry must come forward to support such research

- Organic Farming may be strengthened and promoted in poorly-endowed regions like rainfed and hilly tracts, tribal and north-eastern regions with low productivity and low/negligible usage of agro-chemicals, for chosen crops and commodities where the country has comparative market advantage. Strengthening of complete value chain from organic input availability to product branding and marketing would help raising farmers' income in these niche areas. There is need to promote strong research backup to develop national standards for organic certification coherent with the international protocols. The high productivity zones of irrigated ecosystems practicing intensive cropping should be kept out of the ambit of organic farming or other such alternate farming options, for these zones are critically important to sustain national food security

- The ZBNF process should be transparently and scientifically analyzed involving the main stakeholders, and the outcomes should be scientifically communicated for further action. The issue needs urgent attention to ensure timely science-evidenced action, before Andhra Pradesh and other pro – ZBNF states meet the same fate as Sikkim, thus jeopardizing the hard earned national food security

- A result framework and implementation pathway must be prepared to ensure the desired outcomes and impact under the guidance and governance of the proposed land development department.

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Chapter 10

Crop Health Chemicals Management for Agricultural Transformation

10.1 Introduction

The Green Revolution, as other agricultural revolutions, was technology-driven, of course, in synergy with appropriate policies, services, farmer enthusiasm and strong political will. Semi-dwarf, input- responsive, widely adapted, high yielding crop varieties, duly supported with increased application of irrigation, fertilizer and other agro-chemicals, were the main drivers. In close collaboration with state and local research and technology development institutions, packages of practices were designed, demonstrated and recommended for different agro-ecological zones throughout the country. The technology packages were to be faithfully adopted by farmers and other stakeholders to achieve desired productivity, profitability and sustainability.

10.2 Protecting the Harvest

Protecting agriculture from onslaught of pests and diseases is an age old practice. Certain major crop disease epidemics have sensitized all stakeholders to scientifically handle the challenges for the humanity as a whole. As we know, Late Potato Blight caused by *Phytophthora infestans* devastated the entire Irish potato crop, the main source of food and cash, in 1845, causing the infamous Irish Potato Famine: The Great Hunger, which killed over one million people and caused mass exodus. Hundred years later, in 1943, in India, the devastating Great Bengal Famine caused by *Helminthosporium oryzae* epidemic wiped off the main food crop rice, causing millions of human deaths. Red rot attack on sugarcane during 1937-42 and 1946-47, brown plant-hopper attack in 1973-74, and army warm epidemic on several crops in 1979 have caused severe losses. In India, estimated annual losses due to pests and diseases are as high as US$ 45 million.

One of the main strategies to sustain the Green Revolution and further accelerate the gains has been to minimize these crop losses. In the spirit of saving a grain means producing a grain, pesticides are used to reduce the colossal losses and to enhance availability of quality products. Further, the epidemics underpin the urgency of establishing science-led reliable plant health management systems to eliminate such devastations. The establishment of the Entomology and Mycology Units, along with Agronomy, Botany and Chemistry Units at the Imperial Agricultural Research Institute (IARI) at Pusa, Bihar, in 1905, now Indian Agricultural Research Institute (IARI), New Delhi, laid the foundation of scientific research and technology development in crop protection. And, the move has been duly institutionalized throughout the country. The Corporate Sector had also responded vigorously. Today, India produces nearly 60,000 tonnes of pesticides (technical grade) and is a major exporter, rendering the plant health agro-chemicals a vital and vibrant component of the livelihood system and the Indian economy.

At times, for varying reasons, including lack of education and awareness, the farmers are not able to adopt recommended practices, and non-judicious unscientific use of the agro-chemicals have resulted in high poisoning cases, unintended adverse environmental and economic disadvantages. Further, spurious and counterfeit pesticides, illegal imports, high level pesticides residues and unsafe food are not uncommon. Over 30 pesticides and formulations are banned in the country. The Insecticides Act (1968), Insecticides Rules (1971) and additional notifications issued from time to time to address newer issues regulate import, registration, production, distribution, and use of pesticides with a view to prevent risk to human beings, animals, and environment. But, implementation of the rules is poor. On the other hand, the present policy shift denounces the use of agrochemicals, especially pesticides for promoting the organic way alone, without fully understanding the impact of such a shift on overall food security of this soon becoming the most populous nation of the world. This chapter examines the various issues and suggests the future pathway, including the pending New Pesticide Bill, based on scientific evidence and in line with the Sustainable Development Goals (SDGs) 2030 and the latest Food and Agricultural Organizations (FAO)/World Health Organization (WHO) guidelines for safety and registration. Above all, judicious implementation of the Acts and the Bill and monitoring should be high priority of the Government and the People.

10.3 Role of National Academy of Agricultural Sciences (NAAS)

Three profound statements, namely ‘A grain saved is a grain produced’, “Unsafe food is no food”, and “Save and Grow”, and the associated publications have been the main *mantras* for NAAS’s working on crop protection and crop health management chemicals.

The National Academy of Agricultural Sciences, through its Brainstorming Session on “Agrochemicals Management Issues and Strategies, 2010”, while appreciating the indispensability of these chemicals to meet the food, health and other needs, involving representation of all stakeholders, deliberated the issues and prospects and made recommendations related to the following major aspects of Agrochemicals (NAAS Policy Paper 45, 2010).

A. Pesticides (Inherent toxicity, Improved utility of limited molecules, Production of useful forms of life, Biopesticides, Pesticide formulations, Handling, storage, transportation, General regulatory issues, Quality issues, Environmental interactions and consumer awareness, disposal / decontamination)

B. Agricultural Chemicals Other than Pesticides (Nitrification inhibitors, Seed coats, Hydrogels, Plant growth regulators, Chemicals hybridizing agents and Value adders)

C. Technology, Trade, IPR etc. (Technology development and promotion, Intellectual Property Right, Trade and commerce, Documentation and database)

D. Human Resource Development and utilization and creation of infrastructure (Human resource development and utilization, Creation of infrastructure and others); and

E. Recommendations: Based on the scenario under the above four areas, the following recommendations were made related to policy issues and research and education, as listed below:

10.3.1 Policy Issues:

1. A national centre on agrochemicals, including organisms and bioproducts, to cater to all aspects of education, training, research, development, scale up, commercialization, etc. needs to be established

2. A single nodal agency, like the United States- Environment Protection Agency, to address the multifarious aspects related to agrochemical use in totality needs to be created

3. A network of centrally controlled and duly accredited laboratories to regularly monitor and update the xenobiotics load of the environment and other natural resources, agricultural and industrial produce, and other commodities needs to be established

4. Investment in agrochemicals research, education, and technology generation needs to be increased with due accountability

5. Only agricultural graduates should be licensed as responsible distributors/applicators/ consultants of (on) agrochemicals and other agro inputs

6. Safe food should be integrated with the recognized safety standards, minimum or no risk products and judicious agrochemical management.

10.3.2 Research & Education:

1. Agrochemicals discipline needs to be created in all the national and state agricultural universities and research institutes

2. Biodiversity management in the context of agrochemical use should be included in the curricula of schools and colleges

3. Krishi Vigyan Kendras need to be strengthened as the knowledge based self sustaining agri-clinics for the diagnosis and solution of the constraints related to agricultural production and the human safety

4. Multi-disciplinary groups at the inter-ministerial level comprising scientists, science managers, and other specialists to overview periodically the agrochemicals scenario need to be established

5. Information on all aspects of agrochemicals needs to be documented and a database needs to be created. This information should be accessible to one and all. A mechanism should be devised for taking the researchable issues to the national agricultural research system, and the feedback to all stakeholders.

The Academy recognizes that pesticides are supposed to be inherently toxic, thus it needs to be ensured that they are safely used. Further, we should be able to promote the proven good effects of agro-chemicals and prevent their known and possible bad (ill) effects. This calls for reliable and methodological data collection and Big Data analysis to understand the direct and interaction effects of several economic, social and environmental factors, and risk-benefit balance. Towards granting positivity to such agro-chemicals, these could be named as Crop Health Chemicals in the plant-animal-human health continuum. This puts the onus on all stakeholders, from farmers to policy makers, to ensure comprehensive bio-safety as the country further accelerates its agricultural productivity growth towards doubling the farmers' income and meeting the SDGs, especially food and nutritional security and poverty alleviation goals.

10.4 Crop Health Chemicals a Must for Saving the Harvest

Crop protection chemicals or pesticides comprise of a large group of chemicals that are used in agriculture for preventing the destruction of crops from pests like insects, pathogens, weeds, etc, thereby keeping crops healthy and contribute in increasing the agricultural production. Pesticides, being the last input in agricultural operation, next only to high quality hybrid seeds, chemical fertilizers and irrigation have all contributed and helped India in growing from a food deficient until the early 1960s into a food surplus one that we are today. The chemical pesticides have transformed the agricultural landscape of India. Besides ensuring the food security for over 1.3 billion Indians, it has benefited the farming community through higher yield, better crop protection measures (both in the pre and post harvest stages) and has raised the income level of farmers.

The importance of crop health chemicals has been increasing over the last few decades driven by the need to improve overall agricultural productivity, in order to safeguard adequate food availability and sufficiency for the growing global population. Every year in India pests and diseases eat away on an average 15- 25 per cent of food produce. Past three fiscal years (FY14-16) have been a challenging year for crop protection chemicals market in India as well as throughout the world. As the arable land is limited, increasing productivity is the only option available. This can only be achieved through usage of high yielding seeds, fertilizers and pesticides. As the crop yield increases, the incidence of pest attack rises which leads to increased demand for pesticides. As average yields of our major commodities are significantly lower than those in China, U.S.A and several developed countries, integrated and balanced and judicious use of inputs, including pesticides ought to increase to realize higher yields.

It is a well established fact that on an average the country looses 25-32 per cent of agricultural produce due to the pests and diseases on farm and off farm. It amounts to more than INR 1,50,000 crores by conservative estimates. Therefore, there is wide scope of enhancing productivity by saving the losses. The analysis of yields of cotton over the years revealed that the major jump in cotton productivity in seventies was due to effective management of pests through chemical use. But when the pyrethroids developed resistance there was either decline or stagnation of yield till 2003. This is further substantiated by the introduction of Bt cotton which doubled the productivity in just six years because of effective control of bollworms. The golden revolution of fruits and vegetables is also due to effective use of chemical pesticides; whether it is grapes, apples, pomegranate or tomato, chilli, potato, onion etc.

Nobody denies the role of pesticides in increasing the crop production in spite of the fact that it is difficult to quantify the contribution of pesticides in enhancing the productivity of crops because it is an indirect act of saving the losses from pests, diseases and weeds. Agricultural scientists world over are of the opinion that agriculture with the goal of addressing the future global food and nutritional securities is unconceivable without the use of pesticides in managing the losses due to insect pests, diseases and weeds. Unfortunately, there is a massive campaign to malign the use of pesticides from various angles. The campaign runs around the theme of excessive use, residues causing health hazards, resurgence of new pests and diseases due to its use, pests and pathogens becoming resistant from their (continuous) use etc. The most common fact has been excessive use leading to health hazards, and environmental pollution. Pesticides are an essential tool in farming for protecting the crop health but the most important part of the use is precise and proper dispensation to the target organism. This requires special efforts to educate the users and hence it becomes the prime responsibility of the producers, consumers, extension agencies and all the stakeholders to see how best the crop health is achieved by using the chemicals without disturbing the environment and human /animal health.

Crop protection products are designed to protect crops from insects, diseases and weeds. They do so by controlling pests that infect, consume or damage crops. Uncontrolled pests significantly reduce the quantity and quality of food production. It is estimated that annual crop losses could double without the use of crop protection products. Food crops must compete with 30,000 species of weeds, 3,000 species of nematodes and 10,000 species of plant-eating insects. We know that despite the use of modern crop protection products 25-32 per cent of potential food production is still lost every year to pests. These losses can occur while the crop is growing in the field, when it is in storage, and in the home. In short, an adequate and reliable food supply cannot be guaranteed without the use of crop protection products.

Continued use of the same chemicals, however, results in their own loss through the development of resistance, resurgence of minor pests and pathogens. Thus new products with more favorable environmental and toxicological profiles are needed for shifting pest spectra, and changing agricultural needs and practices. Modern chemical crop protection products are needed which have unique modes of action, based on the latest advances in science, and are designed to target noxious pests and weeds with minimal or no adverse effects to human health or non-target species.

As pesticides are toxic and hazardous to mankind and the environment, the Government of India regulates the manufacture, sale, transport, export/import etc. of pesticides under the guidelines of the Insecticides Act, 1968. As per this Act, no pesticide is allowed for production/import without registration. Currently, India is the fourth largest global producer of pesticides with an estimated market size of around US$ 4.9 billion in Financial Year 2017 (FY17) after United States, Japan and China. India's share in global pesticide market was around 10 per cent in FY17.

In India, paddy accounts for the maximum share of pesticide consumption, around (26 to 28 per cent) followed by cotton (18 to 20 per cent), vegetables (12 to 14 per cent), Fruits (4 to 6 per cent), wheat (4 to 6 per cent), pulses (3 to 5 per cent), oilseeds (3 to 5 per cent) and others (14 to 16 per cent). (DAC&FW 2017)

Indian Agriculture is predominantly insecticide dominated. In 2000, insecticides accounted for 76 per cent while usage of fungicides and herbicides were merely 10 and 12 per cent, respectively. However, situation has been changing over the recent years. Share of insecticides has come down to 51 per cent in 2012 and may well have gone under 50 per cent now. This has been due to drastic reduction in insecticide use in cotton following introduction of Bt cotton and also due to introduction of novel low dose potent insecticides like neonicotinoids, fipronil, buprofezine etc. On the contrary, use of fungicides and herbicides has gone up. Due to intensified control of diseases in fruits and vegetables, whose shares are growing rapidly, consumption of fungicides has doubled from 10 to 20 per cent. Similarly, increased wages, untimely availability of agricultural labour and introduction of new selective herbicides in several crops have pushed the sale of herbicides to 22 per cent from 16 per cent.

10.5 The Pesticide Scenario of India

10.5.1 Pesticides Use and Consumption

Chemical control of pests is a common practice in agriculture. There are more than a thousand pesticides of both chemical and biological nature used around the world to minimize crop losses. Agriculture in developing countries suffers most because of high incidence of various pests. In India, crops are affected by over 200 major insect pests, 100 plant diseases, hundreds of weeds and other pests like nematodes, rodents and the like. Latest estimates suggest the pre- and post-harvest annual losses due to pests as high as Rs. 1,50,000 crore. Although chemical pesticides are well known for their effectiveness, their impact on soil and environment, and presence of residue in food products are matters of concern. Other issues relate to structure of pesticide industry and the regulations for registration and quality assessment. These issues in the context of Indian pesticide industry must be freed from the maladies.

Indian Agriculture is a vital sector of the national economy with over 50 per cent of the population engaged in agriculture. India has 1.3 billion people or approximately 17.9 per cent of the global population which live on 2.4 per cent land and 4 per cent water resources of the world. As mentioned earlier, the Green Yellow, White, and Blue Revolutions have bought unprecedented gains in food and agriculture production, and rendered India as the second largest agricultural economy in the world. India's inherent strength in agriculture are: largest area in cultivated crops, abundant sunlight throughout the year, a wide range of agro-eco conditions for diversified agricultural practices, huge manpower engaged in this profession, largest irrigated area in the world (96 m ha gross irrigated area and 68 m ha net area under perennial irrigation), rich agro-biodiversity, no country grows as many crops as India cultivates, and family managed small farms and their integrated mixed farming systems. Indian agriculture transforming fast and shall be further so in years ahead to meet the new challenges. Almost half of the population is led by nearly 120 million farming families involved in agricultural production systems throughout the year, grow practically all crops with high cropping intensity and thus offer tremendous opportunity to become a global hub for food, feed, and fibre production.

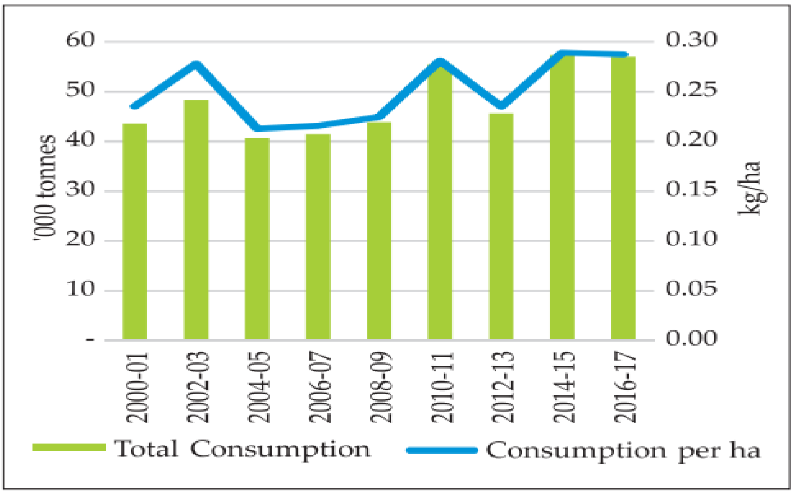
Unfortunately the current farmers' woes and their unmet expectations of higher income from farming are being blamed to these revolutions of agriculture. Some of the policy shifts viz. organic farming and Zero Budget Natural Farming (ZBNF) system have been denouncing the new technologies and the very foundations of agrarian revolution; seeds, fertilizers and pesticides. Instead the advocates and promoters of organic and ZBNA should be informed that these ways alone would not meet the ever-enhancing demand for food and in long run the country may even slip back to "ship-to-mouth" situation. Indian farmer's distress that is observed currently comes not from their inability to produce enough, but from their inability to earn enough profit from the produce. Unless production brings earnings alongwith food security, the progress is meaningless to farmers.

It is a myth that India consumes excessive pesticides. As per facts, India has the largest area of 141 m ha under cultivation of crops but accounts for only 1.7 per cent of the global use of pesticides and still is the second largest producer of agriculture in the world (US$ 367 billion). Japan has 5 m ha area under crops but consumes 53000 tonnes of pesticide, very close to India's consumption of 60230 tonnes. European countries put together use 17 time higher plant protection chemicals per ha than India and account for 11 per cent of the global consumption. Despite the manifold higher intensity use in Europe and Japan, the recorded/reported adverse effects of pesticides in these countries are far lower than those in India. This paradox is primarily attributed to two main reasons: Firstly, the lack of judicious use of agro-chemicals which can only be corrected by education, and secondly, to the ill control on quality of pesticides due to spurious pesticide market, which must be corrected by stringent regulatory measures (governance).

The consumption of chemical pesticides in the country has increased over the past few years, from nearly 43 thousand tonnes in 2009-10, to about 60 thousand tonnes in 2016-17

(Figure 1), the corresponding per ha use being 0.22 kg and now, 0.3 kg, pushed up primarily due to higher use of herbicides (Subash *et al.* 2017).

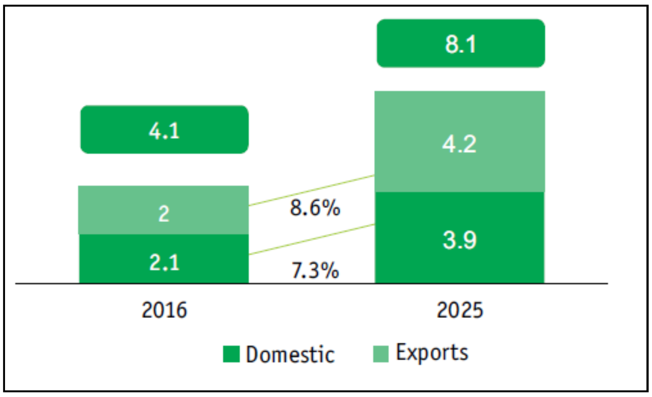
Figure 1. Trend in consumption of pesticide (technical grade) in India



Source: Based on data from Ministry of Chemicals and Fertilizers

The Indian Agrochemical industry was valued at US$ 2.1 billion in FY16, having grown at a compound annual growth rate (CAGR) of around 3.5 per cent from FY13 to FY16. It is further estimated to grow at a CAGR of 7.3 per cent to reach US$ 3.9 billion by FY25. Export market is expected to grow at 8.6 per cent, reaching US$ 4.2 billion in 2025 from US$ 2 billion in 2016 (Figure 2). India is the fourth largest producer of agrochemicals worldwide, after United States, Japan and China, and has emerged as the 13th largest exporter of pesticides globally.

Figure 2. Growth rate pattern of Indian Crop Protection Market



Source: TATA Strategic Research

There is wide interstate variation in pesticide consumption, being highest in Maharashtra, followed by Uttar Pradesh, Punjab and Haryana (Table 1). During the last decade, the total consumption increased in Maharashtra and Uttar Pradesh, while it slightly declined in Punjab and Haryana. States like West Bengal, Gujarat and Karnataka have seen a steep decline in the total consumption. On the other hand, Chhattisgarh and Kerala showed a steep increase in total pesticide consumption. Per hectare consumption of pesticides was the highest in Punjab (0.74 kg), followed by Haryana (0.62 kg) and Maharashtra (0.57 kg) during the year 2016-17, while the consumption levels were lower in Bihar, Rajasthan, Karnataka and Madhya Pradesh (Table 1).

Table 1. State-wise consumption of pesticide (technical grade)

States/UTs	Total Consumption (tonnes)			Per ha (kg)
	2003-04	2008-09	2015-16	2016-17*
Punjab	6780	5760	5743	0.74
Haryana	4730	4288	NR	0.62
Maharashtra	3385	2400	11665	0.57
Kerala	326	273	1123	0.41
Uttar Pradesh	6710	8967	10457	0.39
Tamil Nadu	1434	2317	2096	0.33
West Bengal	3900	4100	3712	0.27
Chhattisgarh	332	270	1625	0.26
Andhra Pradesh	2034	1381	2713	0.24
Odisha	682	1156	723	0.15
Gujarat	4000	2650	1980	0.13
Bihar	860	915	831	0.11
Karnataka	1692	1675	1434	0.10
Rajasthan	2303	3333	2475	0.05
Madhya Pradesh	62	663	732	0.03
All India	41020	43860	54121	0.29

*Note: NR refers to not reported; *GCA based on 2014-15*
Source: Ministry of Chemicals and Fertilizers, Govt. of India.

Often we come across mystified, unfounded, and unscientific arguments on the use of agro-chemicals in Indian agriculture. Indian farmers are falsely accused of using excessive pesticides, as we know that per hectare pesticide consumption in India is only about 0.3 kg against 13 kg in China, 12 kg in Japan, 7 kg in USA, 5 kg in Europe, and 4.6 kg in Brazil. Ambiguous hazards that are projected in the global scenario on Indian agriculture, have been hurting India's global trade. Punjab is often picked up for frivolous charges of excessive use of pesticides causing cancer. This calls for open debate and science-informed discussions on the potential risks, hazard mitigation processes, and informed communication to people.

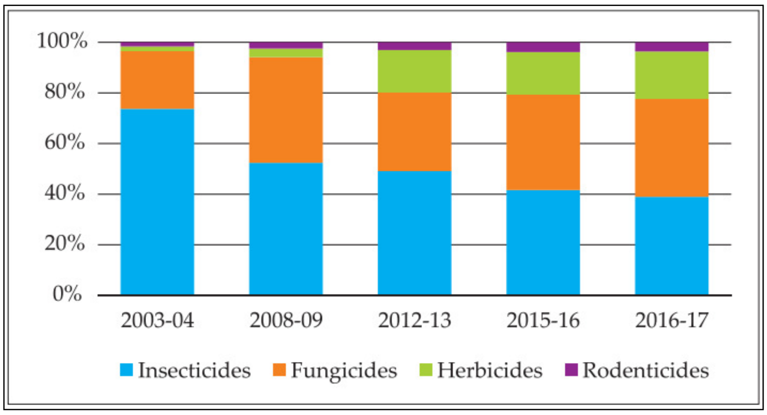
The unfounded mystification is confounded with mismanagement of pesticides in India. Issues with regard to the use of pesticides include use of low-quality pesticides, and a lack of awareness about pesticide use. The Economic Survey 2015-16 noted that the use of pesticides without proper guidelines has led to an increase in pesticide residue being found in food products in India. Over the years Indian Crop Protection Industry has witnessed the proliferation of non-genuine/spurious pesticides. Illegal imports of technical grade chemicals having no Central Insecticide Board (C.I.B.) and Registration Committee (R.C.) registration has led to the formulation of non-genuine / illegal pesticides locally. Apart from the counterfeit products of leading companies, a new practice has emerged by which counterfeiters are selling insecticides in the name of 'bioproducts' to avoid rigorous registration procedure. Market is filled with products having a low Percentage of Active ingredients as compared to what they are registered for, hence are substandard and ineffective. This indeed calls for a serious intervention from government and regulatory authorities to arrest the proliferation of both non-genuine products and companies.

10.5.2 Pesticide Production

Pesticide production in India is dominated by insecticides and fungicides followed by herbicides and rodenticides (Figure 3). However, the share of insecticides has come down from more than 70 per cent in 2003-04 to 39 per cent in 2016-17. The shares of fungicides, herbicides and rodenticides are growing over the period. The growth in the use of fungicides is high mainly because of their application in fruit and vegetable crops. Major pesticides produced in India are Mancozeb, 2-4-D, Acephate and Profenofos.

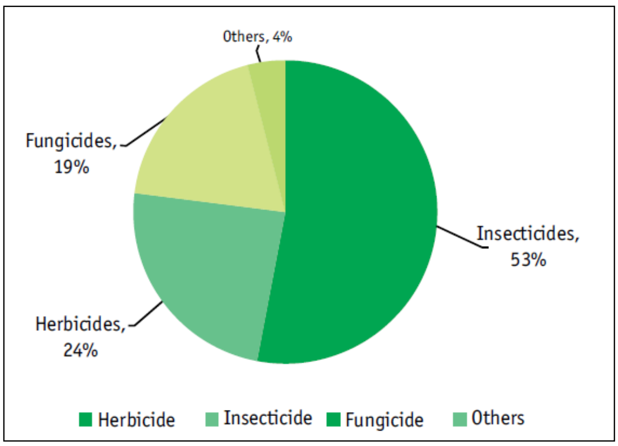
The domestic market split by type of pesticides in 2016 is given in Figure 4. Insecticides accounted for 53 per cent of the pesticides used in India, followed by herbicides (24 per cent) and fungicide (19 per cent).

Figure.3 Share of pesticide groups in total pesticide production (technical grade)



Source: Ministry of Chemicals and Fertilizers

Figure. 4 Domestic Market split by type of pesticide, FY16



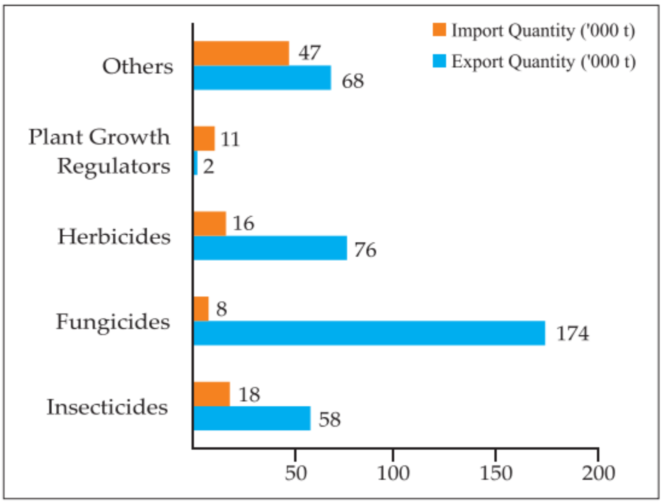
Source: TATA Strategic Estimates

The share of extremely and highly hazardous pesticides (WHO classification) in the total production has been decreasing over the last decade. In 2016-17, the share of extremely hazardous pesticides (WHO Ia) was 6.62 per cent, highly hazardous (WHO Ib) 4.81 per cent, and moderately hazardous (WHO Class II) 38.26 per cent. The share of slightly hazardous (WHO Class III) and unlikely to present acute hazard (WHO Class U) was 6.79 per cent and 39.36 per cent, respectively (FAOSTAT 2017).

10.5.3 Trade in Agro-chemicals

Total export of agro-chemicals in 2016-17 stood at 377.76 thousand tonnes, with the share of fungicides being the largest in terms of export quantity (45.94 per cent) (Fig. 5) and herbicides accounted for the largest share in terms of value of exports (28.19 per cent). As per data provided by Central Board of Excise and Customs (CBEC) for the year 2016- 17, top five pesticides exported from India were mancozeb, cypermethrin, sulphur, acephate and chlorpyriphos, while the major products imported were glyphosate and atrazine. The trade data need careful interpretation as both formulations and technical grade pesticides are traded by different firms. However, Indian firms mostly import technical grades, or formulations which are protected through patents, and the exports are mostly of formulations.

Figure 5. Export and Import of major agro-chemicals by India, 2016-17



Source: DGCI&S, Ministry of Commerce and Industry

10.6 Challenges Faced by Indian Crop Protection Chemicals

10.6.1 Non-genuine Products

There is a significant share of non-genuine pesticides which include counterfeit, spurious, adulterated or sub-standard products. According to industry estimates the non-genuine pesticides could account for more than 40 per cent of the pesticides sold in India in 2014-15. These products are inferior formulations which are unable to kill the pests or kill them efficiently. They also leave by-products which may significantly harm the soil and environment. Apart from crop loss and damage to soil fertility, use of non-genuine products leads to loss of revenue to farmers, agrochemical companies and government. Some of the key reasons for use of non-genuine products are lack of awareness amongst the farmers, difficulty in differentiating between genuine and non-genuine products, supply chain inefficiencies, law enforcement challenges and influencing power of distributors/retailers. This huge use of spurious products is a heinous act, and the Government and other stakeholders along the value chain should be held responsible for this inhuman situation.

10.6.2 Low Focus on Research & Development (R&D) by Domestic Manufacturers Due to High Costs

The industry is facing a serious challenge owing to the rising R&D costs. R&D associated with new product development amounts to around US$ 250 million in costs and takes around 5-10 years. This prevents the companies from investing in R&D activities and they tend to focus more on the generic products which require low investments in research and development. In order to sustain in the long run, the industry needs to be committed to making long term investments and withstand longer gestation periods in order to bring to the market more innovative products. In India average expenditure on R&D for pesticides is abysmally low at about 1-2 per cent of sales, compared to global companies where average expenditure is about 6-7 per cent of sales. The low expenditure of the Indian players towards R&D is due to concentrating on marketing generic and off-patent products by focusing on applied research. This research intensity on agro-chemicals, especially pesticides is weak in public sector as well, which should be corrected without further delay as we are already far behind in frontier research in this area.

10.6.3 Lack of Education and Awareness among Farmers

It is important to educate the farmers about the appropriate kind of pesticide, its dosage and quantity and application frequency. Only 25-30 per cent of farmers are aware of agrochemicals products and the usage, therefore large numbers of farmers are unaware of the cost benefit that could be gained by using agrochemicals. However it is not easy to reach the farmers owing to infrastructure issues, regional languages and dialects and a general inertia towards adoption of newer products on account of possible risks of crop failure. The main point of contact between the farmers and the manufacturers are the retailers who don't have adequate technical expertise and are thus unable to impart proper product understanding to the farmers. It is also very difficult for the farmers to convey their needs effectively to the manufacturers. Trainings of retailers should assume high priority and become a regular feature. It will be highly pragmatic to give retailorship to agriculture graduates.

10.6.4 Need for Efficient Distribution Systems

The large number of end users and the predominantly generic nature of the market makes a strong and efficient distribution network essential for the crop protection market. However, the industry has been plagued by problems arising out of supply chain inefficiencies and inadequate infrastructure which result in post-harvest losses estimated at INR 45,000 crore every year. The lack of an efficient distribution system also makes it difficult for the agrochemical companies to reach the farmers to promote their products and educate them about their usage and benefits.

10.6.5 Long Gestation Period for new Products

It takes almost 10 years to bring a new molecule into the market. Even for the generic products, it can take up to 5 years to get the product registered. The regulatory bodies do not have adequate resources and infrastructure to execute timely registration of products. Sometimes the rules are not clearly defined creating interpretation challenges for the regulatory bodies, leading to confusion thereby adding to the complexities for the crop protection chemical companies.

10.6.6 Seasonal Demand

The demand for pesticides emanates majorly from agricultural production. Therefore, the demand for pesticides in India is seasonal as crops are mainly sown in two cropping seasons, namely *kharif* (July - November) and *rabi* (October - February). The demand is skewed in favour of *kharif* crops with about 70 per cent of annual pesticide consumption.

10.6.7 Brand Awareness and Need of Efficient Distribution System

There is a significant share of local pesticides products available in the market. According to industry estimates these products are ineffective and are unable to kill the pests. Such pesticides could account for more than about 35-40 per cent of the pesticides sold in India. Furthermore, they result in byproducts which harm the soil and environment which will result in crop loss and decline in soil fertility. This is primarily on account of lack of efficient distribution system. On account of this the pesticide companies are unable to reach the farmers and educate them about the products.

10.6.8 Protecting the Most Vital Stakeholder- the Farmer

The Second Green Revolution in addition to adopting modern agricultural practices should also focus on the creation of a robust ecosystem that protects the farmer from the risks of the profession. It should ease the transition of the Indian farmer from the traditional ways of farming to adopting newer, modern methods. This would involve providing easy access to finance for procuring seeds, crop protection chemicals, machinery and equipment as also crop insurance in the event of crop failure. Extensive farmer education on all aspects of modern farming would ensure that these practices are rapidly assimilated.

10.6.9 Recent Pesticide Poisoning Cases/Negligence in Pesticide Management

Over 60 farmers have reportedly died and hundreds have become ill due to pesticide poisoning in several districts of Vidharba region, major cotton growing belt in Maharashtra, since July 2017, where farm workers died due to inhalation of toxic pesticides while spraying it on the fields. Pesticides such as monocrotophos, oxydemeton-methyl, acephate and profenophos are believed to be responsible for the deaths and illness (Deshpande 2017). Pesticides like monocrotophos and oxydemeton-methyl are considered class I pesticides by the WHO, and are categorized, based on acute toxicity, as extremely hazardous pesticide active ingredients, and must be used carefully. The administration has now begun educating the farmer for safe use of pesticides and developed an elaborate plan this season to create awareness about safe usage of pesticides knowing fully that the cotton farmers may not all convert to organic way. The agriculture department has employed MASTER TRAINERS in cotton area to further coach the farmers, farm workers and other stake holders. Instead any panic reaction a very cool and scientific approach would certainly be useful in such cases.

As per the International Code of Conduct on Pesticide Management, jointly released by FAO and WHO, "pesticides whose handling and application require the use of personal protective equipment that is uncomfortable, expensive or not readily available should be avoided, especially in the case of small-scale users and farm workers in hot climates", Center for Science and Environment (CSE) said in a statement. All class I pesticides require the use of personal protective equipment that is impossible to use by small-scale farmers and farm workers in India.

The tragedy primarily occurred because the Bt cotton crop had failed to resist the dreaded cotton bollworm, a pest that attacks approximately 183 host plants including beans, maize and sorghum. It causes a lot of damage in the field and has developed resistance to several insecticides. To curb the menace, many farmers resorted to sprays of deadly cocktails.

Following the spate of deaths, the Central Institute of Cotton Research (CICR), Mumbai conducted a detailed study and submitted a report to the state government. According to the report, herbicide tolerant genes, which are not permissible under the provisions of Environment Protection Act 1986, were found in the Bt cotton seeds of five branded companies.

Cases against Krishi Seva Kendras or agro–input centers were filed under the Insecticide Control Act 1968 for selling non-certified pesticides and selling pesticides without the mandatory license. One of the recommended solutions is to render sale of pesticides illegal unless supported by prescriptions from agriculture officers.

10.6.10 Approval and Enforcement Issues

CSE, over the last several years, has highlighted gaps in pesticide management in the country. There is a major problem with the way pesticides are approved for use in the country. There is even a bigger problem of enforcement. Unapproved off-label use of pesticides continues to be a big problem in India along with unsafe application of pesticide by farmers.

A 2013 CSE review of 11 important crops in India – wheat, paddy, apple, mango, potato, cauliflower, black pepper, cardamom, tea, sugarcane and cotton – showed that the pesticide recommendations made by state agriculture universities, agriculture departments and other boards for a crop do not adhere to the pesticides that the CIB&RC has registered for those crops. The agriculture universities, departments and boards have recommended many pesticides that have not been registered for some crops. For example, in case of wheat the states of Punjab, Haryana and Madhya Pradesh recommended 11, 5 and 9 pesticides which were not registered by the CIB&RC.

Till we reform our pesticides regulations and regulatory institutions, pesticide poisoning and accidental deaths would continue. A Pesticide Management Bill was introduced in the Parliament in 2008 but it was allowed to be lapsed. We need a new Pesticide Management Bill to address the issues related to unsafe use of pesticides.

10.6.11 Fake and Unregistered Pesticides Account for 25 per cent of the Value of Pesticides Sold in India

This data is from a report prepared by the FICCI-Tata Strategic Management Group in 2015. One of the reasons why the Indian market is flooded with fake pesticides is the sheer number of pesticide products that have been approved by the Centre. India has 260 registered pesticide molecules but 2.5 lakh registered products (formulations). Out of 260 molecules, how many are from India? We are good in formulation but not in discovering new molecules. Also, what is happening to nano pesticides?

10.6.12 Biopesticides Laced with Chemical Pesticides

Many unscrupulous parties are selling bio-pesticides mixed with chemical pesticides overlooking the Insecticide Act and the Insecticide Rules. Some biopesticides are often not sufficiently effective as standalone products but are integral part of IPM system. Mixing chemical pesticides enhances the efficacy of bio-pesticides and farmers are satisfied with their performance. However, needless to say that bio-pesticides laced with chemical pesticides are not only illegal but also will create danger to human beings, animals and environment. Many of these products are used in organic farming as a result of which the so called organic, which should be totally free of pesticides, have more pesticides than crops grown under modern agriculture with application of pesticides. Analysis of 166 samples by Government Laboratories of All India Network Project on Pesticide Residues (AINPPR, ICAR) showed that 4.8 per cent of organic vegetables samples had pesticide residues above Maximum Residue Limits (MRL). In contrast to this, in a long term project, where 1,13,000 samples of non- organic fruits and vegetables were analysed only 2.06 per cent samples of fruits and vegetables and other crops had pesticide residues above MRL.

10.6.13 Instead of Taking Responsibility for its Regulatory Failures, the Government Blames Farmers

Even assuming that all pesticide products in the market are safe for use, the Centre and states blame the deaths on the farmers. According to them, farmers do not follow safety instructions. But as found in Tamil Nadu, some of the farmers who had died after spraying pesticides had worn safety gears, indicating either that the product they used was not safe, or that they were not told how to use it correctly.

In fact, as farmers pointed out, the government has made no effort to instruct them on the safe use of pesticides. In the past, government extension workers went to villages to conduct training and demonstration sessions for farmers. But in recent years, subject to funding cuts, the farm extension system has collapsed. Farmers are now forced to rely on private dealers who have an incentive to maximize sales.

10.7 National Legislation on Pesticides

While the production of pesticides is monitored by the Ministry of Chemicals and Fertilizers, their usage is administered by the Ministry of Agriculture. There is a need to review the Insecticide Act, 1968, to provide for a regulatory framework for the pesticides sector. The Standing Committee on Agriculture has also recommended that a Pesticides Development and Regulation Authority be created to regulate the manufacturing, import and sale of pesticides in the country. Other recommendations include developing an integrated pest-management system, which includes a mix of the mechanical & biological methods of pest control, encourages the use of bio-pesticides and safe chemical pesticides which will not leave residues in food commodities.

10.7.1 Insecticide Act, 1968

In India, use of pesticides is regulated by Insecticide Act, 1968, which comprises a Central Insecticide Board (CIB) providing technical support and a Registration Committee (RC) to assist in registration of pesticides. Till few years ago, the Ministry of Health and Welfare jointly with Registration Committee, Ministry of Agriculture, and Government of India established MRLs of herbicides in food commodities after evaluating data submitted by the registrants i.e. the companies. The Ministry of Health and Welfare is responsible for enforcement of MRLs of herbicides in food products through the Prevention of Food Adulteration (PFA) Act, 1955 as amended in 2004.

10.7.2 Registration and Quality Control

The Insecticide Act (1968) and Insecticides Rules (1971) regulate import, registration, production, sale, transport, distribution and use of pesticides with a view to prevent risk to human beings or animals. All pesticides have to necessarily undergo the registration process with the Central Insecticides Board and the Registration Committee (CIB&RC) before production or sale. The Registration situation is given in Table 2. For manufacturing or import, applicant submits data on various aspects, including chemical composition, toxicity, bioefficacy, etc. to CIB&RC. On some aspects (particularly bioefficacy of pesticides) published, authentic report of R&D organizations is also considered as a valid data source. The Committee after ensuring the validity of application provides a registration number and certificate.

Table 2. Pesticides registered under U/S 9(3) of insecticides Act 1968 for use in the country

Total No. registered	261
Pesticides which are banned	32
Pesticides refused registration	18
Restricted for use in the country	13

Source: Chemicals included in the schedule of Insecticide Act 1968 (As on 30.11.2014)

There are regulations and procedures for testing pesticides at different stages. The Central Insecticide Laboratory (CIL) is mandated to test the referral samples submitted by any officer or agency of the Central or State Government, while State Pesticide Testing Laboratories (SPTL) mainly test the samples taken at the manufacturing and point-of-sale for quality control. Results of STPLs indicate that around 2.5 to 3 per cent of samples tested were misbranded (not as per the label) during 2008-09 to 2012-13. In total, 28 pesticides and four formulations are banned for manufacturing, import and use, eight pesticides are withdrawn and 13 pesticides are restricted for use in the country. The situation in 2014 is given above in Table 2. Recently, on the advice of an expert committee, 12 pesticides are completely banned from January 2018 and another six will be banned from December 2020 (DAC&FW, 2016).

10.7.3 Food Safety and Standards Act (FSSA), 2006

However, with the implementation of Food Safety and Standards Act (FSSA), 2006, the PFA Prevention of Food Adulteration rules are being phased into the Food Safety and Standards Regulations, 2010. The new Act authorizes the Food Safety and Standards Authority of India (FSSAI) to specify the limits (MRLs) for the pesticide residues, residues of veterinary drugs, mycotoxins, and antibiotics substances in food. The existing MRLs on pesticides and agrochemicals specified in the PFA are incorporated in the Food Safety and Standards Regulations, 2010. It needs hardly be over emphasized that “unsafe food is no food”.

10.7.4 Environmental Issues

Major challenges faced by the industry are stringent environmental regulations across the world, low focus on R&D by domestic manufacturers due to high costs, need for innovation and product diversification, lack of awareness about safe use of pesticides among farmers, long gestation period for new products and product quality assurance (FICCI, 2015). While the farmers need to be protected for sub-standard products, programs for safe use of pesticides and reduction of potential health and environmental impacts should be undertaken. Possibility of sub-standard products cannot be ruled out and therefore, enforcement of point-of-sale quality inspection and protection of farmers with consumer forums deserve emphasis.

Bio-pesticides have the potential to control crop losses and reduce negative environmental externalities. Bio-pesticides constitute around 3 per cent of pesticide market in the country. So far 14 bio-pesticides have been registered under the Insecticide Act 1968 in India. Consumption of biopesticides has increased from 219 tonnes in 1996-97 to 683 tonnes in

2000-01, and further to around 3000 tonnes in 2015-16 (Sinha and Biswas, 2008; DAC&FW, 2017). Studies indicate that use of bio-pesticides in integrated pest management can reduce pesticide use by 66 per cent in cotton and by 45 per cent in cabbage (Birthal, 2003). Thus, biopesticides can play an important role in shifting the focus from chemical pesticides to reliable, sustainable and environment friendly options. But the pace of development of market for bio-pesticides is not so impressive. Biopesticides have short shelf life. Their storage requires special facilities and skills, which should be developed at all levels in the supply chain. Also, if necessary, fiscal incentives may be provided for production and use of bio-control agents.

10.7.5 Some Recent Developments

10.7.5.1 Pesticide standards in drinking water

There were reports in the media in February, 2003 with respect to residues of extremely harmful pesticides found in popular brands of bottled water marketed in and around Delhi and Mumbai. Vide a notification issued on July 18, 2003, effective from January, 2004, the pesticide residues in carbonated water, fruits and vegetable juices, fruit syrup, fruits squash, fruit beverage or fruit drink, soft drink concentrates (after dilution as per direction), and ready to serve beverages of any kind were set as 0.0001 mg L^{-1} (0.1 ppb) for individual pesticide residues and 0.0005 mg L^{-1} (0.5 ppb) for total pesticide residues with the condition that the analysis should be conducted by using internationally established test methods meeting the residues limits specified herein.

10.7.5.2 MRLs are a pre-requisite for pesticide registration

Henceforth, the Pesticide Registration Committee will consider only those pesticides for registration for which MRL has been fixed on the specified crops. No registration will be granted to any pesticide for which tolerance limits are not prescribed under the PFA Act.

10.7.5.3 Deletion of crops from label and leaflet of pesticides for which MRL is not fixed

Manufacturers of various pesticides are advised from time to time to generate and submit the data for MRL fixation in respect of those pesticides which are sold in market for use on crops without fixation of MRLs. The Central Government, in consultation with the Registration Committee has decided for deletion of the names of the crops from labels and leaflets of such pesticides. In 2014, as per notification of Ministry of Agriculture dated 24 September, 2014, the label claims of some of the pesticides on certain crops have been deleted from approved use (FSSAI, 2011).

10.8 New Pesticides Management Bill

According to the Department of Chemicals and Petrochemicals, the Department of Agriculture and Cooperation is in the process of amending the Insecticides Act, 1968, to be replaced by Pesticides Management Act (PM Act). “Pesticides Management Bill (PMB)” has been introduced by the Department of Agriculture and Cooperation. It is under consideration of the Rajya Sabha since October, 2008. Some major concerns, for redressal are revision of definition of pesticides to cover all substances intended to be used as pesticides; Provision for suspension and/or cancellation of registration to empower the Registration Committee (RC) to suspend and/or cancel registration; Provision for data protection to encourage faster introduction of new pesticide molecules for the benefit of the farming community; Provision for registration of pesticides only after fixation of tolerance limits (Maximum Residue Limits) under Food Safety & Standards Act, 2006 for monitoring pesticide residues on the crops on the pests of which it is intended to be used; Provision for restricted movement of pesticides, registered only for the purpose of export; Provision for improvement in the licensing procedure; No 'Stop Sale' of pesticides by Pesticide Inspectors without permission of a Magistrate; Powers of Pesticide Inspectors to Customs Officers for checking illegal imports of pesticides; Clarity in the procedure for sampling and testing of samples for monitoring quality of pesticides; Mandatory accreditation of laboratories testing pesticides for monitoring their quality; Classification of offences and provision of penalties commensurate with the gravity of offence; Provision for 'Compensation' in case a pesticide fails to perform. Provision for time-bound disposal of obsolete pesticides Pesticide Management Bill 2008)

10.8.1 Anomalies in Pesticides Management Bill 2008 Pending Clearance

The draft Pesticides Management Bill greatly expands on the Insecticides Act of 1968 in defining usage and registration norms and other regulations. It addresses the manufacturing, field usage and disposal of pesticides. It also codifies harsher punishments for manufacturers of spurious pesticides. Yet, there remain certain anomalies which must be addressed as suggested below.

10.8.1.1 Power of pesticide sales in states

The draft Bill retains for the Central Government the powers it already has in the Insecticides Act. This may disappoint states such as Maharashtra and Punjab, which have been asking for greater control over the pesticides sold in their territories. Under the spirit of Cooperative Federalism" and allowing the states to be responsible and accountable for development activities, the states may be given the necessary power.

10.8.1.2 Punishment for spurious manufacturers

The PMB is proposing to enhance punishment for spurious manufacturers which is a good idea. However, unless the government laboratories are made foolproof so that no false analysis and report can be generated there are chances that some genuine manufacturers will end up in jails and the business of spurious manufacturers will flourish. Samples of many big companies fail due to corruption in the system. Therefore all central and state government laboratories must be accredited with GLP. Just increasing the punishment will not help.

10.8.1.3 MRL of pesticides

Regulation on fixing MRL prior to registration already exists. There is already a Supreme Court decision that no product can be registered without the establishment of MRL. However, what the PMB does not address is the number of pesticide which gains entry into the country via imports of various fruits, vegetables, oil and other agricultural and animal products. Where is the law to address these issues? Other countries treat this as non-tariff barrier to stop the exports of many commodities such as tea, grapes, basmati rice, etc. if we are really concern about the health and safety of the environment, there must be provisions to address such issues along with PMB. Sadly we find that PMB is completely silent on this issue.

10.8.1.4 Cost–effective pesticides

Cost of pesticides can only be brought down by increasing competition. Section 9(4) had provided right to compete. In the past cost of many products such as Cypermethrin, Sulfo-sulfuron, Clodinafop, Imidacloprid, Thiamethoxam, Byspyribac-methyl sodium, etc. have been brought down less than half. Policy makers have kept a loophole to provide monopoly to the Multi National companies (MNCs) for about hundred products over last ten years by ‘import of formulations without registering technical’. The PMB is not addressing this serious issue. However, CIB & RC, Faridabad flouted this rule and did not issue simultaneous registration of the technical grade pesticides to Indian agro-chemical industries. As a result of which the Indian agro-chemical industries could not get a ‘Me-too’ registration. The importers got absolute monopoly on about hundred products which are now being sold at exorbitant prices. Farmers are being looted and the Indian agro-chemical industries are suffering. It is doing no good to the country but is benefitting the MNCs. The PMB does not address this issue explicitly. It is a sad story. Imported products are manufactured with expired technical material for which we have no check and PMB talks about ensuring ‘quality’.

10.8.1.5 Regulation on pesticide export

The PMB wishes to regulate exports primarily for internal safety. If this is assured by the exporting companies, the exporters need not be penalized and put behind bars if the product meant for export fail to meet the Indian standards. It should be assured that the product is exclusively for export. Should that be the case, national provisions should ensure zero use of such chemicals within the country. However it is easier said than done. Therefore the proposal may not appear too harsh on the exporters.

10.8.1.6 Price control on pesticides

The price control in the modern economy can be put to use only under exceptional situations, either when the products are in short supply or the goods are not readily available to consumers at a fair and reasonable price. The situation is so bad that Indian companies are denied registration on patent expired products ‘of MNCs’ and Indian companies with valid patent are ignored and registration is granted to others. As a result imported formulations have monopoly and Indian companies cannot recover the cost of investment.

10.8.1.7 Clause on compensation to farmers

There is absolutely no way to monitor the way the farmer uses the product with regard to doses, timing of application, etc. All these have bearing on the performance of the product. Manufacturers can be held responsible for the declared content which conforms to its specifications and the conditions of registration. This provision will only lead to litigations. The extension machineries to raise the awareness and close monitoring of correct use of chemicals should be strengthened and must be proactive in ensuing safe use of pesticides. (Crop Care, 2018)

10.9 Development of New Agrochemical Molecules

The need for the discovery and development of new agrochemicals continues unabated. On the agrochemical production front, pesticides are first manufactured as technical grade product (85 per cent or more of the active chemical ingredients), which has a higher commercial purity. The active ingredients are then mixed with inert ingredients (solvents, adjuvant and fillers) to achieve the desired formulation. The active ingredient kills the pest whereas the inert ingredient facilitates ease of handling, spraying and coating on plants.

10.9.1 Trends in Synthetic Pesticides

During 1960s to 1990s synthetic pesticides *viz* organochlorine , organophosphate, carbames and synthetic pyrethroids insecticides; phenoxy alkanoic acids, triazines, substituted phenylureas, dinitroanilines etc. herbicides; thio and dithicarbamates, metalaxyl, carbendazim etc. fungicides were all effective when applied at high rates of 1-2 kg/ha. Their regular use led to problems of environmental persistence developing pest resistance.

Research for need to reduce load of pesticides in the environment led to the development of newer molecules during 1990 to 2005 based on stereochemistry; and new generation of low dose potent pesticides *viz*. neonicotinoids, sulphonylureas, imidazolinone, triazoles etc. were introduced in 1990’s. These were effective at as low dose as 5-50 g/ha. Many of these compounds were hydrophilic in nature with possibility of leaching down on application and contaminating ground water. Also their analysis for residues at parts per billion (ppb) level by technique involving High Performance Liquid Chromatography (HPLC) was quite challenging.

10.9.2 Development of Molecules with New Mode of Action

During 2005 to 2017, new mode of action, newer insecticides like spinosad, indoxacarb, fipronil, etofenprox, buprofenzin; fungicides such as hexaconazole,,tebuconazole, pyraclostrobin; and herbicids like sodium bispyribac-methyl were introduced early in the period and were found effective. As a constant research effort for developing new molecules certain MNCs have preferred to the development of herbicide with new action mechanism, including the 4-Hydroxyphenylpyruvate dioxygenase (HPPD) inhibitors (e.g. bicyclopyrone, topramezone, tembotrione) launched in 2016, attributable to its multiple advantages such as the distinctive action mechanism and the feature of non-cross resistance with existing herbicides.

Succinate dehydrogenase inhibitor (SDHI) fungicide Solatenol™ (benzovindiflupyr) launched to market in 2013, to be applied mainly to cereals, soybean, corn and cotton crops, is reported to be the most effective product in history for control of 'Asia soybean rust'. Also launched was fluopyram which is nematicide cum fungicide

10.9.3 Pre-Mix Pesticides

MNCs have launched in 2015 and 2016 several mixtures of pesticides each with different mode of action such as 'Acuron', 'Acuron Flexi' as mixture of two and three herbicides, respectively. 'Orondis Ridomil' Gold is mixture of fungicides.

10.9.4 New Pesticides Launched in India

A new herbicide 'Agil' has been launched in Hyderabad recently that can be used on cotton, chillies, black gram and other broad-leaved crops.

Crystal Crop Protection launched five new products for farmers namely 'Apex 50'**-** an Insecticide, 'Abacin' is world renowned miticide, 'Azotrix' - an excellent product for the control of blast in paddy crop and under patent consideration is Crystal's own R&D., Bio stimulant – 'Toggle Plus'**.** The bio–stimulant is based on *Ascophyllum nodosum*, a natural extract scientifically proven to increase crop yields.

Agrochemicals firm Insecticides India Ltd (IIL) has tied up with Japan's Nihon Nohyaku Co Ltd for launching of new generation insecticide for different crops under the brand name 'SUZUKA'. Suzuka, the new generation insecticide flubendiamide (20 per cent SG), of Nihon Nohyaku, Japan, which is an effective solution for control of lepidopteron pests in different crops like pulses, vegetables and paddy. Suzuka is an important product for farmers of Madhya Pradesh (MP) especially for *rabi* crops like gram and other vegetables.

10.9.5 New Chemicals for Extended Health of Fruits and Vegetables

In India Bayer has launched 'Luna Experience' a fungicide for table grapes to 'Extended Grape Health' benefit. Extended Grape Health refers to the superior protection provided by Luna® against crop quality related diseases like Powdery Mildew as well as latent diseases. Latent infections remain in a dormant stage in the berry and start showing disease symptoms only after harvest, thus affecting the shelf-life.

'Slowed', a Dutch company product is an **adsorbent granules** that will keep fruit and vegetables **fresh for longer**. Fresh fruit, vegetables and herbs produce ethane, a natural gas, that helps them ripen. Bananas and avocados, in particular, release a lot of this gas. This can speed up the ripening process of other fruit and vegetable varieties. These granules are adsorbents and comes in the small sachets which neutralize and adsorb the ethane. This means fruit and vegetables can stay fresher for 2 – 2.5 times longer.

10.10 Key Imperatives for Government, Agrochemical Companies and Regulatory Bodies

All, from chemical producers, quality/safety/assurers, registration authorities, distributors, retailers, and finally farmers along the value chain are responsive for safe and need based use of pesticides. It is often seen that whenever these men-created disasters occurred, the stakeholders, from the Government to farmers get busy in blaming games. This is most unfortunate and must stop. Each stakeholder must carry on his/her responsibility with utmost honesty and commitment. A fool-proof strict monitoring and evaluation system should be in place before the pesticide put to use. The extension system must ensure effective training to and awareness rising of farmers, and timely availability of quality/safe/registered pesticides to the end user. The Public and Private sector, Farmer Organizations and Non-Government Organizations (NGOs) collaboration is a must for the purpose. The Corporate/Public Social Responsibility must be integrated with Public/Corporate Science Responsibility. A most judicious implementation pathway for the pesticide sub-sector is a high priority. Otherwise, the prevalent accusation games will hurt the cause of safe and accelerated agricultural production.

Product innovation needs to capture emerging market trends and match international standards. It is imperative for the Public and Private Companies in agrochemical space to focus on emerging trends and developments. For next revolution relying on generic agrochemicals won't suffice for the ever increasing demand of the country. Hence, it would become crucial for the companies to adopt innovation and developments such as Genetically Modified (GM) crops, hybrid seeds, seed coating etc. All this would result in better output and yield, disease resistance, enhanced nutritional value, and would reduce pesticides spraying, cost and labour intensity for farmers.

Companies need to undertake product developments which can improve the effectiveness of pesticide usage as well as reduce negative impact on the environment. With the advent of GM crops and increasing popularity of bio-pesticides, environment friendliness of the agrochemicals could be a differentiating factor. Indian companies would need to increase focus on developing new active ingredients rather than just focusing on generics. Research intensity on developing new molecules is extremely low in India, and must be improved considerably to be contemporarily relevant. Indian companies usually spend 1-2 per cent of their turnover on R&D as compared to global companies which spend 10-12 per cent of their turnover on R&D.

Another development in this area is the use of targeted pest protection products that are effective against a particular pest rather than a broad spectrum pesticide which is supposed to target a variety of pests. The thrust is welcome as focused/targeted pesticides are more effective rather than broad spectrum ones. Most crops have a particular strain of pest which is a major nuisance and thus targeted solutions are better than broad spectrum ones. More developments on these lines should follow with such product innovations being linked to the needs of the farmer and the pest related nuisances faced by them.

Companies should look for opportunities to provide a comprehensive agro offering to the farmer. A one stop solution for the farmer ranging from agriculture and farm inputs to procurement, storage and distribution services on the output side would help companies develop sustainable business models. End to end solution not only creates a better reach with the farmers but also turns threats like genetically modified seeds, organic farming etc. into opportunities. Many companies are already following the integrated model. While it has helped the farmers improve their yield, get technical assistance and better value for their produce, it has also helped companies strengthen their presence amongst the farmers.

As mentioned earlier, non-genuine pesticides are a critical challenge which not only impact the industry image but also hamper the crop productivity and soil fertility. Strict actions, regular crackdowns and punishments are, therefore, required to stop the menace and damage caused by non-genuine products. Agrochemical companies as also the regulatory bodies need to work in tandem in order to curtail this menace.

DuPont has introduced several unique solutions which can help identify genuine DuPont products from illegal/counterfeit pesticides. DuPont has introduced DuPont™ Izon®, which is a secure authentication technology - a visible 3D security system with a unique code that helps farmers identify DuPont crop protection brands. A web based verification system or an SMS based verification system allows the farmer to send an SMS to a phone number to validate the authenticity of the product. Another unique solution is DuPont™ Traceology® which is a cloud based product verification system that keeps track of products and provides critical product information such as batch, lot, and part number to verify products. The use of this technology helps prevent the use of counterfeit product and safeguards farmers' interest.

10.10.1 Product Innovation

Towards strengthening domestic pesticide industry and safe use of pesticides, the issues needing immediate attention are to: (i) regulate and encourage the use of cost-effective and environmentally safe pesticides, (ii) harmonise testing procedures, (iii) undertake deregistration of outdated, hazardous pesticides, and (iv) assure point-of-sale quality and farmers protection mechanisms in case of spurious products. In this context it is interesting to note that the central sector scheme on “Monitoring of Pesticides Residues at National Level” comparing the level of pesticides recorded on food commodities in developed countries versus India, had proven that the edible commodities in India are safe. Further, the 2013 report of Sandhya Kulshrestha (Ex-Secretary, CIB&RC) had revealed that no banned pesticide residues were found in any samples tested out of 2170 in 14 different laboratories, and residues of currently used pesticides were detected in 12 samples which is 0.5 per cent of total sample tested. Notwithstanding, the favourable report on MRL, the not so uncommon use of spurious and banned pesticides, defective method and dose of application of pesticides, and use of pesticide cocktails and their adverse multiple effects cannot be ignored. Awareness on part of farmers and dealers and other stakeholders, the status of chemical testing laboratories, intensity of data collection and the methodologies used need serious improvements.

10.10.2 Joint Research and Development Initiatives for Food Safety from Use of Agrochemicals

In international trade of agricultural commodities under World Trade Organization (WTO), in mid-90s, 'pesticide residues' was introduced as one of the trade barriers. This required residues of a pesticide in export food to be compatible with MRL of the importing country and also required absence of any banned or unauthorized pesticide in export food (NAAS 2006). Many food consignments of India were rejected initially due to presence of insecticide residues in wheat, grapes and spices in respective years. Various Liquid Chromatography-Mass Spectrometry-Mass Spectrometry (LC-MS_MS) analytical technique involved multi-residue methods were developed for target, non-target pesticides and unknown toxic contaminants in food for use in import/export food. This has resulted in decreased rejections of export food commodities for presence of residues, thus enhancing Indian export. However, some of the importing countries, such as European Union and USA, keep tightening their MRL particularly on imported items. For example, as per a recent report appearing in Tribune (19 November, 2018) titled "Pest Protocol", Basmati rice, one of the country's key exports, is under cloud, and the export to European Union (EU) had reduced by 58 per cent in January to July 2018. The Government, private sector, especially the rice exporting companies, and the growers, must ensure recommended spray and management schedules o meet the MRL requirements. The entire value chain should be sensitized and strengthened, including suitably trained personal and farmers to judiciously implement the schedule, as being followed in the grapes industry.

Considering several reports of presence of pesticide residues in farmgate and market samples of food commodities, a national project on monitoring of pesticide residues in food commodities financed by the Ministry of Agriculture and Farmers Welfare with headquarter at IARI was started in 2005. It has 25 Indian Council of Agricultural Research (ICAR)/Government laboratories spread all over the country to assist in the work. The objective of the project was to ascertain prevalence of pesticide residues in farmgate and market yard food commodities in the county. To generate reliable and comparable pesticide residues data, all the laboratories have been accredited under National Accreditation Board for Testing and Calibration Laboratories (NABL) as per International Standards Organization (ISO)-17025 for quality assurance. As per recent report more than one lakh food samples have been evaluated during the period 2008-2015. Out of nearly 60,432 vegetable and fruit samples analysed during this period, only (2.4 per cent) samples were found having residues above MRL which is comparable with pesticide residue data of fruits and vegetables of some of the advanced countries.

10.11 Government of India Initiatives:

Some of the initiatives of the Government of India and especially that of ICAR-IARI Division of Agrochemicals are briefly elucidated below:

10.11.1 Soil Health Card Scheme

The GOI had initiated 'Soil Health Card Scheme' in February 2015 which is aimed at improving soil health and reducing input costs for farmer. It will contain crucial information on macro nutrients in the soil, secondary nutrients, micro nutrients, and physical parameters. The Card will be accompanied by an advisory on the corrective measures that a farmer should take to improve soil health and obtain a better yield. The soil health card should also contain information on pesticides residue and microbial health.

10.11.2 Paramparagat Krishi Vikas Yojana

This programme has been launched by GOI to support and promote organic farming and thereby improve soil health. Lately, Zero Budget Natural Farming (ZBNF) with several synonyms has been endorsed by National Institution for Transforming India (NITI) Aayog and the Government and several states are promoting it without any scientific validation. It is hoped that these will encourage farmers to adopt eco-friendly concept of cultivation and reduce their dependence on fertilizers and agricultural chemicals to improve yields. But, the approaches should be critically scientifically verified and analyzed in view of the priority of sustainable food and nutritional security, farmers' income, and poverty alleviation.

10.11.3 New Synthetic and Bio-pesticides

Most of the insect pests, diseases and weeds develop resistance to a pesticide when used continuously year after year. Research for innovative chemistries with different chromophoric group seeking lead from natural resources and alternate mode of action is constantly carried out in search of new active molecules. Hence, establishing R&Ds in Institution and manufacturing units with proper funding is essential. Division of Ag Chemicals has developed large number of products and technologies that have been licensed to industries (nearly 30 licenses). Besides around 700 new organic products were synthesized and evaluated for diverse pesticidal activity (Parmar and Walia 2016). The Agrochemicals Division of IARI, in collaboration with the Divisions of Agricultural Economics and Environmental Sciences, should undertake an impact study of its various products (formulations).

10.11.4 Natural Products

Besides lipids and medicines in neem as effective pesticides and nitrification retardants, several natural products of plant, animal or microbial origin have been explored and bioactive constituents identified.

The Council of Scientific and Industrial Research (CSIR)- Indian Institute of Chemical Technology (IICT) is starting a Mission Mode Project on Innovative Processes and Technology for saving crop losses due to pests, will also contribute to food security. The Project aims to develop processes for several Agrochemicals, but none of the active ingredients in these chemicals were invented in India or by any Indian company. It is high time that India must prepare herself to be an inventor of new molecules. Further, being a CSIR Project, all the seven participating laboratories belong to CSIR. ICAR should make an attempt to join this Mission. Further, we should have national capacity to create new molecules.

10.11.5 Agrochemical Formulations

Several products based on dillapiole, dihydrodillapiole were commercialized as pyrethrum synergists. Controlled release formulations involving several effective pesticides employing novel carriers, encapsulation materials and nano ranged emphiphilic polymers were developed and evaluated extensively in laboratory and field for their release kinetics and performance. Nano pesticides involving sulphur, hexaconazole. pyridalyl and acetamiprid were prepared to augment the pesticidal efficacy and evaluated for their biosafety. The bioactivity of nano pesticides was many fold higher compared to conventional pesticides.

10.11.6 Safety Evaluations and Related Studies

More than 1000 pesticide schedules were examined and recommended for pest control in agricultural crops such as vegetables, cereals, pulses, oilseeds, cash and other crops for dissipation and/or persistence for the active ingredient or their toxic metabolites in edible produce. The safe schedules have been recommended for adoption by farmers. These studies have enabled establishing of maximum residue limits (MRL), waiting periods etc. in cases where such limits were nonexistent. Effect of non biotic factors such as sunlight, play a role in the degradation of pesticide in the environment.

Pesticide residue research was carried out for safety to human beings by determining terminal residues in harvest produce and waiting period from supervised field trials. Studies relevant to environmental safety such as persistence in soil was carried out at Agrochemicals Division of IARI from dissipation half-lives as influenced by soil edaphic and climatic factors; adsorption, leaching and abiotic and biotic transformations involving microbial, chemical and photo degradations; and plant metabolism. Studies were also conducted on long term field studies especially with herbicides for accumulation and carry-over effects, persistence in soil and toxic metabolites. Adsorption-desorption of more than 45 pesticides, chemical and light induced transformations, microbial degradation have been carried out.

Contribution of agricultural application of pesticides on quality of river water reservoirs was investigated along a part of Ganga river basin at Farukhabad in Uttar Pradesh (UP) most of the sample of soil collected were found contaminated with oganophosphorus (Ops) and organochlorine (OCs) pesticides. Vegetable samples collected from this region were also contaminated (Agnihotri *et al.* 1995).

The IARI-Agrochemicals Division has played a major role in development and sharpening of analytical techniques for pesticide residue analysis. Several spectrophotometric, chromatographic [gas chromatographic (GC), HPLC] methods have been standardized. Protocols are available for simultaneous analysis of >78 pesticides as mixture in rice and tea in a single run. And >200 pesticides as mix in single run by LC-MS-MS from vegetables and fruits. Mass spectrometry technique with advanced quadrupole detector made detection and identification of pesticides in fruits and vegetables simple and easy (OECD, 2007).

Detailed studies were conducted to decontaminate pesticide residue from food commodities, water and environment. Bioremediation of contaminated soils with acclimatized microorganisms etc under taken for DDT, chlorpyrifos, atrazine, alachlor, mtolachlor, bifenthrin, fipronil etc. (Kulshrestha, 2009). Further, research has been carried on neutrceuticals and high value phytochemicals, nitrification inhibitors and hydrogels. Education and human resource development by providing theoretical and practical training to post-graduate students should be strengthened. The Division at IARI should be particularly strengthened, in chemistry research to be able to come up with new molecules which may favourably compete with such products being developed by private sector and several public/private sector universities in developed countries like USA, Japan, Germany, and also in China. Let industries get together and support creation of a national centre at IARI for innovating new, safe, efficacious molecule/s.

10.11.7 Pesticide Referral Laboratory

Pesticide Referral Laboratory (ISO/IEC:17025:2005; NABL accredited) established under ICAR-National Agricultural Technology Project - Team of excellence (NATP-TOE) generates globally acceptable data for export certification and international trade. The competence of the laboratory has been demonstrated by participation in international and National proficiency testing programmes. It has state of art facilities in the country and is manned by qualified, experienced and competent team of scientists and technicians. It is the first such laboratory in India established in the public sector. The laboratory undertakes need based analysis of the referred samples. It also serves as a national facility for capacity of trained and super speciality human resource in pesticide residue analysis, and develops and validates analytical methods for the analysis. Preparation of reference materials of pesticides is also undertaken. Thus, safety evaluation studies on new synthetic agrochemicals prior recommending to farmers takes full care for safety to consumers (Kulshrestha *et al.* 2005).

10.12 Integrated Pest Management (IPM)

Integrated Pest Management (IPM) which promotes biological, cultural and mechanical methods of pest and advocates need based, judicious use of pesticides must be the most preferred environment friendly approach for managing pest problems. It is an ecological approach and strives for eliminating or significantly reducing the use of pesticides and at the same time containing pest growth at acceptable levels.

IPM is thus a big part of the solution. Increasingly it is being adopted in both developed and developing countries for long-term, sustainable agriculture that achieves adequate, safe and quality food production, improves farmer livelihoods and conserves non-renewable energy. Its specific benefits are:

- Improved crop profitability owing to better pest control measures & appropriate use of crop protection solutions
- Stable, reliable and good quality crop yields
- Fall in intensity of pest infestations
- Reduced potential for problems of pest resistance or resurgence

The IPM strategy seeks judicious integration of three components: (i) prevention through crop and varietal choice and adoptions of cultural and soil water management practices. (ii) Monitoring for accurate assessment of the pest/disease build up, even using Geographic Information System (GIS) and remote sensing, before adopting interventions and (iii) Intervention undertaken to reduce incidence of pests and disease to economically acceptable level, which include cultural, physical, biological, and chemical measures. Although the efficacy of the approach is well demonstrated and IPM is a priority program of the Government, the ground level adoption by the farmers is suboptimal.

Apart from IPM, newer molecules with better efficacy are being developed. These molecules such as neo-nicotinoids, sulfonylureas, imidazolinones triazoles etc. require lesser volume of chemicals per net treated area. Newer products such as biological pesticides, seed treatment chemicals, and semiochemicals are being introduced. Seed treatment chemicals require a very small volume of the chemical as compared to normal crop protection chemicals (Kulshrestha et al. 2003).

10.13 The Way Forward

Towards attaining evergreen economy through green agriculture and green chemistry, the following actions (steps) are necessary:

In coming years, new agrochemicals should focus on developing new processes and products with sustainability as the core principle. This requires developing a collaborative platform in which the scientists, government and regulatory bodies, farmers associations, manufacturers and farmers come together to promote safe and judicious usage of pesticides. Future lies with higher production of generic products, newer safe chemistry and products, efficient formulations and growth in herbicides and fungicides.

In coming years, the need for safe and effective use of crop protection chemicals will further increase to brace with larger climatic variations and emergence of new invasive insects, weeds and diseases. Hence, it is important for companies to invest today in science and practices which promote safe and judicious use of crop health chemicals. Judicious use of pesticides implies using the right product, with correct dosage and with correct application methodology. When used judiciously, the products deliver maximum impact on the target species. Therefore, it is critical for both the government and for crop protection chemicals manufacturers to work closely with the farmers and farmers associations to educate them on safe and judicious use of existing pesticides as well as advancements happening in products on a regular basis.

Crop protection products can also be considered for environmental impact audit of their existing products and adopt green chemistry practices. To move to "green practices", in the short term, companies can implement zero discharge solutions, adopt Chemical Oxygen Demand (COD) reduction techniques and develop collaborative platforms. In the medium term, companies can implement solvent recovery practices, explore alternate green solvents, evaluate biocatalysts and microwave chemistry technology. Embracing farmers to promote judicious usage of crop protection products will be an appropriate way to develop a long term sustainable business model in Crop Protection Chemicals.

The green chemistry practices cannot be done in isolation. It is imperative to build a collaborative ecosystem in which the academia, industry, government and regulatory bodies come together and create opportunities for the industry, academia and the entrepreneurs to test, scale-up and commercialize their ideas in the domain of green chemistry practices. Future agrochemicals will serve as a facilitator of the Indian agriculture as also of national economy.

National capacity in plant health agro-chemical research, technology and innovation, should be strengthened. The CSIR, ICAR and other concerned research and technology development centres, including corporate centre, should create world class centre of excellence which must be able to dynamically discover and produce new more selective, effective and safe molecules/chemicals.

The Government must pass the latest/updated 2017, Pesticide Management Bill and strictly enforce regulations to ensure effective implementation of all the rules, and laws, especially the elimination of the unethically high incidences of spurious, counterfeit, banned, misbranded and substandard agro-chemicals. The point-of-safe quality assistance and farmers protection mechanism in case of spurious products must be strengthened. Transparent system of licensing should be established and popularized.

As the bill seeks to improve the regulations in the manufacture, inspection testing, and distribution of pesticides, a Central Pesticides Board to advise the Government should be constituted, which among other things, should also oversee fixation of tolerance limits by FSSAI for pesticide residues on crops and commodities. The state governments are envisioned to implement the provisions. While FSSAI is mandated to fix the MRL, the relevant provisions of the Food Safety and Standard Acts should be enforced simultaneously. The bill must also specify penalties for pesticide inspectors and enforce their implementation. The large number of deaths due to pesticide spraying reported in recent years, should bring the focus on the pending Pesticide Management bill.

Agro-ecologically differentiated proven IPM technology packages should be adopted throughout, the country. Farmer's awareness, training and strong extension support, including e-National Agriculture Market (NAM) linkage, is essential.

The human resources and awareness along the entire agri-chemicals management chain, from farmers to industry leaders, need urgent strengthening; university curricula should be updated to internalize the latest technological safety, and agri-business developments, with emphasis on practical training. Barring IARI and a couple of other public sector centres, agro-chemcials education in the National Agricultural Research, Education System is rather weak. The situation should be critically assessed and necessary solutions provided in time. The Policy Makers should also have a clear science-informed vision to formulate effective policies on Crop Health Management and pesticide use.

Data on various aspects of chemical and other pesticides from different sources seldom reconcile. All stakeholders and concerned ministries should jointly address this major shortcoming to enable effective planning, policy formulation, programming and implementation.

The Department of Agriculture, Cooperation and Farmers Welfare of the Ministry, hopefully in close consultation with other directly concerned Ministry of Food and Civil Supplies, Ministry of Commerce and Trade, and Ministry of Health is in process of bringing out an updated pesticide Management Bill. The Draft Bill 2017 has been widely circulated and hoisted on the official website of the DAC & FW for comments of concerned stakeholders within stipulated time frame. The NAAS had interacted with the DAC & FW and shared its policy papers on the subject. I am pleased that several of the recommendations of the NAAS Policy Paper 45 on Agrochemicals Management have been internalized in the Draft Bill. However, a few aspects which seek deeper scientific evidences need to be further updated, Towards this, the NAAS should organize a Brainstorming Policy Dialogue session to internalize some of the relevant goals of the Sustainable Development Goals, 2030, FAO / WHO new initiatives, and Paris Declaration.

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Chapter 11

Innovations for Transforming Agriculture

11.1 Why Innovations in Indian Agriculture

"Innovation is the process by which inventions are produced – it may involve new ideas, new technologies, or novel applications of existing technologies, new processes or institutions, or more generally, new ways of doing things in a place or by people where they have not been used before" (Juma *et al.* 2013). Agricultural innovations are needed to enhance productivity growth through increasing efficiency in the production process and along the entire value chain, formulating and implementing evidence-based policies, smart institutions, skilled human resources, smart technologies, functional infrastructures, access to quality information, insurance services, and employment security towards meeting the SDGs (Ganguly, Gulati and Van Braun, 2017). IFPRI study has shown that greater the emphasis on agricultural research for innovation, higher has been the growth of agriculture GDP.

Agriculture employs more than 50 per cent of the people (nearly 700 m), accounts for 15 per cent of GDP, and is almost three times more effective than other sectors in alleviating hunger, poverty, and undernutrition, the sector (agriculture) matters the most in India. Thus, besides enhanced production, Agriculture and Food System (AFS) should emphasize ecological efficiency, More from Less for More (MLM), Save and Grow, environmental health, nutritional adequacy, inclusiveness, sustainability, and remunerative income (Doubling farmers' income by 2022). Inter-disciplinary, innovative and integrative approaches, adequate investment, vibrant STI, trained human resources, and responsive and effective implementation are a must to reach the unreached to help build a Zero Hunger New India.

Agriculture is not only the main source of employment and livelihood security for nearly 50 per cent of India's population, bulging to be the largest in the world by 2027, but also as a business opportunity, service provider, industry, and ecosystem protector. Reflecting on the journey from the Green Revolution to the Gene Revolution, the need for innovations to drive congruent acceleration of productivity, profitability, sustainability, equity and inclusivity can hardly be overemphasized. Besides leaps in genetic enhancement, innovations are increasingly needed in precision agriculture, natural resource management, climate smart agriculture, mechanization, micro-irrigation (per drop more crop), ICT, digital technology, farmer-market linkage, value chain and post-harvest management, renewable energy, price realization, and, of course, doubling of farmers' net income.

With a population of over 1.3 billion and expected to be the most populous country in the world by 2027 and likely to reach nearly 1.7 billion by 2050, India will exceed China by about 400 million people, and its demand for food, feed and fiber will keep increasing substantially. Expecting the GDP growth rate of 7-8 per cent over the next decade or more, fast expanding urbanization, the number of people in middle classes annually growing by 10-

12 per cent, and high expenditure on food (40-45 per cent), India will require to step up its food supply significantly to meet the expanding demand. However, with shrinking land holdings - average operational holding size at around 1 hectare and about 85 per cent farmers being marginal and small, operating on less than 2 hectares of land, increasing productivity of smallholder farmers will be critical.

Moreover, per capita water availability at about 1400 m^3 is already between stress and scarcity zones. India is projected to suffer the most by climate change in terms of rising temperatures and erratic monsoons resulting in recurring droughts and projected to lose 25 per cent of its agricultural production, thus further jeopardizing food and nutrition security and farmers' incomes. India faces a huge challenge to grow more and grow sustainably with limited resources. Moreover, agricultural resources including land, water and labour face competition from non-agricultural sectors. Hence innovations all along agricultural value chains will be needed for India to sustain its food and nutrition security as well to provide income and livelihood security to farmers. Realizing that India is home to one-fifth of the world's poor people and nearly 35 per cent of stunted children, and agriculture is the best bet to fight the maladies, innovation imperatives in agriculture for attaining nutrition security can hardly be overemphasized.

Accounting for almost one-fourth of the world's smallholder farmers, innovation pathways in India are a must for effectively accelerating gains in productivity, climate resilience and risk mitigation, social protection, price realization by farmers through market linkages, credit, insurance, and increased income, by ensuring congruence of high productivity, profitability and sustainability. Further, Ganguly, Gulati and Von Braun (2017) have elucidated the need for access to quality information and services, boosting employment opportunities for the youth, improving accessibility and affordability of healthy and safe food, prevention of losses and wastes, value addition along the chain, optimizing utilization of natural resources (micro irrigation), per drop more crop, and energy efficient power sources (like solar).

11.2 Biological Innovations

11.2.1 Green Revolution

An innovation of its own kind, Green Revolution was instrumental in transforming India from a ship-to-mouth condition to the Right to Food Bill status, and rendering the country a major foodgrain and other agricultural products exporter. The Revolution was triggered by the adoption, adaptation and development of semi-dwarf, input responsive, photoperiod nonsensitive and widely adapted high yielding varieties of rice and wheat, and hybrids in maize, pearl millet, sorghum, and other crops. Innovations in varietal development and seed technology to enhance productivity and production, resilience to abiotic and biotic stresses, efficient use of soil, water, nutrient, and energy have greatly benefitted farmers through increased yield, savings in production costs, increased production, and higher incomes. Within ten years of the release of the rice and wheat HYVs between 1965 and 1975, their adoption had increased almost from zero per cent to 40 and 70 per cent, respectively. During the same period, rice paddy yield had increased from 1.3 to 1.9 t/ha and production from

45.88 to 73.35 mt, whereas the wheat yield had gone up from 0.9 to1.3 t/ha and production from 12.3 to 24.1 mt (Table 1).

Table 1. Area, production and yield of wheat and rice paddy during 1965 to 1975

Year	Area (m ha)	Production (m t)	Productivity (t/ha)
Wheat			
1965	13.4	12.3	0.9
1970	16.6	20.1	1.2
1975	18.0	24.1	1.3
Rice Paddy			
1965	35.5	45.88	1.3
1970	37.6	63.33	1.7
1975	39.5	73.35	1.9

Source: Agricultural Statistics (MoA&FW) GoI, various years

The above unprecedented success was due to synergistic congruence of new effective technologies, availability of critical inputs, farmers-market linkage and remunerative prices, farmers' enthusiasm, and political will.

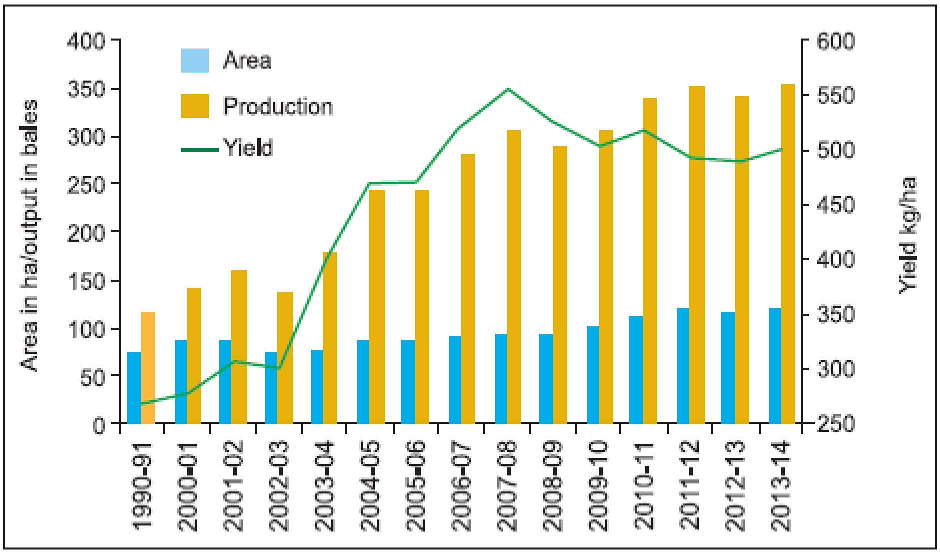
11.2.2 Gene Revolution

Innovations in the field of biotechnology, molecular biology, genomics, and synthetic biology have rendered crop, livestock, fish and microbe improvements highly precise, targeted, and accelerated – known as gene revolution. Starting from hardly 2 million ha under GM crops in 1996, today nearly 200 million ha in over 30 countries, of which over 20 are developing countries, including China and India which together account for nearly 40 per cent of the world population, grow GM crops. During the past 20 years or so, farmers gained from increased productivity and production and reduced cost of production to the tune of nearly US$ 160 billion at the farm level, let alone the huge environmental gains due to reduced pesticide use. On an average, GM technology adoption has reduced chemical pesticide use by 37 per cent, increased crop yield by 22 per cent, and increased farmers' profit by 68 per cent (Kuimpy and Qaim, 2014).

11.2.2.1 Bt Cotton

Genetically modified (GM) transgenic crops carry "transgene(s)" conferring either a new trait to the plant, which was not earlier present in the native form (*e.g.* insect resistance, as in *Bt* cotton) or enhance the already existing trait (*e.g.* nutritional quality as in Golden Rice). *Bt* cotton is the only transgenic crop commercially cultivated in India, over an area of about 11 million hectares, 92 per cent of the cotton acreage. First released in the year 2002, with the approval of the Genetic Engineering Approval Committee (GFAC) of three Bt hybrids- MECH 12, MECH-162 and MECH-184, it has created a "*Gene Revolution*" in the country (Figure 1). Using five events, namely, Bollgard I, Bollgard II, GFM-Cry1A, Event 1, and MLS9124, five groups of *Bt* cotton varieties were commercialized in India. Using these events, 40+ companies, adopting regulatory procedures of the Government have gotten 800+ hybrids developed and registered carrying the Bt technology.

Figure 1. Revolution in cotton production and productivity in India after the introduction of Bt Hybrid in 2002 (Area in 100,000 ha and production in 100,000 bales)



Source: James (2014)

The revolutionary impact of the Bt Hybrid Cottons in India was manifested as below:

- Over 11 million ha of total cotton area of 12 million ha, 92 per cent is under *Bt* hybrids
- More than 7 million of 8 million farmers have opted for Bt cotton, most of them are smallholders
- Average cotton yield had increased by 70 to 100 per cent
- A seven fold reduction in pesticide use in cotton has been recorded
- Net income of *Bt* cotton farmers is 53 to 71 per cent higher than that of non Bt cotton farmers; averaging additional income of US $ 250/ha
- Today, India, with 39 million bales production of cotton lint, ranks first in cotton production in the world
- The Country has transformed from being an importer until 2004 to an exporter now of nearly 9-10 million bales each year, accounting for nearly US$ 3 billion
- The higher yield and increased production has created millions of additional jobs.

However, in recent years, some instability, even decline in some years has been witnessed in cotton production (Table 2).

Table 2. Cotton production (mt) in the world as well as in the top three cotton producing countries during 2013/14-2017/18

Geographic entity	2013-14	2014-15	2015-16	2016-17	2017-18
World	26.23	26.24	21.48	23.08	26.63
India	6.77	6.56	5.75	5.89	6.15
China	7.00	6.60	5.20	4.90	5.89
USA	2.81	3.55	2.81	3.74	4.55

Source: FAO Stat Book, 2014 to 2018

The decline or stagnation in production is attributed mainly to the increasing incidence of pink bollworm. The decline in Bollgard I began in 2009 and in Bollgard 2 in 2014. USA has already come up with Bollgard 3 to manage the pest. Indian biotechnologists have not risen to the challenge in creating the desired events. Moreover, the farmers have not followed the recommended practices of growing 150-160 days varieties/hybrids, timely planting, rows of refuge variety, and adoption of IPM. A holistic approach is needed to keep the pest population below the threshold level. The recent decision of the Supreme Court against protecting Monsanto's proprietary rights on Bt cotton will discourage the multinationals in sharing their new biotech products. But, this should induce the local private sector to join hands with public sector research system to develop new events and products. Other routes of molecular breeding, especially translational genomics approach for transformational changes in cotton productivity and quality should be institutionalised through a consortium approach.

11.2.2.2 Other GM Crops

Seeds/materials of transgenic events have been imported for research purposes on a regular basis through the ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi, which is the designated nodal agency to issue import permits and undertakes the quarantine processing of transgenics as per the Government of India Notification and Plant Quarantine Order. Besides quarantine processing, molecular testing for checking the specific transgenic elements of imported transgenic seed/planting material is undertaken prior to release to the indenters/importers.

The imported or indigenously developed transgenic crops/ events undergo field trials at Biosafety Research Levels, BRL I and BRL II. The Review Committee on Genetic Manipulation (RCGM), functioning in the Department of Biotechnology, is the Regulatory Authority for BRL-1 trials. The Genetic Engineering Appraisal Committee (GEAC), functioning in the Ministry of Environment & Forests and Climate Change, is the Regulatory Authority for BRLII trials. Besides cotton, transgenics are ready for field trials in several crops (Table 3). In 2014, GEAC approved field trials of transgenic mustard, Bt chickpea, transgenic rice for nutritional enhancement, and Bt brinjal (James, 2014).

Table 3. Genetically modified crops ready for field trials in India, 2014

Crop	Organization	Transgenic(s)	Trait	Pending status
Cabbage	Nunhems, Gurgaon Sungro Seeds, New Delhi	cry1Ba and cry1Ca cry1Ac	IR	
Castor	Directorate of Oilseeds Research, Hyderabad	cry1Ec and cry1Aa	IR	Event selection
Cauliflower	Sungro Seeds, New Delhi	cry1Ac	IR	
	Nunhems, Gurgaon	cry1Ac and cry1Ca	IR	
	Mahyco, Jalna	cry1Ac and cry2Ab	IR	Final stage
	Mahyco, Mumbai	Ala-At (MAH-11501 – MAH-11512)	NE	Event selection
	Dow Agro Sciences, Mumbai	cry1Ac and cry1F	IR	Final stage
	JK Agri-Genetics, Hyderabad	cry1Ac and cry1Ec	IR	BRL-2 trials
	Metahelix, Bengaluru	cry1C	IR	
	CICR, Nagpur and UAS, Dharwad	cry1Ac	IR	BRL-1 trials
Cotton	CICR, Nagpur	cry1Ac	IR	Event selection
		cry1F	IR	Event selection
	UAS, Dharwad	cry1Ac (Event D1 Ac to D7 Ac)	IR	Event selection
		cry1Ac (Event SB1 Ac to SB7 Ac)	IR	Event selection
		cry1Ac (Event J1 Ac to J24 Ac IR)	IR	Event selection
		Cry1Ac x cry1F (Event BNAcF)	IR	Event selection
	Bayer BioScience Pvt. Ltd, Gurgaon	Bar, cry2Ae,	IR, HT	BRL-1 trials
		cry1Ab, 9GHB119 x T304-40)	HT	BRL-1 trials
		vip3A (Cot 102)	IR	BRL-1 trials
	Monsanto Holdings Pvt.	cry1Ac, cryAb,	IR	BRL-1 trials

	Ltd., Mumbai	vip3A (MON 15985 x COT 102) (Bollgard III)		
		cry1Ac, cryAb, vip3A, CP4EPSPS (MON 15985 x COT 102 x MON 88913)	HT, IR	BRL-1 trials
Groundnut	ICRISAT, Hyderabad	Rice chit and DREB	FR, DST	-
Maize	Monsanto, Mumbai	cry2Ab2 & cryA. 105 & CP4EPSPS	IR, HT	Final stage
	Pioneer/Dupont, Hyderabad	cry1F and CP4EPSPS	IR, HT	BRL-2 trials
	Dow Agro Sciences, Mumbai	cry1F	IR	BRL-1 trials
	Pioneer Overseas Corporation Hyderabad	ms45, zm-aa1(DP-32138-1)	Male sterility fertility restoration	BRL-1 trials
	Sygenta BioScience Pvt. Ltd. Pune	cry1Ab and m-epsps		
Okra	Mahyco, Mumbai	cry1Ac	IR, HT	BRL-1 trials
	Sungro Seeds, Delhi	cry1Ac	IR	
	Bejo Sheetal, Delhi	cry1Ac	IR	
	Arya Seeds, Gurgaon	CP-AV1	IR	
Potato	CPRI, Shimla	RB	DR	
		GA20 Oxidase 1	AP	
	NIPGR, Delhi	Ama1	NE	
		cry1Aabc	IR	
Rice	IARI, New Delhi	DREB	DST	
	TNAU, Coimbatore	Chi11	FR	
	MSSRF, Chennai	MnSOD	DST	
	DRR, Hyderabad	cry1Ac	IR	
		cry1Ac, cry2Ab	IR	
		Event OS_A17314	HT	BRL-1 trials
	Mahyco, Mumbai	OsNHX1	Salinity tolerance	Event selection
	Bayer Crop Science,	cry1Ab and	IR	Event

	Hyderabad	cry1Ca		selection
Crop	Organization	Transgenic(s)	Trait	Pending status
	JK Agri Genetic Ltd. Hyderabad	JKOsE081 x E016/IR	IR	BRL-1 trials
	Devgeri Seeds and Crop Technology Pvt. Ltd., Secunderabad	OSLR-01 OSLR-04	IR	BRL-1 trials
		OSHT-01 OSHT-02	IR	BRL-1 trials
	BioSeed Research India Pvt. Ltd. Hyderabad	glyl and glyll	DST	BRL-1 trials
		T1-3, T1-5 and DREB	DST	BRL-1 trials
	Pioneer Overseas Corporation, Hyderabad	cry 1Ab+cry1Ad	IR	Event selection
	Metahelix Life Science Ltd. Bengaluru	cry1Ab	IR	Event selection
Sorghum	NRCS, Hyderabad	cry1B	IR	
	Sugarcane Research Institute, UP	cryAc	IR	
Sugarcane	IARI, New Delhi	Antisense replicase, ACC Synthase gene, osmotin, DREB	IR, DR,FR, NE, DST	
Tomato	Mahyco, Mumbai	cry1Ac	IR	
	Avesthagen	NAD9	NE	

Source: Reports of Concerned Organizations.

Abbreviations: *TNAU- Tamil Nadu Agricultural University; IIVR- Indian Institute of Vegetable Research; UAS-University of Agricultural Sciences; CICR-Central Institute of Cotton Research; ICRISAT-International Crop Research Institute for Semi-Arid Tropics; CPRI- Central Potato Research Institute; NIPGR- National Institute of Plant Genome Research; IARI- Indian Agricultural Research Institute ; MSSRF- MS Swaminathan Research Foundation; DRR- Directorate of Rice Research; NRCS- National Research Centre on Sorghum; AP-Agronomic Performance; BR-Bacterial Resistance; DR- Disease Resistance; DST- Drought and Salinity Tolerance; FR- Fungal Resistance; IR- Insect Resistance; HT-Herbicide Tolerance; NE-Nutritional Enhancement.*

11.2.2.3 Genomics and Gene Editing

Innovations to promote genomics and gene editing must be priority novel approaches to ensure comprehensive food, nutritional, economic, social and environmental security. In the new era of genomics, phenomics, proteomics and other omics, the availability of high quality reference genomes of crop plants has accelerated the discovery of genes, QTLs and DNA markers linked to the traits of agronomic importance, which are now being routinely applied in molecular aided selection (MAS) of crop varieties for increased selection efficiency with utmost precision, heralding a new thrust area called Molecular Breeding, which is being routinely used in several crops like wheat, rice, maize, mustard, pigeonpea, chickpea and soybean under Indian context with excellent success. ‘Super domestication’ of crops and the genetic dissection and breeding for complex traits is now routinely used. Progress in the use of GM crop technology on the other hand has suffered due to the lack of clear policy, and so far Bt-cotton remains the only commercialized GM crop in India.

NAAS has issued several guidelines and policy options for developing and commercializing transgenics and other biotech products. These include the NAAS Policy paper 52 “Biosafety Assurance for GM food Crops in India”, 2011; Policy Brief “to Accelerate Utilization of GE Technology for Food and Nutrition Security and Improving Farmers’ Income”, 2016; and the Declaration on Transgenic Mustard (see the Box 1). These recommendations have been widely circulated in the country and outside and specifically brought to the attention of concerned Minister and Department Heads for necessary action. But, baseless fear, emotion and non-scientific considerations continue to deny the farmers and other stakeholders the disruptive technologies and innovations which will sustainably transform their socio-economic status.

Box 1. NAAS Resolution on Commercialization of GM Mustard, 2017

Whereas, The National Academy of Agricultural Sciences (NAAS), presently comprising nearly 625 Fellows, is the national think-tank for analyzing technological, socio-economic, and eco-environmental aspects of agricultural and food systems transformation and for suggesting holistic solutions for sustained, inclusive and accelerated agriculture-led development;

Whereas, The best bet for alleviating the stubbornly high incidences of hunger, undernutrition, and poverty in an agriculturally important country like India, and that efficacy of such an agriculture will be underpinned by the development of ever-improving technologies and technological innovations as well as their effective adoption to produce More from Less for More (MLM);

Whereas, Despite ushering in the Green Revolution during the past 50 years and achieving food self-sufficiency and Right to Food based on home-grown food and becoming a formidable exporter of rice, cotton and other commodities, the situation of edible oilseeds remains gloomy;

Whereas, India meets 60 per cent of its demand for edible oils through imports, costing nearly Rs. 80,000 crore annually, let alone the opportunity lost for the farmers to enhance their agricultural productivity and income, and national average yield of oilseed crops is low and sluggish;

Whereas, Brassica/rapeseed mustard is an important oilseed crop of India, occupying 6.6 million hectares of the 33 m ha global area, of which 8.5 m ha in Australia, Canada, and USA is under GE Mustard, and farmers in these countries have been reaping socio-economic and environmental benefits from GM canola since 1996, rendering Canada as the foremost exporter to India;

Whereas, In order to enable India also to benefit from GM mustard, our scientists have toiled hard during the past 20 years to develop promising biotech mustard varieties, such as mustard hybrid DMH-11, using *barnase-barstar* system to produce stable male sterile and fertility restorer lines for hybrid seed production;

Whereas, In field trials, DMH-11 has out-yielded the national and zonal checks by 20 to 30 per cent, and future breeding using these two transgenic events will provide mustard hybrids with canola quality and better yield through mustering extensive diversity available in mustard in the country for creating progressively higher yielding superior multi-trait hybrids;

Whereas, appreciating that regulatory approval is an essential requirement for commercialization of GE crops, India has developed a multi-tier regulatory system, which is one of the most robust regulatory systems in the world to address the biosafety and environmental concerns;

Whereas, The DMH-11 hybrid and its parental lines were rigorously tested for biosafety as per the guidelines and procedures, and all the biosafety studies conducted were submitted to GEAC in September 2015, and clearance from GEAC has been accorded on May 11, 2017, after thorough analyses by the expert committees;

Whereas we have apprised ourselves of all the conducted studies and unequivocally state that this technology is as safe as the non-GE mustard and will help the farmers and the country in improving its edible oils economy;

Whereas, The scientific and regulatory authorities around the world have consistently and repeatedly refuted the unfounded concerns of the activists, the Academy is deeply concerned about unscientific and ill-motivated attacks on the use of the GM mustard hybrid for improving the edible oil economy in India;

Therefore, towards greening the edible oil economy and connecting the people to nature on this World Environment Day, June 05, 2017, now, we the Fellowship (nearly 200 at this AGM) of the National Academy of Agricultural Science (NAAS), New Delhi, resolve that:

- The Central and State Governments should immediately endorse the recommendations of the GEAC so that the coming growing season can be fully utilised for the multiplication of parental lines and production of hybrid seed, which will hasten the environmental release of the two mustard parental transgenic events and hybrid DMH-11, thus allowing this technology to be available to farmers soon at a low-cost, and to breeders, to develop better and better hybrids in future
- Having fully met the regulatory, biosafety, and performance requirements, a biotech product must not be denied to the farmers, who should have options to make informed choices, and empowered to become globally competitive in the fast changing world
- All stakeholders must have full faith in the power of science & technology and the national regulatory & scientific agencies to improve our agricultural and food system productivity, profitability, and sustainability in perpetuity so that we not only help the farmers in improving their income and help the country in reducing the burgeoning edible oil deficit, but also ensure that science is not denied the opportunity to serve the society, and
- Finally, the government should proactively support the agricultural scientists to pursue frontier sciences and to take new developments in science and technology to the farmers, as delays in decision making will only dishearten and de-motivate the scientific community, particularly young scientists.

The Center of Excellence in Genomics and System Biology (GEGSB) at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) thorough its collaborative efforts has developed a large number of genomic resources, including genome assemblies for 9 crops and several improved lines through molecular breeding. Its translational genomics approach has transformed the so-called ‘orphan crops’ to ‘genomic resource-rich crops’ and contributed to develop several improved lines in some dryland crops. (Varshney, 2019). Through deploying next-generation sequencing (NGS) technologies, it has developed high quality reference genomes for chickpea, pigeonpea, groundnut, sorghum, and pearl millet – the so-called orphan crops in dryland regions (Table 4). Keeping in view the fast changing climate, the diminishing natural resources, the higher incidence of poverty, hunger and undernutrition, increasing population pressure and food demands, greater attention is needed for sustainably enhancing the productivity, production and agro-ecological security of the vast rainfed areas. In this context a national program on genomics, alongwith a centre of excellence, for rainfed agriculture may be created to complement the ICRISAT centre.

Table 4. Advances in the genomics, trait mapping and molecular breeding in the ICRISAT mandate crops during last 11 years.

Feature	Chickpea		Pigeonpea		Groundnut		Sorghum		Pearl Millet	
	2007	2019	2007	2019	2007	2019	2007	2019	2007	2019
Genomic resources										
Genome assembly	No	***	No	***	No	**	No	***	No	***
Transciptome assembly	No	***	No	***	No	***	No	**	No	**
Genetic maps	*	***	No	***	*	***	**	***	*	***
Market genotyping platforms										
SSR markers	**	***	*	***	*	***	***	****	*	***
SNP markers	No	***	No	***	No	**	**	****	No	****
DArT markers	No	***	No	***	No	***	No	***	No	*
KASP assays	No	***	No	***	No	**	No	No	No	No
Golden Gate	No	**	No	**	No	**	No	No	No	No
SNP arrays	No	***	No	***	No	***	No	No	No	No
Trait mapping										
Biotic Stress	*	***	No	***	*	**	**	***	*	**
Abiotic Stress	*	***	No	**	No	*	*	***	*	**

Other traits	*	***	No	**	*	***	*	**	*	***
Diagnostic markers	No	***	No	***	No	***	No	**	No	**
Molecular breeding products										
Superior lines	No	***	No	No	No	***	*	**	*	**
*limited; **optimum; ***abundant; ****highly abundant; No- non availability										

Source: ICRISAT

For harnessing genetic diversity from germplasm collection in these important crops, various re-sequencing efforts were carried out, such as 'The 3,000 Chickpea Genome Sequencing Initiative'- an international effort to sequence and phenotype the chickpea global composite collection. Similar efforts were carried out in pigeonpea, groundnut, sorghum, and pearl millet. Genome-wide association studies using resequencing and genotyping data together with multi-location phenotyping data have provided marker-trait association in several cases. Further, through a collaborative interdisciplinary approach, 20 to 50 traits have been mapped in the ICRISAT mandate crops. The efforts have resulted in several superior lines for a number of traits in different crops, and the genomic selection in crop improvement programs is in full swing to develop improved varieties, especially climate resilient varieties in dryland region (Varshney R.K. *et al.,* 2017).

The recent disruptive innovation of asexual propagation through seeds of hybrid rice by Sundaresan *et. al,* 2018 is indeed a dream come true. Heterosis exploitation is now possible in any crop without going through the usual female x male crossed F1 seed production, which has to be made every year and sold on premium. Seeds without sex produced by hybrids will breed true in subsequent generations, thus can be saved by farmers as F1 seeds for further seeding. The management of Baby Boom (BB) genes, alongside substituting mitosis for meiosis (MiMe), could revolutionize this unique farmers-friendly asexual propagation through synthetic apomictic seeds. The technique also enables creation of mapping populations for economic traits and accelerated genetic improvement.

Genome editing technology is currently among the most promising in terms of applied biological research with huge economic potential. Genome editing refers to the strategies and techniques developed for the targeted, specific modification of the genetic information of genome of living organism or cells through the use of nucleases like (i) Meganucleases (ii) Zinc finger nucleases (ZFNs), (iii) Transcription Activator-Like Effector-based Nucleases (TALEN) and (iv) CRISPR/Cas system. These nucleases/nickases create site-specific double-strand breaks (DSBs) at desired locations in the genome. The induced double-strand breaks are repaired through non-homologous end-joining (NHEJ) or homologous recombination (HR), resulting in targeted mutations ('edits').

The genome editing technologies are much more precise and have revolutionized the product development cycle and its delivery to the market. Compared to currently used conventional genetic engineering technologies, it is reliable, reproducible and easy to achieve desired modification, in certain cases leaving no footprint of genetic manipulation as opposed to earlier technologies. Genome edited products in crops and animals are being already commercialized. The technique is being directed to cure or treat serious human diseases viz. cancer and other genetic disorders. Coupled with speed breeding, the technique is the fastest route to develop new crop varieties and other market products.

Selected centres of excellence should be created in the country and brought together in a consortium mode to undertake multidisciplinary projects activities with defined outcomes with defined and differentiated responsibilities and accountability of the various partners in the consortium.

11.2.2.4 Climate Resilient Varieties:

India is projected to suffer the most from climate change, especially temperature increase, drought intensity and frequency, floods, and decreasing per capita water availability. Innovations in developing and popularizing climate resilient varieties are the most effective way to save the losses. For instance, in USA, the development of Biotech Drought Gard maize hybrid released in 2013, increased more than 15 fold from 50,000 ha in 2013 to 8,10,000 ha in 2015. The Drought tolerant varieties are a part of systems approach that combines best agronomic recommendations and other recommended management practices especially making available quality hybrid seed to nearly 43 million farm families in Africa through collaborative arrangements among USA, CIMMYT and IITA (in Nigeria) and the drought affected maize countries in Africa.

As mentioned earlier, CRISPR enables a more precise way to discover and develop valuable traits within the crop's own genome, and create the specified variations. Dupont pioneer has been applying CRISPR to develop new varieties, combining productivity, resilience, and sustainability (Greene, 2019). It is hoped that this approach will be more acceptable also from the biosecurity and regulatory points of view. In India, the National Agri-Food Biotechnology Institute (Tiwari, 2019) has used targeted editing (CRISPR/Cas9) of phytoenedesaturase (PDS) for mutation of LCY-€ gene in the banana genome. The LCY-€ mutated lines showed the increase in β-carotene while significant lower-down of α-carotene and lutein contents was observed. The best DXS2 overexpressing line showed nearly 20-fold higher content of β-carotene compared to control in banana fruits. These results establish that the genome editing and over expression of DXS2 can be effective modes for pro-vitamin A biofortification of banana.

In India, a good number of QTLs for abiotic stress tolerance (flood, drought, salinity, unusual temperature) have been identified in several crops. For instance, Sub1, an exceptionally strong QTL, conferring submergence tolerance in diverse genetic backgrounds of rice under different environments, is being widely utilised in floodprone rice growing areas (Figure 2). A marker-assisted backcrossing (MAB) approach was developed at the International Rice

Research Institute (IRRI) and in several national programmes, including India, to introgress Sub1 in mega varieties which are already popular with famers and consumers, such as Swarna, TDK1, and Samba Mahsuri in India.

Figure 2. New Sub1 lines after 17 days submergence in the field at the IRRI

Source: IRRI, 2011

Swarna-Sub1 has already been released for commercial production and is significantly contributing to enhanced and sustained production under flooded conditions with 2-4 weeks of submergence, out-yielding the original intolerant Swarna by about 30-35 per cent. The submergence tolerance QTL has now been transferred to several popular lowland varieties like Samba Mahsuri, Savithri, IR64 etc. Other submergence tolerance genes distinct from Sub1 have also been identified and their use will help in diversifying the genetic base and tolerance to varying submergence conditions. Moreover, genes conferring drought as well as salinity tolerance have been pyramided with the submergence tolerance genes, rendering Swarna tolerant to multiple stresses (IRRI-STRASA project; U.S. Singh, IRRI, personal communication).

Through an IRRI-ICAR collaborative program, drought tolerance has been combined with higher temperature tolerance in a recently released rice variety DRR52. Emphasizing the significance of 3K RG resequencing information for harnessing genetic diversity in rice, led by Arvind Kumar, IRRI (Abbai, *et.al.* 2019) has developed superior combinations of haplotypes influencing the target traits for developing “tailored rice” by assembly of superior haplotypes into any genetic background. A “Haplo –GS” (superior haplotype-based genomic selection) is an effective breeding approach for designing tailored crops. This approach could be adopted for improvement of other crops as well. Rice drought breeding program at IRRI has identified 14 major effect grain yield QTLs under reproductive stage drought (qDTYs). Through marker-assisted introgression, several of these QTLs have been pyramided in several popular varieties and their drought tolerant versions have been released and commercialized in India and neighboring countries, providing yield advantage of 1.0 to 1.5 t/ha under moderate – to severe drought (Sandhu *et.al.* 2019).

Recent releases of varieties like Pusa Basmati 1509 are a milestone development towards "more from less" and "save and grow". Being a 115 to 120 day high yielding quality rice, it's per day, per liter water, and per kg fertilizer productivity is the highest in the contemporary world of Basmati or scented rices. This is easily a brilliant example of genetic alchemy for convergent economic, environmental and social transformation. This genetic improvement will further consolidate India's position as the world's leading rice exporter, particularly of high quality aromatic rice, currently valued at US$ 5.0 billion per year. These developments must also induce creation, implementation and institutionalization of niche and differentiated production.

Pusa Basmati 1509 saves at least five precious irrigations and this saved water could be deployed for producing an excellent wheat crop in the subsequent season for free (in context of water) – "save and grow" in true sense. An equally brilliant complementary development in form of wheat variety HD 2967, is an exceptionally high yielding and widely adapted variety possessing multiple resistances to rust, especially yellow rust, and, most importantly, is resistant to extreme weather fluctuations, especially heat and cold.

Stress-tolerant varieties will thus be the main plank of climate resilient agriculture. Plant adaptation to stress involves key changes in the 'central dogma', the 'omic' architecture, adaptive changes in genes, proteins and metabolites after individual and multiple environmental stresses. Basic understanding of physiological and molecular bases of stress management will help adopt effective crop-stress protection strategy and develop more robust varieties for high risk environments. Systems-biology and systems level modelling and development of computational models will strengthen efforts to enhance plant fitness to changing climates and varying stresses.

Notwithstanding the ongoing plant breeding efforts to develop climate resilient crop varieties, it is being increasingly felt that the climate change is putting new and enhanced demand for plant genetic resources. Making use of the climate analogues, more and more breeders should be targeting new varieties with adaptation to future climate stresses. The pressure for collecting, conserving and sharing of genetic resources by the centres of origin or of crop diversity will increase significantly. The UN and other concerned international systems *viz.* CGIAR, Global Crop Diversity Trust should work closely with national programmes in this drive. The development partners should view conservation as a part of development and allocate resources accordingly. As we march towards an Ever Green Economy, crop diversity and overall biodiversity conservation and sharing of the genetic treasure should be mainstreamed into the national and international policies in mutual harmony with Climate Smart Agriculture and Farmers' Rights.

11.2.2.5 Innovative Biofortification

India is home to the largest number of undernourished children and women. Fortified foods must be a major strategy to overcome this entrenched deprivation in our country. Foods like iron-rich pearl millet and beans; Vitamin A rich cassava, orange sweet potato; and zinc rich rice, wheat, and maize are already approved for commercial production and use. Many

National and International programs *viz HarvestPlus* are focusing on micronutrient deficiency, especially iron (Fe), Zinc (Zn), Vitamin. In India, two iron-rich pearl millet varieties Dhanashakti and Shakti1201 are already in use by more than 1,00,000 farmers. A wheat variety BHU-35, rich in zinc is being popularized in UP and neighboring north-eastern states. Vitamin A supplementation in rice has served millions of under 5 children.

Having recognized micronutrient deficiencies as a major public health challenge, HarvestPlus was established to add food nutritional quality to agricultural production research paradigms and reduce micronutrient malnutrition. Collaborating with multiple partners to tackle hidden hunger globally by breeding vitamins and minerals into everyday foodcrops, and attempt to bridge the gap between agriculture and nutrition. It has developed and promoted dissemination of iron, zinc, and pro-vitamin A enriched staple foods. HarvestPlus has spanned three project phases: (i) discovery, (ii) development and (iii) delivery. More than 200 biofortified varieties have been released in more than 30 countries, and biofortified crops in the testing phase in more than 60 countries. Currently, the program is emphasizing communication and marketing. HarvestPlus estimates that nearly 20 million people in four million farming households in the Harvestless target countries are conserving biofortified foods (Bouis and Saltzman, 2017). With emphasis on the delivery system, more than 10 million farming household had been reached with biofortified crops, providing access to biofortified foods to more than 50 million farming household members.

HarvestPlus has adopted the following strategic priorities for demonstrating globally the efficacy of fighting undernutrition as elaborated by Wolfgang Pfeiffer (2019).

(i) Strengthening the pipeline of biofortified varieties

(ii) Scaling up delivery in target countries, expanding delivery to new countries in target geographies through partnership, and

(iii) Laying the foundation for global scale through: consolidating evidence of the efficacy, effectiveness and impact of biofortification; engaging key stakeholders to embed biofortification into policy framework, standards, investments and practices; establishing a broadly-endorsed roadmap for coordinating biofortification activities globally.

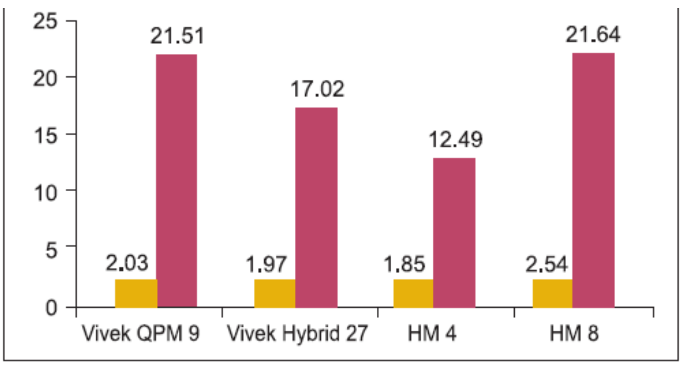
An action oriented agenda for scaling biofortification through the development of inclusive and sustainable markets for biofortified crops should be institutionalized to improve nutrition globally.

Longvah (2019) at the recently held NAAS Agricultural Science Congress had emphasized that both the content and bioavailability of micronutrients in the diet are important for achieving optimal micronutrient status. Several chemical (anti-nutrient and promoter substances) and nonchemical factors affect the nutrient bioavailability, but our understanding of the process that control it is somewhat limited. Thus, it remains a priority area of research. Outcomes of these researches and innovations will facilitate science-based dietary diversification, supplementation of specific micronutrients and food fortification. Agriculture and food systems should be aligned to the specific goals of improving human nutrition and health, and provide functional foods containing desired quality and quantity of micronutrients.

Biofortification innovations have been extremely successful in maize, especially in provitamin enrichment. Using MAS, vitamin A rich maize was developed by selecting favourable alleles of the two key genes, *viz.* lycopene ε-cyclase (lcyE) and β-carotene hydroxylase (crtRB1), causing β- carotene enhancement in the carotenoid biosynthesis pathway (Harjes et al., 2008; Yan et al., 2010). In Zambia, first generation CIMMYT developed provitamin A enriched hybrids were released in 2012 that have 5-9 µg/g of provitamin A.

Scientists from IARI using MAS, introgressed the favourable crtRB1 allele to enhance β-carotene concentration in seven elite parental inbreds, viz. VQL1, VQL2, V335, V345, HKI 1105, HKI 323 and HKI 161 (Muthusamy et al. 2014). These inbreds are parents of four high yielding commercial maize hybrids in India, viz. Vivek QPM 9, Vivek Hybrid 27, HM 4 and HM 8 (Figure 3). The improved inbreds had kernel β-carotene concentration from 8.6 to 17.5 µg/g; much closer to 15 µg/g, the target level set by Harvest Plus for alleviating vitamin A deficiency. The reconstituted hybrids developed from improved parental inbreds also showed enhanced kernel β-carotene as high as 21.7 µg/g, compared to 2.6 µg/g in the original hybrid (Muthusamy *et al.,* 2014). Improved version of Vivek QPM 9 possesses high β-carotene coupled with higher lysine and tryptophan, thereby providing multinutrients in the maize-based diet. Further, MAS to pyramid favourable alleles both lcyE and crtRB1 are also in progress at the IARI to further enhance kernel β-carotene in the maize hybrids (Gupta, 2014). Diverse inbreds with favourable alleles of lcyE and crtRB1 have also been characterized both at morphological and molecular level for their effective utilization in the breeding program (Choudhary et al., 2015a; Choudhary et al., 2015b).

Figure 3. β-carotene enrichment in hybrids



Target level set for maize hybrids by Harvest Plus is 15 µg/g

Enhancement of the factors increasing bioavailability of minerals in the human body can also be exploited to develop micronutrient-rich staple foods (Gupta et al., 2015). Among various anti-nutritional components, phytic acid/phytate in maize plays the major role in reducing bioavailability of minerals mainly Fe and Zn. Maize has more than 80 per cent of the total phosphorus as phytic acids (Frossard et al., 2000; Raboy, 1997). Although the primary function of the phytate in seeds is to store phosphorus as energy source and antioxidants essentially required for the germinating seeds, the negative charge of phytic acids significantly chelate positively charged minerals and forms insoluble complexes in the gut (Raboy, 2001). Hence breeding for low phytic acid assumes significance. Research efforts at TNAU, Coimbatore successfully introgressed low phytate mutants (lpa2-2) into elite normal maize inbreds (UMI 395 and UMI 285) (Suresh kumar et al., 2014; Tamil kumar et al., 2014). Marker-assisted introgression of lpa1 and lpa2 mutants in early maturing inbreds, viz. CM 145 and V 334, respectively, has been recently carried out at VPKAS, Almora. These newly derived low phytate maize genotypes hold promise as they increase bioavailability of Fe and Zn in maize, and enhance phosphorous availability for growth in monogastric animals such as poultry that digest phytate poorly. Further, phosphorus level in the environment and water is increased due to higher concentration of undigested phytate eliminated by the monogastric animals. Thus newly developed low phytic acid genotypes of maize can effectively reduce environmental and water-pollution.

Agriculture scientists are attempting to improve the nutrient content of foodgrains and vegetables through conventional breeding, marker-driven molecular breeding, and genetic engineering. While ample care is needed for ensuring safety to health and environment (biodiversity) misguided opposition to GM products needs to be countered. The Consultative Group on International Agricultural Research (CGIAR) has initiated the bio-fortification of seven food crops, including wheat, rice, pearl millet and maize through its Harvest-Plus initiative involving conventional breeding (Chakraborty et al. 2010). India is an active partner in this initiative. India commercialized the cultivation of iron- rich pearl millet in 2012, and this variety is being grown in a few hundred acres. It is being marketed by Nirmal seeds. This firm is also trying to develop high-zinc wheat. Bangladesh Rice Research Institute has developed zinc-rich rice. Sweet potato varieties enriched with β carotene have also been developed. These varieties can meet the preschool child's requirement of vitamin A. Bioavailability of β carotene from orange-flesh sweet potato has been found to be good. Agriculture scientists need to work closely with nutrition scientists to promote such varieties. Biofortified varieties do not pose the problem of vitamin A toxicity that chemical supplements do, since there is regulation in absorption.

Improved rice for nutritional security has the most profound impact at the global level. Rice is the staple food and main source of nutrition for about 50% world and 70% of Indian population. But it is deficient in protein and micronutrients, malnutrition of which are predominant in Asia and India. Although rice is deficient in protein (7-8%), due to higher digestibility and better nutritive value of glutelins, major fraction of seed protein of rice is nutritionally superior to other cereals. Therefore, the impact of increasing the protein content in rice would be enormous, particularly in the scenario where more than one third of world's children are affected by protein-energy malnutrition (PEM). In addition, if rice varieties are fortified with zinc along with high protein, it helps to combat the Zn-malnutrition of people dependent on rice-based diet.

Considering the severity of malnutrition, India initiated genetic biofortification program of staple food crops, especially rice focusing on most limiting nutrients *viz*., protein, zinc, and vitamin A. A few biofortified rice varieties, bred through conventional breeding, have been released in India with high contents of protein (10.1-10.3%) and Zn (Table 5). These enrichments in protein by 45% and Zn by 40% have been achieved without any yield penalty i.e., the yields of common and bio-fortified varieties are similar.

Table 5. Bio-fortified rice varieties released in India.

Grain protein content (%)			Zn content (ppm)			
Common rice	Biofortified rice		Common rice	Bio-fortified rice		
Samba Mahsuri	CR Dhan 310	CR Dhan 311 (Mukul)	Samba Mahsuri	Zinco Rice	DRR Dhan 45	CR Dhan 311
7.0	10.3	10.1	15	22	22	20

Source: ICAR-National Rice Research Institute, Cuttack

Golden Rice, a genetically engineered, yellow-orange rice grain that contains beta-carotene is another development to meet the challenges of malnutrition. The human body converts beta-carotene into vitamin A. The polished grains from the Golden Rice varieties produce up to 37 micrograms per gram of betacarotene and other provitamin A carotenoids. This could supply 50% of the Recommended Dietary Allowance (RDA) of vitamin A from a cup of rice, if consumed daily. Effort is under way for introgression of golden rice into the popular indica varieties with confined field trials in some countries. Golden rice in BR Dhan29 background is ready for release in Bangladesh.

Golden rice, enriched with β carotene has been developed by genetic engineering involving introduction of three genes. Its safety, bioavailability and acceptability have been tested and now registered as safe in Australia, Canada, New Zealand, and U.S.A. On October 10, 2019, Golden Rice was named Among Project Management Institute's most influential projects of the last 50 years. Realizing that vitamin A deficiency is a major public health issue and the most significant cause of child mortality and blindness globally, its inventors, Ingo Potrykus and Peter Beyer donated the technology to the world in 2000. But, Golden Rice is still not in the hands of those who need it the most, while nearly 5,000 children are dying every day due to vitamin A deficiency. The Project Management Institute must lead the campaign to enable the technology reach the needy and save millions of sights and lives. Bio-availability of micronutrients from bio-fortified crops should be the constant agenda for research since excess of one micronutrient, particularly trace elements and minerals is known to inhibit the absorption of other micronutrients competitively.

Wheat is the foremost cereal of the world. In India, it is the second largest cereal produced and consumed after rice. Recent release of the 11 biofortified wheat varieties will greatly enhance nutritional security of our people (Table 6).

Table 6. Biofortified Wheat Varieties in India

Sl No.	Variety	Year Of Release	Trait	Contact Person & Institute
1	**WB 02**	2017	Fe: 40.0 ppm Zn: 42.0 ppm	PI-CI/ Dr. Amit Sharma, ICAR-IIWBR, Karnal, Haryana-132001 Email: amit.sharma@icar.gov.in Mobile: 9678622622
2	**DBW 187 (Karan Vandana)**	2019	Fe: 43.1 ppm	
3	**DBW 173**	2018	Protein: 12.5% Fe: 40.7 ppm	
4	**HPBW 01**	2017	Fe: 40.0 ppm Zn: 40.6 ppm	Dr. VS. Sohu, PAU, Ludhiana Email: sohuvs@yahoo.com Mobile: 9876134373
5	**PBW 752**	2019	Protein: 12.4%	
6	**PBW 757**	2019	Zn:42.3 ppm	
7	**HI 8759 (Pusa Tejas) durum**	2017	Protein: 12.0% Fe: 41.1ppm	Dr. SV Sai Prasad, ICAR-IARI (Regional Station), Indore Email: sprasad98@yahoo.com Mobile: 9425957920
8	**HI 1605 (Pusa Ujala)**	2017	Protein: 13.0% Fe: 43.0ppm	
9	**HD 3171**	2017	Zn: 47.1ppm	Dr. Rajbir Yadav, ICAR-IARI, New Delhi-110012
10	**MACS 4028 durum**	2018	Protein: 14.7% Fe: 46.1 %	Dr. Yeshavantha Kumar, ARI, Pune Email:
11	**UAS 375**	2018	Protein: 13.8%	Dr. Suma Biradar, UAS Dharwad Email:

Source: ICAR- Indian Institute of Wheat and Barley Research

11.2.2.6 Speed Breeding

Accelerated development and dissemination of improved plant varieties with associated improved production technologies provides opportunities for enhanced productivity. Speed breading protocols shorten plant generation times. With the increasing calls for broadening the crop choices by including proven nutrient-rich and climate smart, orphan crops. Speed breeding is a tool that, when used with other inter-disciplinary R&D approaches, can contribute to the rapid creation of new crop varieties, agricultural practices and products, promoting commercial agriculture. Speed breeding protocols can improve genetic gain in crop improvement program by increasing the number of plant generations cycled in one year, reducing the breeding cycle (Watson *et al.,* 2018).

Manipulating photoperiod exposure and temperature regime, for long-day, short-day, and neutral plant species, such as legumes and oilseeds, including peanut, amaranth and cereals such as wheat and barley, flowering periods were synchronized, enabling 3 to 6 generations per year.

Using speed breeding in peanut, varietal development period was reduced to 6-7 years from 10-15 years. This approach should be integrated with other breeding techniques as well as cost efficient high-through-put genotyping and phenotyping to speed up the generation, testing and commercial release of orphan crop varieties, a value-chain approach involving the breeder, extension expert, and the farmer.

11.3 Innovative Food Fortification:

Food fortification is a promising method for reaching micronutrients to the vulnerable groups. The success seen with iodised salt is a case in point. However, as elaborated by Mahtab Bamji (personal communication) the food vehicle selected for fortification should be one which is consumed by a majority of the vulnerable people. In the Indian context, salt is one such vehicle. The micronutrient added should be stable and absorbed. Iodised salt was initially tested by Late Prof. Ramalingaswamy and colleagues at the AIIMS in the Kangra valley. Based on their findings, National Goitre Control programme was introduced. The Government of India in 1984 launched the programme of universal iodisation of salt. Recent ICMR survey shows very favourable impact. Stability of iodine in salt has to be ensured. NIN has developed a simple kit for estimating iodine content of salt which can be used for monitoring.

Since in the areas which are endemic for iodine deficiency, anaemia is highly prevalent, the NIN has developed iron fortified iodised salt (double fortified salt-DFS), to address the dual problem of iodine and iron deficiency. The technological problem of stability of the two nutrients and availability has been overcome. A technical committee constituted by the Government of India has recommended use of NIN-DFS salt in nutritional programmes for vulnerable groups. Commercial production of DFS has also started in different parts of India. One laudable development is the involvement of state governments like Tamil Nadu in production and distribution of iron and iodine fortified salt. The quantum of fortification of iodine and iron was determined on the basis of consumption of 10g salt per day. However, cardiologists now recommend much lower (5g) consumption of salt to prevent hypertension. This is a new dimension which needs to be addressed. However, even with lower intake of salt, it may be possible to supply 5 mg of iron. With more vehicles for fortification on the agenda, fortification can be a useful approach to reach iron through food.

Attempts are being made to fortify wheat flour with iron. Bio-availability of iron from fortified wheat flour is a problem because of phytate content. Though foods such as sugar and soy sauce have been used in some countries for fortifying with vitamin A, they are not suitable for India. Oil fortification with fat- soluble vitamins is being tried in Gujarat.

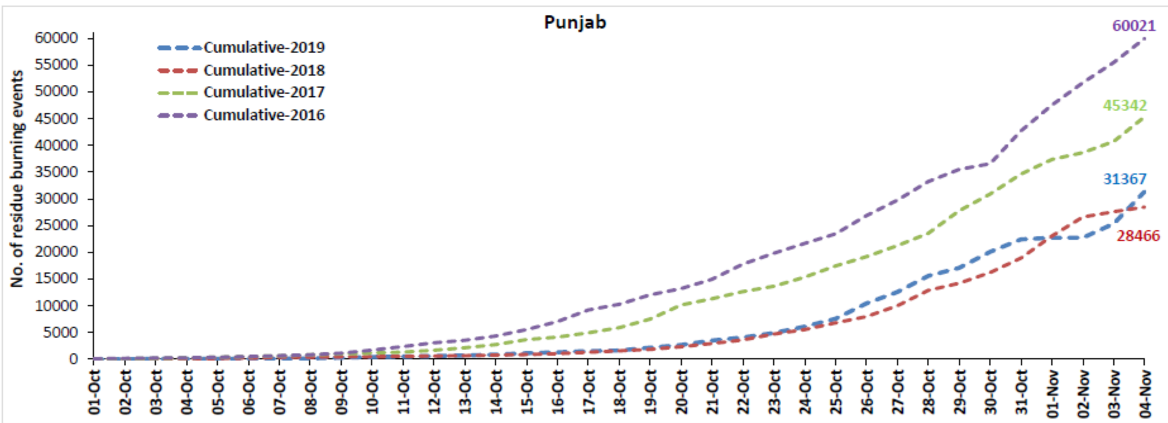
11.4 Innovative Viable Solutions to Rice Residue Burning in Rice-Wheat Cropping System

In recent years, rice crop residue burning has become a serious national concern due to deteriorating air quality, particularly in the rice-wheat cropping system in North-West India. This problem was also highlighted by the Hon'ble Prime Minister in the meeting of the Secretaries of Science Departments chaired by him on July 18, 2017, and he desired the urgent need "…to address this problem in next one year".

Yet, the situation as of November 04, 2019 was as below:

- Satellites detected 6459 residue burning events in the three study states on November 04, 2019.
- The burning events detected on November 04, 2019 are 6001, 383 and 75 in Punjab, Haryana, and UP, respectively
- The number of events has increased from 2770 on November 03, 2019 to 6459 on November 04, 2019 in the three states.
- Total 37861 burning events were detected in the three States between October 01, 2019 and November 04, 2019, which are distributed as 31367, 4797 and 1697 in Punjab, Haryana and U.P. respectively.
- Overall, the total burning events recorded in the three states are 2.7% more than in 2018 till date. UP recorded 48.8% reduction, Haryana recorded 5.5% reduction, and Punjab recorded 10.2% increase, respectively, in the current season than in 2018(Figure 4).

Figure 4. Comparison of residue burning events in Punjab in current year (2019) with previous years (2018, 2017, & 2016) (01 October to 04 November)



The NAAS developed a policy brief to address the problem of air pollution due to crop residue burning, detaching an innovative viable solution to check burning of rice residues, which is a major contributor to air pollution in the early winter months in North-West plains of India. The Academy hopes that the Central and State Governments of the affected States will approve promotion of the simple solution suggested in the brief as complementary approach to the ongoing efforts, to provide a sustainable solution to the problem of crop residue burning. Main advantage of the approach proposed in the brief is that it will improve economic returns to the farmers and will improve soil health, while eliminating environmental pollution from the area covered by the proposed technology, without any extra cost to the exchequer.

As a policy measure, promoting the Turbo Happy Seeder technology package though payment for environmental services could be considered as a pilot for a mechanism to encourage increased adoption of technology that helps in eliminating residue burning on the one side and making more efficient use of financial resources on the other side. In addition, on a pilot scale carbon credit of Rs. 250/t may be considered as sufficient to encourage the adoption of Turbo Happy Seeder technology package. Farmers may actually receive additional income by adopting the new technology. Also, in a broader policy perspective, promoting Turbo Happy Seeder technology will complement the Government schemes on soil health, water saving, climate risk reduction, food security, doubling farmer income, etc. and the 'One Health' program (Figure 5).

Figure 5. Multiple benefits of the rice residue management through concurrent use of SMS-fitted combines and turbo happy seeder

Source: NAAS, Policy Brief No. 2

Rapid adoption of Happy Seeder technology needs a major government push to publicize and popularize the technology. State governments of Punjab and Haryana have made some interventions such as financial support in the form of subsidy for purchase of Happy Seeder and legislation for completely banning residue burning. The scaling of this innovative technology is deemed vital for safeguarding objectives of National Mission on Sustainable

Agriculture (NMSA). It is estimated that to cover 50 per cent (5 million ha) of the total acreage under RWCS in India, about 60000 Turbo Happy Seeders and 30000 super SMS fitted combines will be required; at present, there are only about 3000 Turbo Happy Seeders and 1000 super SMS fitted combines are available. We need to act soon to save the environment from further deterioration (NAAS, 2017).

Fortunately the existing manufacturers have the capacity to increase their output to supply the required quantities of the two implements. This, however requires putting in place enabling policy environment and mechanism for quality control assurance.

To achieve the objectives, the following approaches were suggested:

- Attachment of super SMS (straw management systems) needs to be made mandatory for registration of all new combine harvesters in all the states affected by crop residue burning; this approach has already been initiated by the State of Punjab. Also, there is a need to encourage all the combine harvester operators to attach super SMS on the old combine harvesters through an appropriate mechanism and policy environment

- Promotion of manufacturing of good quality happy seeders is essential to cover all the combine harvested rice acreage where residues are being burnt. It is estimated that a total of about 60000 Turbo Happy Seeders will be required. Fortunately, the manufacturing industry has the capacity to produce the required number of Turbo Happy Seeders and super SMS with in a year's time

- Development of suitable mechanism to ensure availability of good quality happy seeders and SMS fitted combines to the farmers should be encouraged through promotion of Agriculture Service Centers Since most farmers are small and marginal, purchase and owning Turbo Happy Seeder and super SMS by individual farmers is neither feasible nor desirable. Hence there is a need to promote 'Turbo Happy Seeder Technology Package' led self-sustaining business models through cooperatives (agriculture service centres), private service providers, farmer groups, young entrepreneurs etc. Suitable policy environments need to be devised to facilitate the agriculture service centers

- Training and capacity development is one of the core areas for out-scaling of 'Happy Seeder Technology Package'. Therefore, there is a need for strengthening of capacity development of whole range of value chain actors involved in the process of Turbo Happy Seeder Technology Package (manufactures, operators, farmers, extension agents, civil society, policy planners, etc.). The SAUs and ICAR institutes can play an important role in training capacity building

- Large scale awareness campaigns should be undertaken at different stages of cropping season through range of activities including farmers' fair, field days, exhibitions, traveling seminars, choupals, use of digital technologies (ICTs), social media, electronic and print media etc need to be launched and monitored for their efficacy in terms of implementation and adoption

- Convergence of relevant Government schemes and pooling resources will greatly enhance efficiency and wholesome outcomes. There are several Government schemes related to soil health, water saving, adapting to climate risks, reducing environmental footprints, doubling farmers' income, food security, etc., wherein promotion of Turbo Happy Seeder technology package can contribute substantially. A mechanism therefore should be devised for incentivizing adoption of efficient management of crop residues and elimination of crop burning. Turbo Happy Seeder technology package therefore can also get a special place in such policy and incentive programmes

- Inclusion of technology of concurrent use of SMS-fitted combines and Turbo Happy Seeder for Certified Emission Reduction (CER) certification will enhance access to environmental funds. A reduction in emissions entitles the entity to a credit in the form of a Certified Emission Reduction (CER) certificate. The CER is tradable and its holder can transfer it to an entity which needs Carbon Credits. This provision will not only accelerate adoption of this technology, but will also play an important role in increasing farmer's income, to complement the Government's policies in this direction.

The NAAS should play an important role in implementing the suggested recommendations, by (a) organizing interactive meeting of the Agriculture Officers of the affected States, representatives of industry, service providers and other stake holders, (b) developing extension materials – posters, leaflets, short videos, TV programmes, etc., (c) arranging training programmes, (d) providing technical back up to the industry and farmers, and (e) monitoring and impact assessment.

In addition, the following possible remedies may be adopted:

- Breeding rice varieties not exceeding 130 days seed to seed maturity.
- Ex-situ (feed block, use as fuel in power generation, manuring) and In-situ straw management system (baler, chopper, spreader, mulcher) to made available to farmers on custom hiring.
- Use of Pusa Decomposer, a fungal consortia for fast degradation of ex-situ and in-situ biomass.
- Farmers to be incentivized with Rs. 3000 per acre for straw removal (it is just labour cost, which amounts to increasing paddy price by Rs. 150 per q). Govt. to open collection centers where farmers can deposit and get payment instantly.

11.5 Way Forward for Strengthening Innovative Drive

11.5.1 Leveraging Agritech Startups in Indian Innovation Ecosystem

Dr. Raghunath Mashelkar in his A.B. Joshi Memorial Lecture on this subject delivered on the XIVth Agricultural Science Congress of the NAAS on 20 February 2019 had analyzed the current status, challenges and way forward to promote disruptive innovations.

Referring to the daunting challenges in our agriculture system, namely, productivity enhancement, rainfed farming, small fragmented land holdings, climate change, poverty, malnutrition, he emphasized that India needs to take recourse to innovations, especially disruptive game changing innovation. This calls for development and use of "collective intelligence' that involves several stakeholders especially the innovative youth being at the core. The ongoing efforts of ICAR related to "Motivating and Attracting Youth in Agriculture" (MAYA) and "Attracting and Retaining Youth in Agriculture" (ARYA), should enthuse the youth to fuel the movement on agri-tech startups and create a future ready agriculture innovation ecosystems. Challenges of change – *viz*. rural to urban agriculture, traditional farming to vertical farming, food as a product to food as a service and life style based diets to DNA based diets. Changes such as precision agriculture, gene editing for multiple trait improvements, biological based crop protection, micronutrients and soil management and microbiome technologies to enhance crop resilience etc.

He pointed out that the innovations involve: (i) indoor farming; (ii) pursuits of increased efficiency through use of robots, (iii) Use of CRISPR to create drought tolerance, disease tolerant/resilient and high yield crops, and (iv) lab grown meat alternatives. Precision agriculture along the value chain ensures "more from less". Digital farm advisory, insurance, big data, mobile banking, etc, all lead to "more from less".

India is expected to become second largest startup nation by 2025, having 100,000 startups with 3.25 million employees, mostly by youth – the Government is supporting the innovation systems in many ways, viz. by startup programs such as the Agri-Uddan Accelerator and the Agri Ground Challenge, the Credit Guarantee Fund Trust for Micro and Small Enterprises (CGTMSE), Innovation Parks and Incubators etc, which would lead to ASSURED Innovation:

A (Affordable)
S (Scalable)
S (Sustainable)
U (Universal)
R (Rapid)
E (Excellent)
D (Distinctive).

Two of the Govt of India's innovations, namely, JAM-J (Pradhan Mantri Jan Dhan Yojana), A (Aadhar identification and Authentication) and M (Mobile telecommunications) have created the fastest and largest financial inclusion in the world, the 360 million plus bank accounts opening up in record time; and the Reliance Jio, making India first rank in mobile data transmission, adopting 'free voice call' innovation.

Mashelkar emphasized two issues, namely, public procurement policy and the IPR challenge-conducive policy on patents for success of the innovation movement. He had suggested specific five actions for judicious implementation of the two policies, as elaborated below:

1. Set up a fully integrated, National Innovation Policy to also include non-technological innovations such as social, business model, system delivery, processes and policy innovation

2. Innovation oriented public procurement policy, which should be both 'for' innovation as well as 'of' innovation, thus catalyzing both demand and supply side of the innovation, thus catalyzing both demand and supply side of the innovation equation

3. The above two policies should be based on four pillars of talent, technology, transparency, and trust. To achieve this, a legal framework, will have to be designed based on the ASSURED principles which will facilitate smooth implementation

4. Public sector procurement should have minimum targets for innovation procurement. The private sector should join hands with public sector for financing as well as implementing plan

5. An "Innovation Procurement Platform" involving various stakeholders should be created to ensure speedy implementation. The centre should have central databases and documents on all aspects of public procurement policy of and for innovation.

Patents are helpful to startups in many ways – establishing R&D partnerships and forming joint ventures, protecting from theft of its innovations, rapidly increasing its market share, and enhancing chances of a startup getting acquired. The various regulatory mechanisms and provisions viz. Breeders' Rights, Farmers' Rights, International Treaty on Plant Genetic Resources, and Equitable Benefit sharing of the gains arising from the use of genetic resources and biotech programs. Our Agriculture Innovations Ecosystems should place the Agritech Startups at the core and enable the youth to contribute to the greatest public good-agriculture, and accelerate the disruptive innovation led agriculture based inclusive growth.

Investing in Innovations

The past success in the Rainbow Revolution and its impact on food income and overall livelihood security was closely listed with enhanced investment, particularly the public sector, in research, technology, inputs and price supports. Today, in this fast changing and ever-competitive world, faced with complexities of shrinking land, water and biodiversity resources, and market and climate change volatilities, investment in technologies and innovations must be enhance substantially to ensure more from less for more. The private sector must complement the public sector and invest adequately to harness the fast expanding cutting-edge technologies and innovations. Both, corporate social responsibility and science social responsibility should synergistically transform the agriculture and food system to create right innovation ecosystems to benefit the farmers, including the young entrepreneurship Public spending should be strengthened for not only building climate resilience, but also for risk mitigation through establishing suitable social protection floors and ensuring credit, insurance, and direct cash transfer support.

11.5.3 Atal Innovation Mission: A Platform for Coordination

The Government of India (NITI Aayog) has created the Atal Innovation Mission (AIM), which alongwith the Self-Employment and Talent Utilization (SETU), endeavor to promote innovation ideas.

The objectives of the AIM are as below:

- To create an umbrella structure to oversee innovation eco-system of the country
- To provide platform and collaboration opportunities for different stakeholders
- To study and suggest best and novel practices to be adopted by different stakeholders in the innovation chain
- To provide policy inputs to NITI Aayog and various Government Departments and Organizations
- To create awareness and provide knowledge inputs in creating innovation challenges and funding mechanism to government, and
- To develop new programmes and policies for fostering innovation in different sectors of economy.

The Mission has two core functions:

1. Entrepreneurship promotion through SETU, leading to a force of successful entrepreneurs

2. Innovation Promotion: to provide the following a platform, from where innovation ideas are generated:

a) Atal Tinkering Labs: There are being established in schools across India to foster curiosity, creativity and imagination in young minds, and inculcate skills such as design mindset, computation thinking, adaptive learning, physical computing etc. Here the young minds can give shape & their ideas through hands on do it yourself mode, which will help them understand the concepts of STEAM (Science, Technology, Engineering, Agriculture and Mathematics)

b) Atal Incubation Centres: These will nurture innovation start-up businesses in their pursuits to become scalable and sustainable enterprise. These centre across the country will have the necessary infrastructure, operating funds, expert mentors, business planning support, seed capital, industry partners etc. The AICs will be established in subject specific areas such as manufacturing, transport, energy, health, education, agriculture, water, sanitation etc. AIM provide grant-in-aid of upto 10 crore for a maximum period of five years to cover the capital and operational expenditure to establish the Atal Incubation Centre

c) Scale-up Support to Establish Incubation Centres: The Mission supports creation of world class incubation centres across the country and provides financial scale-up support to incubation centre

11.5.4 Building and Strengthening Global Partnership:

With the increasing interdependence of local and global, especially in managing market and climate change vulnerability and volatilities, and with greater acceptance of world grant concept for managing global problems, new international collaborations should be established and the ongoing World Bank Project on Education could facilitate international collaborations. Several ongoing India's DARE-ICAR, bilateral, trilateral and multilateral collaboration could be used for sharing the technologies. India with its vast and varied agro-ecologically-differentiated experience would be helpful in establishing tripartite collaboration involving India, a developed country, and another developing country. A global network of talented young entrepreneurs should be established to harness international experiences and remunerative models. Innovative institutional arrangements should be made to sustain such collaboration. The ongoing bilateral collaboration of India with several African countries on one hand and with developed countries viz. USA, Germany, Scandinavian Countries and Australia could be converted into trilateral collaborations.

11.5.5 Impact Pathways Research to Guide Effective Implementation

Impact pathways analysis should be undertaken to identify promising innovations, particularly their profitability, social, and agro-ecological compatibility and scalability so that the successful experiences could be scaled up and scaled out, especially under the socio-economic settings of the majority smallholder farmers. Innovations need to be backed by research and continuous monitoring and evaluation of technology and innovation in a given socio-eco-system.

11.6 Overall Recommendations for Promoting Innovations

- In order to tackle the negative impact of climate change and other stresses, to meet nutritional and food security needs and the SDGs targets, there has to be a substantial increase in the investment in agriculture as it is also proven that every Rupee invested in agriculture returns the maximum benefits among all the sectors in the country in poverty and hunger alleviation

- Adopt and promote inter-disciplinary, interactive research based on agro-ecologically and socio-economically differentiated, disaggregated approaches to enable sustainable, equitable, nutrition sensitive and climate smart agriculture

- Strive to enhance farmer's income through effective farmer-market linkage along the value chain, thereby ensuring quality and minimizing wastage, and realization of remunerative price

- Enable science to serve the society, appropriate regulatory policies should be in place so as to, (a) ensure development and transfer of need based technologies and to promote public-private co-operation and (b) bring congruence between Science Social Responsibility and Corporate Social Responsibility (NAAS, 2015, 2016)

- Transform agricultural education system for developing necessary human capital with entrepreneurship, employability and leadership qualities in meeting the SDGs-2030 and to contextualize and provide academic legitimacy to various national initiatives to build a zero hunger and prosperous India

- Create and follow effective implementation pathways to measure and manage the expected outcomes and impact with due accountability and responsibility of the stake holders.

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Chapter 12

Precision Agriculture: Need of the Day

12.1 Why Precision Agriculture

Agricultural production system is an outcome of a complex interaction of seed, soil, water, and agro-chemicals (including fertilizers). Therefore, judicious management of all the inputs is essential for sustainability of such a complex system. The Green Revolution process, based essentially on increased use of high yielding variety seeds, fertilizer and irrigation, transformed the country from a food deficit to a food self-sufficient and foodgrain exporting country. Due attention was, however, not paid to the inputs use efficiency (precision) and the ecological and environmental health, resulting in diminishing sustainability, profitability, and productivity growth.

In order to transform Green Revolution into an Evergreen Revolution and to enhance productivity in a sustainable manner from the limited natural resources at the disposal, optimizing the resource input use efficiency assumes high priority, especially in face of the decline in the total factor productivity, diminishing and degrading natural resources, stagnating farm incomes, lack of eco-regional approach, declining and fragmented land holdings, trade liberalization, limited employment opportunities in non-farm sector, and global climate change. Against these odds, to feed a population of 1.7 billion by 2050, land productivity would need to be improved by four times, water productivity by three times, and labour productivity by six times. And, these targets can be achieved only by generating and widely adopting innovative science-based policies and efficiency-enhancing precision technologies.

12.2 What is Precision Agriculture

Precision agriculture, which exploits all the modern tools, technologies and innovations, including genetically enriched seeds, Artificial Intelligence (AI), drones, sensor, robots etc, leading to economically improved and environmentally sustainable agriculture, is the way forward to achieve Evergreen Revolution. It is an integrated farm management system that attempts to match the kind and amount of inputs with the actual products needs for small areas within a farm field to be realized in a practical production setting. Referred to as precision farming, the approach recognizes site-specific differences within fields and adjusts management actions accordingly, adopting the concept of "doing the right thing in the right place at the right time." Thus, precision agriculture provides a new solution using a systems approach for today's agricultural issues such as the need to balance productivity with environmental concerns. Using advanced information technology, it includes describing and modelling variation in soils and plant species, and integrating agricultural practices to meet site-specific requirements. It aims at increased economic returns, enhanced sustainability, protection of the land, water, and genetic resources at reduced energy input, and least environmental footprint.

12.3 Goals and Applications of Precision Agriculture

The goal is not to obtain the same yield everywhere, but rather to manage and distribute inputs on a site specific basis, a variable-rate farming, to maximize long term cost/benefit through congruently enhanced efficiency, effectiveness, productivity, and profitability. India, housing the largest numbers of marginal farmers in the world, its precision agriculture and related technologies must be geared to match the needs, aspirations, and opportunities of the smallholders (Gatzweiler and Von Braun, 2016), especially: (i) increased land and labour productivity by means of technology, (ii) intensification, diversification and off-farm employment, (iii) institutional arrangement to grant property rights, entitlements, and land rights, and (iv) balanced agro-ecological settings compatible with minimum risk.

12.3.1 Precision Technologies for High Value Commodities:

Precision technologies equip farmers to take smart decisions to optimize resource utilization and maximize output per unit of resources), adopt safe farming and post-harvest management practices to ensure quality production, and remunerative marketing. Complementary infrastructure, institutional support, services, and policies are needed for effective adoption of the technologies. Prevention of post-harvest losses and value chain management of high value agriculture *viz.* Horticulture and Livestock will greatly enhance farmers income as well as consumers satisfaction.

India has a long unique experience of linking smallholder dairy farmers (milkmen) with the modernized world farmers Dairy Cooperative, Amul. Under the setup, every morning nearly 4 million women across over 16,000 villages bring milk worth Rs. 500 million to the cooperative centre, celebrating their economic development and independence. The Amul movement involves 15 million farmers, mostly smallholders, 1,45,000 village level dairy cooperatives, rendering India highest (176 million tonnes in 2017-18) milk producer in the world and per capita milk consumption (nearly 300 gm) surpassing the world average. Other such linkages of high value agriculture with corporate sector are delivering higher incomes to farmers as observed from innovative business models of Nestle, Heritage Foods, others. In the vegetable value chains, companies like PepsiCo, Mahindra and Mahindra, Desai Fruits and Vegetables, Mahagrapes, etc. have adopted innovative models. These ventures have been successful in scaling up their engagement with the farmers, establishing backward integration and facilitating access to key agricultural inputs and services. Such innovations should have been widely adopted throughout the country. Special effort is needed to scale-up and scale out the success stories across the country to maximize the benefits accruing to the farmers in a sustainable manner, contributing significantly to the Prime Minister's call for doubling farmers' income.

Energy efficient cold chain networks powered by IoT and cloud technologies are set to revolutionize postharvest management and agricultural logistics. The products and solutions offered are aimed at rural users; smallholders and help users optimize their capital expenditures (capex) and operational expenses (opex). In order to mitigate the onion crises onion storage is critical for containing the extreme price fluctuations and also delivers higher prices to onion growers preventing them to undertake distress sale. Conventional ventilation storage of onions results in high wastage up to 35 per cent depending on the weather conditions, which can be reduced to less than 5 per cent with cold storages.

Considering the importance of promoting sustainable agricultural practices, innovations in agricultural inputs that help prevent further deterioration of soil and water health are gaining momentum. For instance, *Mycorrhiza*, a fungal micro-organism feeding host plants with nutrients from the air and soil have the potential to reduce chemical fertilizer use up to 50 per cent in certain cases and improve yields by (5-25) per cent. Market for algae based bio stimulants, pheromones, among others are fast expanding wherein use of chemical pesticides and fertilizers are being rationalized and gradually substituted by more natural and organic products.

Technology that enables preserve the quality of high value commodities and improve their shelf life will help address the issues related to food losses as well as provide an option to consumers to avail cheaper processed products. Dehydration of fruits and vegetables, often using solar energy, which removes the moisture and extends the shelf life without addition of any chemicals has a large potential market.

12.3.2 Precision Agriculture for Enhanced Input Use Efficiency and Productivity

"Per drop more crop" seeks high precision in water use. Water, the most vital input in the agricultural production system, is becoming scarcer each passing day. The country became "water stressed" in 2007 and if the 'business as usual scenario' continues the entire country may become "water scarce" by 2050. It is estimated that only a handful of basins will have per capita water availability above the critical level by 2025. The irrigation projects developed at a very huge cost to the exchequer, function at an efficiency level of 38-40 per cent. Moreover, mismanagement of water has been causing degradation of natural resources.

In spite of a plethora of technologies available like drip and sprinkler having water application efficiency between 60-90 per cent, water use efficiency continues to be low. The latest estimates put the area under drip and sprinkler irrigation systems around 7.8 million ha out of a potential of 69.5 m ha. It has been established that increase in water use efficiency automatically results in increase in nutrient use efficiency. Under fertigation, nitrogen, phosphorus, and potash use efficiencies are enhanced to 95, 45, and 80 per cent, respectively, and drip fertigation leads to a quantum saving of at least 40 per cent fertilizers applied. Moreover, solar-driven micro-irrigation systems help reduce energy costs, and help regulate availability of power, allow farmers to earn extra income by selling surplus power and allow savings for the government in terms of subsidy to power allocated to agriculture.

Further, a map of topsoil depth can be used to guide the variable-rate application of nitrogen. Moreover, the use of advanced GIS soil sampling and soil nutrient management would help increase yields, reduce fertilizer costs and improve management of the environmental impact of intensive agriculture practices. Not only soil water content patterns and relation have profound implications for precision agriculture in general, but also on water management in particular. Spatiotemporal variability in soil water have shown that knowledge of the underlying stable soil water distribution could provide a useful basis for precision water management and lead to savings in energy, water, equipment cost, and labour, and to improved production efficiency.

Use efficiency of fertilizer nitrogen, which constitutes more than 60 per cent of total plant nutrients consumed in India, is abysmally low; 30-40 per cent in rice and 40-60 per cent in other crops. Excessive use of nitrogenous fertilizers is leading to ground water pollution as well as increased N_2O emission. Nitrogen use efficiency can be increased by treating urea with nitrification inhibitors or coating with some hydrophobic substances to retard the release of urea in soil solution or its microbial oxidation to nitrates, which leach down or are lost to the atmosphere as N2 or NOx gases. The global warming potential (GWP) of NO_2 is about 310 times that of CO_2. Phosphorus use efficiency is even lower at 15-20 per cent while that of micro nutrients is a bismally low varying between 2-5 per cent. Such low use efficiencies lead to considerable financial losses to the exchequer and cause serious environmental hazards. Urea Super Granules (USG), Leaf Colour Chart (LCC), and Green Seeker using sensor are some of the developments which can enhance nutrient use efficiency. Hundred per cent neem coating of urea, as made compulsory through a recent policy decision and championed by the Hon'ble Prime Minister himself has significantly increased nitrogen use efficiency, enhanced yield at least by 10 per cent, and resulted in lowering expenditure on fertilizer.

Based on the concept of zero waste, save and grow, per drop more crop, unsafe food is no food, etc., several technologies have varyingly been adopted to promote precision agriculture. For instance Global Positioning System (GPS) receivers ensure precise location information at any time allowing soil and crop measurements to be mapped. GPS receivers, either carried to the field or mounted on implements, allow users to return to specific locations to sample or treat those areas. In highly mechanized systems, grain yield monitors continuously measure and record the flow of grain in the clean-grain elevator of a combine. When linked with a GPS receiver, yield monitors can provide data necessary for yield maps. Yield measurements are essential for making sound management decisions. Used properly, alongwith related parameters, yield information provides important feedback in determining the effects of managed inputs such as fertilizer amendments, seed, pesticides and cultural practices including tillage and irrigation.

Grid soil sampling and variable-rate fertilizer (VRF) application should be widely adopted. The goal of grid soil sampling generates a map of nutrient requirement, called an application map. Grid soil samples are analyzed in the laboratory, and an interpretation of crop nutrient needs is made for each soil sample. Then the fertilizer application map is plotted using the entire set of soil samples. The application map is loaded into a computer mounted on a variable-rate fertilizer spreader. The computer uses the application map and a GPS receiver to direct a product-delivery controller that changes the amount and/or kind of fertilizer product, according to the application map. The Soil Health Card initiative of the Government should be linked with VRF program.

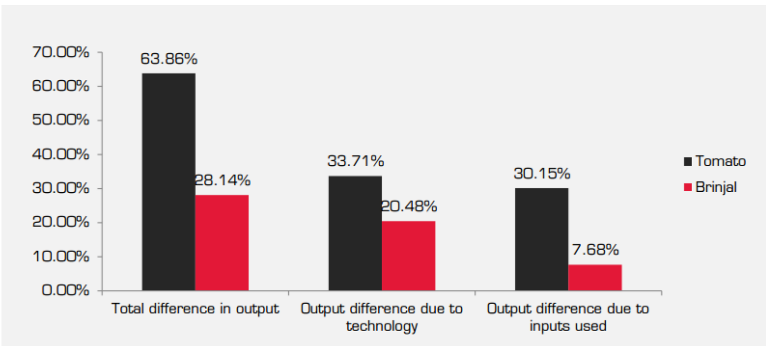
Development of crop-region specific customized fertilizers is needed to maximize fertilizer use efficiency. It is important to note that inclusion of nutrients like boron, copper, manganese and molybdenum has to be done cautiously because of a narrow margin between the deficiency and toxicity thresholds of these nutrients. Nano-fertilizers, nano-pesticides are being formulated and evaluated by many researchers and will definitely reduce the quantum of chemicals used and enhance their use efficiency. However, bio-safety and environmental issues have to be addressed before their large-scale applications. We have to do away with the conventional form of agriculture that focuses on Recommended Dosage of Fertilizes with emphasis on NPK only. Soil Health Card Scheme, if executed effectively, provides ample opportunity to switch over to site specific nutrient management immediately.

In today's Internet of Things, the precision agriculture (PA), digital green, smart farms and the like are fitting examples of how diverse universes such as a farmland and software can be brought together through ICT. With enhanced decision making capacity, farm productivity can be enhanced substantially. Tech Mahindra have innovated a home grown solution - Farm Sensor which measures critical farm attributes at 3 different levels of a farm, namely, the soil, the crop level and above the soil level.

At the soil level is measured the impedance rate of the soil, moisture, water retention, NPK values, and nutrient migration. At the crop level is measured chlorophyll, susceptibility, plant level temperature, and humidity. And at above soil level is measured the weather conditions such as ambient temperature, humidity, dew point, rainfall, etc. These data, with the help of Big Data and Analytics predict, prescribe and warn the farmer of the inputs, diseases and weather conditions that help him take accurate mitigation or remediation.

A study was undertaken in Tamil Nadu (India) to understand the impact of precision farming on resource-poor regions and underprivileged farmers. It looked into productivity, income, employment, and adoption behavior of technology in agriculture. The study had revealed that adoption of precision farming has led to 80 per cent increase in yield in tomato and 34 per cent in eggplant production. The contribution of technology for higher yield in precision farming has been 33.71 per cent and 20.48 per cent, respectively in tomato and eggplant production (Figure 1). Yet, the adoption was sub-optimal. Lack of finance and credit facilities have been identified as the major constrains in non-adoption of precision farming. The study has suggested that providing of subsidies for water-soluble fertilizers and pumpsets will increase adoption of precision farming.

Figure 1. Productivity Difference in Precision and Non-Precision Farming



Source: Tech Mahindra, White Paper: Research Insights

Quoting from a Tata's case study, some of the key challenges that need to be considered while taking PA to the Indian market are briefly shared below:

- Conceptualizing ICT platforms have to be done after consulting the users. Agricultural practices are crop specific and region specific. ICT platforms have to be specifically customized for user needs
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- Designing ICT platforms for agricultural systems have to be done very systematically. Relationships have to be developed with the users and platform holders
- Business Intelligence and Strategy (BIS) Research estimates the global market size for precision agriculture to grow over \$6.34 billion by 2022 at an estimated CAGR of 13.09% from 2015 to 2022. The trends suggest that with U.S. at the forefront, North America will continue with its dominance during the forecast years. Also, with the world's most populous countries China and India, Asia Pacific (APAC) will emerge as the fastest growing region in the market at a CAGR of 18.29% from 2015 to 2022
- In conclusion, Indian market is quite ready for introducing PA and the time is ripe with the government releasing a farmer-friendly budget for the purpose. The only caution would be to select progressive states in which adoption of PA is easy to start with
- The way forward is to develop cost-effective solutions keeping in mind the challenges an Indian farmer faces in the real world. Soil management, productivity challenges and optimizing inputs are just a few challenges that can make a difference to the science of food production in one of the oldest democracies of the world.

12.3.3 Remote Sensing, GIS and ICT to Build Knowledge Platforms

Remote sensing now a common device, yields data which provide a tool for evaluating crop health. Plant stress related to moisture, nutrients, compaction, crop diseases and other plant health concerns are often easily detected in overhead images. Electronic cameras can also record near infrared images that are highly correlated with healthy plant tissue. New image sensors with high spectral resolution are increasing the information collected from satellites. Remote sensing can reveal in-season variability that affects crop yield, and can be timely enough to make management decisions that improve profitability for the current crop. Remotely-sensed images can help determine the location and extent of crop stress. Analysis of such images used in tandem with scouting can help determine the cause of certain components of crop stress. The images can then be used to develop and implement a spot treatment plan that optimizes the use of agricultural chemicals. Wireless sensors are now becoming affordable and available for a wide range of parameters. Their inputs can help in quantifying variability of the field in a finer resolution.

Agricultural GIS maps contain layers of information, such as yields, soil survey maps, remotely sensed data, crop scouting reports, and soil nutrient levels. Geographically referenced data can be displayed in the GIS, adding a visual perspective for interpretation. In addition to data storage and display, the GIS can be used to evaluate present and alternative management by combining and manipulating data layers to produce an analysis of management scenarios.

Likewise, information management, and ICT technology has grown, promoted the adoption of precision agriculture through linking management skills and pertinent information databases. Effectively using information requires a farmer to have a clear idea of the business objectives and crucial information necessary to make decisions. Effective information management requires more than record-keeping analysis tools or a GIS. It requires an entrepreneurial attitude toward education and experimentation. ICT platforms, e-NAM, and access to critical information related to production resources, market prices etc, enable the farmer to plan his activities and enable him/her to manage financial transaction and to be digitally linked with the credit delivery system.

12.3.4 Nanotechnology to Boost Precision Agriculture

Nanotechnology applications are already impacting agricultural production by allowing better scientific management and conservation efforts to plant production. Nanotechnology provides a much better effective way of environment detection, sensing, and bioremediation. It can enhance agricultural productivity by using: (i) nanoporouszeolotes for controlled release and efficient amount of water, fertilizer etc; (ii) nanocapsules for delivering of herbicide, vector and managing of pests; (iii) nanosensors for detecting aquatic toxins and pests; (iv) nanoscale biopolymers (proteins and carbohydrates) based nanoparticles with few properties such as low impact on human health and the environment may be used in disinfection and recycling of heavy metals; (v) nanostructured metals can be explored in decomposition of harmful organics at room temperature; (vi) smart particles can be useful in effective environmental monitoring and purification processes; (vii) nanoparticles as a novel photocatalyst; and (viii) for waste water treatment (NAAS, 2014).

12.3.5 Robotics to Transform Agriculture

As traditional farmers in most developing countries deploying traditional methods struggle to keep up with the efficiencies required by the market, farmers in developed countries suffering from a lack of workforce, have increasingly taken to automated farming to solve the problems by using robotics and advanced sensing. Robots also have an advantage as they are able to access areas where other machines cannot. For example, Maize growers face a problem that the plants grow too quickly to reliably fertilize them. “Rowbot” aims to solve this problem as it easily drives between the rows of corn and targets nitrogen fertilizer directly at the base of each plant. Some Drone companies offer farmers combined packages which include robotic hardware and analysis software. The farmer can then move the drone to the field, initiate the software via a tablet or smartphone, and view the collected crop data in real time. Ground based robots, can provide even more detailed monitoring as they are able to get closer to the crops. Some can also be used for other tasks like weeding and fertilizing. Some weeding robots don't even need to use chemicals. “RoboCrop”, for example, uses computer vision to detect plants as it is pushed by a tractor. It then automatically hoes the spaces between plants to uproot the weeds. Other weeding robots use lasers to kill the weeds.

12.4 Cloud Computing for Building Decision Support System

Cloud-based information systems are being developed to provide real-time decision support. They are being built on a cloud computing platform to provide scalability needed for processing a large volume of field data. New data integration techniques are being worked out to process data in various formats and form different devices including data visualization techniques in context of precision agriculture. Compared with existing DSSs that are modeled after a human-in-the-loop decision process, the next generation Decision Support and Automation Systems (DSAS) will feature a fully automated decision process, from data acquisition to data analysis and decision synthesis, to control field devices based on the recommended decision. Adoption of modern technologies and the information system will create an ecosystem for developers – designers and entrepreneurs in agriculture.

Precision agriculture is designed to apply exactly needed location-specific inputs for attaining targeted output, maximizing the cost effectiveness and net income with least side effects. As India increasingly pursues the Doubling Farmers Income campaign and adopts Conservation Agriculture, the Climate Smart Agriculture and Precision Agriculture drives will congruently be strengthened. Conservation Agriculture, if practiced strictly, is also an effective way to address climate related changes. Although all Resource Conservation Technologies are not generally included as a component of Precision Agriculture, their focus on improving input use efficiency helps in enhancing climate resilience and inputs saving (Table 1).

Table 1. Potential benefits of resource conservation technologies (RCTs) in terms of climate change adaptation and input use efficiency

Resource conservation technologies	Potential benefits relative to conventional practices
Zero tillage	Reduced water use, C sequestration, similar or higher yield and increased income, reduced fuel consumption, reduced GHG emission, more tolerance to heat stress
Laser-aided land leveling	Reduced water use, reduced fuel consumption, reduced GHG emissions, increased area for cultivation, increased productivity
Direct drill seeding of rice	Less requirement of water, time saving, better postharvest field condition, deeper root growth, more tolerance to water and heat stress, reduced methane emission
Raised-bed planting	Less water use, improved drainage, better residue

	management, less lodging of crop, more tolerance to water stress
Leaf color chart (LCC) for N management, nitrification inhibitors	Reduces fertilizer N requirement, reduced N loss and environmental pollution, reduced nitrous oxide emission
Crop residue management	Moderates soil temperature, improves soil quality, reduces soil erosion, reduces evaporation losses and conserves soil moisture, increases C sequestration, avoids burning and reduces environment pollution, increases tolerance to heat stress, reduces weed infestation
Sprinkler/drip irrigation	Increases water and nutrient-use efficiency, reduces GHG emissions, increases productivity and product quality

Source: Wassmann *et al*. (2009); Jat *et al*. (2016)

12.5 Practical and Affordable Approaches for Precision in Farm Equipment and Machinery – NAAS Deliberation

Precision and timeliness are most critical for increased efficiency of inputs use for increased and sustained productivity, precision indices were analyzed for commonly used machines and operations *viz.* land leveling, seedbed preparation, paddling, irrigation, seeding and planting, intercultural operations, plant protection, harvesting, threshing, and cleaning. The built in precision in the commonly used farm equipments and machines, can further be enhanced in consort with GPS technology (VRT), and remote monitoring of fields (NAAS 2016).

Despite the veritable proven benefits of precision in farm equipment and machinery, the adoption in India is low, which is attributed to the following constraints:

- Small size farms, heterogeneity of cropping systems, and land tenure/ownership
- restrictions, high cost of obtaining site-specific data
- Lack of adequate technical expertise, complexity of tools and techniques requiring new skills
- Lack of extension services and availability of high performance equipment
- Lack of awareness and resistance of farmers for adoption of new techniques and equipment
- Lack of infrastructure and institutional support for development of precision farm equipment
- High initial investment for purchase of precision equipment and technologies
- Uncertainty in returns from high initial investment in precision equipment and information management systems
- Knowledge and technological gaps including:
  - Inadequate understanding of agronomic factors and their interaction
  - Lack of understanding of the geo-statistics necessary for displaying spatial variability of crops and soils using current mapping software.

To address the above constraints, NAAS had made the following recommendations:

Research and development: Concerted efforts need to be made in Research and Development to enhance precision in farm equipment. Some of the efforts required are outlined in the sequel.

- Conduct research to validate and further modify the proposed concept of precision index for farm equipment and machinery
- Develop (equipment) to cope up with the requirements of high precision, low application doses, safety, etc
- Intensify R&D on developing sensors, monitors for Indian farm equipment by suitable modification wherever required
- Develop gender neutral, efficient, robust and easy to operate precision farm equipment and machinery.

Testing: The following recommendations are made for testing the precision farm equipment / machinery:

- Develop/revise national and International standards for critical components and input application equipment wherever required
- Test critical components and equipment for quality and performance to ensure that the observed data falls within the specified range of accuracy
- Test precision farm equipment and machinery as per the standard test code by a recognized testing agency
- Calibrate the sprayers as well as seed and fertilizer application equipment before use.

Manufacturing and standardization of equipment: The following recommendations are made for quality manufacturing of farm equipment:

- Use jigs and fixtures for manufacturing of inter-changeable components
- Ensure specified tolerances, fits and limits during manufacturing of standard components
- Need to use precision machines for manufacturing of critical components to ensure desired degree of precision
- Provide interchangeable components of standard design on all farm equipment and machinery
- Ensure proper heat treatment, hardness and finish for various components of precision farm equipment and machinery
- Adoption of nanotechnology/nano-coating to enhance wear and corrosion resistance for fast wearing components of farm equipment.

Awareness, extension and training: For sensitization and training of the stakeholders and the farmers for manufacturing and adopting precision farm equipment and machinery, the following recommendations have been made:

- Create awareness and initiate sensitization programs to educate all stakeholders regarding application of precision equipment and machinery
- Enhance input use efficiency by farm machinery management
- Promote precision farm equipment and machinery by joint efforts among farmers, community groups, NGOs, machinery manufacturers, research and extension agencies and other public and private agencies
- Enact a policy for the manufacturers to install and calibrate the equipment and train the operator
- Manufacturer must provide parts catalogue and operator’s manual with every equipment to ensure proper adjustment, calibration and maintenance.

Financial assistance and incentives: The following recommendations would help enhance the usage of such equipments and machinery by the farmers:

- The service providers may be encouraged to provide farm equipment and machinery services on rental basis to marginal, small and medium farmers to reduce cost of cultivation
- The farmers may be provided additional incentives/subsidy for use of precision farm equipment and machinery to enhance input use efficiency
- Banks may provide financing/subsidy to the farmers for purchase of an equipment or machine that fulfills the specified requirement of precision, performance, human safety and environmental standards.

12.6 Ways Forward with Special Reference to Precision Agriculture

12.6.1 Political will to adopt/adapt Precision Agriculture

Precision Agriculture is tailored to provide the exactly needed amount of a specific input at a given location. Site specific input management in terms of water and agro chemicals is the precursor to Precision Agriculture. Further, the high production levels have to be not only sustained but also achieved with emphasis on energy savings and low emission technologies considering climate change impacts. Technology-driven farming is the only option for increasing farmers’ income and reducing cultivation costs with the ultimate aim of shifting to Precision Agriculture. As precision agriculture must excite the youth and ignite the young mind, a sustainable roadmap is needed to attract and retain youth in agriculture. Flagship programs like Make-in-India, Digital India, Start-up India, e-NAM etc should greatly strengthen entrepreneurship and employment security.

Small sized farms coupled with scattered holdings will be a major hindrance in switching over to Precision Agriculture as it involves a seamless merging of remote sensing, GIS, GPS, sophisticated machinery and sensors for application of various inputs in measured quantities varying over space and time. The Government's decision to use drone technology for estimating crop yields and damage is an indication of its intention to use modern technologies in agriculture. Precision Agriculture is already fairly common in developed nations like USA, Australia and several European Countries where the focus is on cost cutting, minimal environmental damage and high quality produce, the road to New India. Ongoing international programs *viz* Feed the Future, the World bank supported NAHEP etc. should provide opportunities to the agricultural graduates entering farming to share the successful global experiences of precision agriculture.

12.6.2 Towards Personalized Farming

Moving upstream, it is now possible to differentiate between stresses caused by different nutrients through hyper spectral signatures. Smart phone controlled drip system is no longer a distant goal. Flying drones have already entered the domain. Can self-driving tractors, robotic harvesters, integration of data technology into day to day operations in the digital era, field level data collection by sensors attached to tractors or installed in the field, be far behind. The sooner we shift to personalized farming, the faster will be reduction in environmental footprints, productivity enhancement in a sustainable manner and moderation of climate change impacts. While moving forward, no doubt, all mutually inclusive socio-economic and agro-ecological and sustainability factors must be scientifically weighed in choosing the complementation pathways.

12.6.3 Uberization of Precision Agriculture Innovations:

Precision agricultural service providers and properly trained extension workers should be promoted to offer a variety of precision agriculture services to farmers. By distributing capital costs for specialized equipment over more land and by using the skills of precision agriculture specialists, custom services can decrease the cost and increase the efficiency of precision agriculture activities, especially in intensive soil sampling, mapping and variable rate applications of fertilizer and lime. Equipment required for these operations include a vehicle equipped with a GPS receiver and a field computer for soil sampling, a computer with mapping software and a variable rate applicator for fertilizers and lime. Purchasing this equipment and learning the necessary skills is a significant up-front cost that can be prohibitive even for many large farmers. Agricultural service providers must identify a group of committed customers (Self Help Groups or Co-operatives) to justify purchasing the equipment and allocating human resources to offer these services. Once a service provider is established, precision agriculture activities in that region tend to center around the service providers. For this reason, adopters of Precision Agriculture practices often are found in clusters surrounding the service provider. "Uberization" through effectively connecting innumerable small cities and towns, especially those in the agricultural heartland will greatly accelerate precision agriculture throughout the food and agricultural system value-chains.

12.6.4 Strengthen Transfer of Cost-effective Precision Technology and Innovations

Thus, precision agriculture gives farmers the ability to use crop inputs more effectively including fertilizers, pesticides, tillage, and irrigation water. More effective use of inputs means greater crop yield and/or quality, without polluting the environment. However, it has proven difficult to determine the cost benefits of precision agriculture management. At present, many of the technologies used are in their infancy, and pricing of equipment and services is hard to pin down. This can make our current economic statements about a particular technology out-dated. Precision agriculture addresses both economic and environmental issues that surround agricultural production today. Questions remain about cost-effectiveness and the most effective ways to use the technological tools we now have, but the concept of "doing the right thing in the right place at the right time" is an urgent need. Ultimately, the success of precision agriculture depends largely on how well and how quickly the knowledge needed to guide the new technologies can be generated and implemented on farmers' fields.

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Chapter 13

Renewable Energy Based Agriculture in India*

13.1 Introduction

Energy is the basic necessity for human being to survive. Demand for daily energy requirements creates pressure on finite source of fossil fuel based energy, which is rapidly declining in different parts of the world. Therefore, there is need to reduce our dependency on fossil fuel based energy, which can be achieved by increasing the share of renewable sources. Solar radiation is the ultimate source of energy which can be harnessed by photosynthesis (3-4 per cent efficiency), photovoltaic (15-30 per cent efficiency) and futuristic biophoto voltaic-chemical pathway of *Moorella thermoacetica* bacteria. Agriculture is one sector, which consumes about 7-8 per cent of total energy consumption of India. Pumping of irrigation water, use of heavy machineries for different farm operations, processing and value addition of farm produces etc. are major activities by which energy is consumed in agriculture sector. With the advancement of food production system from agrarian to a futuristic technology-driven system, there has been rapid increase in energy use in agriculture. It has been expected that energy use in agriculture needs to be increased from its present value 1.6 kW ha-1 to 2.5 kW ha-1 to meet the production target of next 20 years. The rise in energy use has adverse effects on climate due to burning of fast depleting fossil fuels and thus emitting greenhouse gasses. In this context, we need to harness and use more renewable forms of energy, especially solar energy that is plentiful in most part of the country. Also, at several locations in India harnessing wind power and utilizing biomass could be effective alternatives. At present, about 16 per cent of the country's installed electricity generation capacity is contributed by renewable sources e.g. wind, solar, biomass etc. The national solar mission has been in progress to increase the renewable energy use share at different sectors including agriculture.

13.2 Future of renewable energy based agriculture in India

In spite of significant progress made in renewable energy generation and utilization in agriculture during last few years, there are several opportunities to contribute largely to 175 GW renewable energy target by 2022. Although, there are several advantages of renewable energy technologies whether it is utilization or generation in agricultural field, adoption of these technologies in farmers' field and rural hinterland is far from satisfactory. Therefore, suitable policy interventions need to be formulated in addition to addressing some researchable issues so that future Indian agriculture becomes renewable energy driven. Some of the issues for wider utilization and generation of renewable energy in agriculture are discussed below.

Solar PV pumping systems are being installed across the country with 70-80 per cent support from Government because of high cost of installation. For example, 3 HP and 5 HP solar PV

* *Adopted/Reproduced from NAAS Strategy Paper 10, 2018*

pumping systems costs about Rs 3 lakhs and Rs 5 lakhs, respectively, for installation in farmers' field. Beneficiary farmers are satisfactorily using these pumps for irrigation to mostly horticultural crops. Although there is high demand from farmers to install the system in their field, but the number of allotted beneficiaries under Government subsidy scheme is much lesser than expected. For example, only 38,687 solar PV pumps have been installed in the country till 2017, whereas there is scope of replacing about 17 million irrigation pumps across the country, which are presently being operated either through diesel or grid connected electricity. To get maximum benefits from solar PV pumping system, bidirectional energy metre or net metre may be attached to solar PV pumping system. Although solar PV pumps provide assured power supply to farmers for providing irrigation at critical crop growth stages, provision should be made so that farmers can apply irrigation even during cloudy days and night also. Lastly, the size of solar PV modules in a solar PV pumping unit increases as the depth of ground water becomes high. Since, the major cost of a solar PV pumping system is contributed by PV modules, overall cost of pumping groundwater becomes high when the groundwater is deep. On contrary, if the initial cost is met, a solar PV pump indiscriminately withdraws deep groundwater, which is again a concern for groundwater management. Therefore, present subsidy schemes of Government allows for installation of solar PV pumps only up to 5 HP capacity, which can withdraws groundwater from a depth of about 200-250 ft with satisfactory discharge. Whereas, most of the present grid tied electric pumps in the country are in operation with wells or bore wells, deeper than 200-250 ft. Therefore, there is need for promotion of solar PV pump based irrigation from farm ponds specifically in dryland areas where ground water depth is high.

Agri-voltaic system provides opportunity to generate electricity from farmers' field and thus can increase farmers' income. However, the cost of its installation is quite high. For example, Rs 50-60 lakhs investment is required for establishing agri-voltaic system on 1 acre land. To overcome this problem, Public-Private Partnership (PPP) model may be developed. In the PPP model private party will take lead role in PV installation and generation whereas the land owner or farmers will take lead role in farming. The accrued benefits from the system may be shared between private party and farmer. Ministry of New and Renewable Energy has recently launched the scheme KUSUM (*Kisan Urja Suraksha Evam Utthaan Mahaabhiyan*), in which it is planned to install 10,000 MW capacity solar farming system across the country. It is to be ensured that agri voltaic system is a part of the KUSUM scheme. Moreover, performance of suitable crops for agri voltaic system needs to be tested in different agro-ecological regions of the country. Even, the installation of rainwater harvesting system facility to all land-based solar PV installations across the country may be made mandatory.

A major limitation of any PV system is its inability to produce electricity during night. PV system generally produces electricity effectively for 4-5 hours a day. On the other hand, wind turbines can generate electricity 24 hours a day depending on the diurnal variation of wind speed. Thus, solar-wind hybrid may be a good option to generate energy during 24x7 hours in a week. However, research efforts are required to resolve few technical issues of solar-wind hybrid system including designing of solar-wind hybrid system so that effect of wind turbine shade on PV generation can be minimized, and developing smart inverters to combine PV and wind turbine generated energy together of supplying it to grid. Even, further ahead of it, ‘four-in-one’ land use system may be thought of where wind energy generation at higher atmosphere, solar energy generation near to ground surface, rainwater harvesting from top of PV surface and crop cultivation on ground surface can be done together.

Soil erosion by wind action and deposition of eroded dust on PV module is a major problem for maintaining higher performance ratio (PR) factor of solar PV plants specifically in arid region. Even, the loss of finer particles from top surface of agricultural field makes the soil poor that affects adversely plant growth. Under such situation, dual purpose wind barrier can be used surrounding field boundaries to generate renewable energy from wind resources which can be further used on farm for different purposes. Design of such barrier has been developed. However it needs further field evaluation at different locations of arid region in the country.

Solar PV driven tools and implements can share a large portion of renewable energy utilization in agriculture. Therefore, research efforts are required to develop PV driven tractors, tools and implements etc. Solar fencing can be a viable option to protect crop damage by wild animals and can be promoted for installations in farmers’ field. Policy guidelines may be formulated to make it mandatory to cover a portion of polyhouse cultivation system with PV modules.

Solar thermal devices e.g. solar drier, solar cooker, solar water heater etc. are most proven technology since long time but adoption of these in farmers field is comparatively less. Although, there is demand of the devices in the rural areas, however, availability of the devices in market is less. Major limitations of its adoption are: (i) lack of entrepreneurs for fabrication of the devices, (ii) lack of awareness to farmers about the operations of solar thermal devices, (iii) lack of business model for marketing process based products. To address the issue, it is required to promote entrepreneurship for fabrication of the devices and to develop business models to attract investors.

Use of agro-waste or biomass residue for thermal power generation is often debated because of its unviable high tariff rates leading to heavy subsidies; it also liberates gases into the air and does not provide compost to maintain soil health, fertility, productivity and profitability of the farmers. Recently, second generation (2G) bio-fuel technologies have been announced during 2018-19 annual budget, in which biogas and bio-CNG will be produced from wastes through anaerobic digestion. Unlike solar and wind power, liquid and gaseous bio fuels can be stored economically Bio-refineries being set up in India for liquid and gaseous bio fuels production provide compost and minimize greenhouse gas liberation. The anaerobic digestion also provides compost, liquid manure and other bye products. Entrepreneurship development for densification (bailing, briquetting and pelleting) of agro-residues may be promoted for utilization of surplus crop residues for meeting domestic and industrial needs and also to be used as fuel for electricity generation. Production of biochar is upcoming technology for efficient management of crop residues which needs support for field level demonstration and utilization of value added solid and liquid products. There is need for a National level e-database of biomass availability, utilization pattern and surplus quantities. Database also needs to be generated considering economic environment impact of in-situ and ex-situ management of straw being burned in the field. biomass as soil amendment, liquid fuel (by-product) as furnace oil and feed stalk for value added solid and liquid products. There is need for a National level e-database of biomass availability, utilization pattern and surplus quantities. Database also needs to be generated considering economic environment impact of in-situ and ex-situ management of straw being burned in the field.

Recommendations

- Bidirectional energy meter or net meter may be attached to solar PV pumping system so that farmers can sell additional PV generated electricity to local grid when pump is not used for irrigation purpose and thus will provide extra income to farmers. Indian Council of Agricultural Research (ICAR), local DISCOMs and Solar Energy Corporation of India (SECI) under MNRE may come together to implement the system in different states of the country

- Additional battery backup facility may be included in solar PV pumping system scheme so that farmers can apply irrigation water in their field even during cloudy days and night also. ICAR, MNRE and state agricultural department may come together to provide the facility to farmers of the country

- There is need for promotion of developing surface water storage of rain water and runoff either through farm ponds or water storage tanks and irrigating with the stored water through solar PV pumping system. The system can be developed through linking of Pradhan Mantri Krishi Sinchay Yojana (PMKSY), National Solar Mission (NSM) and KUSUM

- Renewable Energy Service Company (RESCO) model can be formulated for installation of agri-voltaic system in farmers' field for food production and PV based electricity generation from a single land unit. SECI may formulate and implement the model in collaboration with Ministry of Agriculture and Farmers' Welfare similar to the RESCO model for roof top solar system

- Agri-voltaic system needs to be tested in different agro-ecological regions of the country with different crops, for which research efforts need to be strengthened. ICAR may take a lead role to develop the network on agri-voltaic system in India

- Rainwater harvesting system facility along with cultivation of high-value medicinal crops at interspace area may be made mandatory for land-based solar PV installations across the country so that stored rainwater may be recycled for cleaning of PV modules and for providing supplemental irrigation to crops. National Institute of Solar Energy (NISE), SECI and other concerned organizations in India working on medicinal plants may formulate the necessary guidelines for this purpose

- Solar-wind hybrid may be a good option to generate energy throughout the day and night and therefore needs to be promoted on agricultural land so that overall land productivity may be improved. National Institute of Solar Energy (NISE), National Institute of Wind Energy (NIWE) and ICAR may work together to develop such model and implement at suitable locations in the country

- Small Vertical Axis Wind Turbine (VAWT) based hybrid barrier may be used on farm boundaries to reduce wind erosion as well as to generate electric energy, which may be further used for pumping irrigation water. Design of such barrier has been developed, though it needs further field evaluation at different suitable locations of the country and ICAR may take lead role on this aspect

- Suitable solar PV/thermal tools, implements and devices may be included in package of practices for agriculture in different states of the country. State agricultural departments and Krishi Vigyan Kendras (KVKs) in collaboration with ICAR institutes may take initiatives for promotion of these solar PV/thermal devices

- Solar PV covered polyhouses need to be promoted for protected cultivation of horticultural crops so that energy requirement for operationalization of polyhouses can be met from renewable energy sources. National Horticulture Mission (NHM), SECI and ICAR Institutes working on protected cultivations may come together to develop and implement such system in farmers' field

- Entrepreneurship for fabrication of solar devices may be promoted so that small scale industries on solar based food processing units may be developed. MNRE and ICAR Institutes working on agricultural engineering may take lead role on this aspect

- There is need for formulation of policy guidelines on proper management of residues for renewable energy generation, compost preparation and providing it as feed to livestock. ICAR institutes working on Agricultural Engineering and National Institute of Bio-Energy (NIBE) may take the lead to develop suitable model for this purpose in consultation with other departments and stakeholders.

NAAS's Brainstorming-cum-Workshop on Energy in Agriculture 2015, based on its discussion on Energy Foot Prints of Indian Agriculture involving Hon'ble Suresh Prabhu (Former Union Minister), R.B. Singh, Anwar Alam, Pitam Chandra, and Dipankar De, had suggested the following steps for efficient management of energy in agriculture:

1. Periodic energy audit of production, processing, and rural living to identify inefficient and avoidable uses of energy for energy conservation and interjection of energy-efficient equipment and practices at the same time create balance in demand and supply of energy supply

2. Intensification of R&D on harnessing of renewable energy sources supplementing and substituting commercial energies. Popularize use of efficient cookstoves using briquetted fuel

3. Specific fuel consumption of diesel engine use is too high, especially power tillers (PT) and pump sets which need to be brought down. Diesel pumps be phased out in favour of electric/photo-voltaic pumping sets

4. R&D evolving energy-efficient crops and crop rotations, energy-efficient equipment and management practices

5. Solar, wind, hydel and biomass energy need to be harnessed for agriculture, agro-processing and rural living.

6. To get over paucity of petroleum products at affordable costs, liquid fuel options from biomass of crops, cultivated crops rich in oils preferably non-edible oils should be developed

7. Promotion of biogas plants both domestic size as well as community size for cooking, illumination and power through dual fuel engine and spent slurry as VA manure. Large size (>500 $m^{3)}$ biogas plants be integrated with large diary operations

8. Awareness, training and operationalization of energy-efficient equipment and practices and alternate sources of energy available. Massive effort in skill development, in farm mechanization and sustainable energy for agriculture, agro-processing and rural living

9. Reclamation of plant nutrient from urban refuse, farm, community and market refuse through biological pathway obtaining compost, vermi-compost, biogas spent slurry reducing dependence on chemical fertilizers,. Incineration of biomass should be avoided/banned

10. Animate energy use should be rationalized through scientifically established work-rest cycle for different applications

11. For extending mechanization to small and marginal farms, custom-hiring is a good option

12. As a matter of policy, agriculture and rural sector in general should be assured due share of diesel and 20 per cent electricity available)

13. For double cropping on average the farm-power requirement is estimated at 2.5 kw/ha

14. Biofertilizer and biopesticides production and use be popularized to reduce requirement of synthetic fertilizers and pesticides which have negative impact on ecology.

Selected References

NAAS (2018) Renewable Energy : A New Paradigm for Growth in Agriculture. Strategy Paper 10. National Academy of Agricultural Sciences, New Delhi. 20 pp

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Chapter 14

Towards Oilseeds Sufficiency in India*

14.1 Indian Oil Economy Unacceptably High Gap in Demand and Domestic Production of Oilseeds

In 2017 the NAAS had brainstormed the issues and prospects of vegetable oil economy and made some tangible recommendations in Strategy Paper 7, as largely reproduced in this chapter with necessary amendments. Under each recommendation, a detailed strategic action plan should be prepared and implemented at the ground level in each district, as done in case of pulses. Question arises as to why the success story of pulses could not be repeated in vegetable oils economy?

The demand-supply gap of edible oil in India is widening every year, thus resulting in huge import. For meeting the current requirement of 21-22 mt of vegetable oil, the country imports 14.8 mt of edible oil, accounting for nearly 70 per cent of our total requirement, costing the exchequer around Rs. 75,000 crore. The consumption demand growing annually by 5 per cent, the vegetable oil requirement is estimated that to rise to more than 39 mt by 2050, including the annual estimated requirement of 10.65 mt for industrial use (Table 1).

The mismatch between demand and supply has grown much faster over the last 20 years. The domestic availability of oilseeds, encompassing nine crops, including soybean, mustard and groundnut comprising 70 per cent of the domestic production, was around 8 to 10 million tonnes of edible oil during 2005-06 to 2015-16. During the same period per capita consumption of vegetable oil had increased from 10 kg/annum to 18 kg/annum. Driven by the population and income growth the domestic demand of vegetable oil increased to about 22 mt, necessitating annual import of 11 to 15 mt during the past five years.

Table 1. Projected Vegetable Oil Requirements in Next Few Decades

	2020	**2030**	**2040**	**2050**
Projected population (Billion)	1.32	1.43	1.55	1.68
Per capita consumption (Kg/year)	15.33	15.88	16.43	16.97
Vegetable oil requirement for direct consumption (mt)	20.24	22.71	25.47	28.51
Vegetable oil for industrial use (mt)	3.57	6.34	8.88	10.65
Total Vegetable oil requirement (mt)	23.81	29.05	34.35	39.16

Sources: Adapted from ICAR-IIOR Vision 2050

Productivity of our major edible oil crops including mustard and soybean in India has remained one third of the global average. Other edible oil crops fetch much lower produce

* *Adopted/reproduced from NAAS Strategy Paper 7 - Vegetable Oil Economy and Production Problems in India, 2017; Present Status of Oilseeds Crops and Vegetable Oils in India, Ministry of Agriculture and Farmers Welfare, 2018*

per hectare than other parts of the world (Table 2). India also remained isolated from the technological revolution in edible oil crops except cotton where approval of insect resistant Bt cotton hybrids played a considerable role in increasing supply of cotton oil from 0.5 mt in 2002 to 1.5 mt in 2015. Unfortunately, India bypassed technological revolution led by genetic modification that was adopted widely by edible oil producing countries including Argentina, Australia, Brazil, Canada and USA. Ironically, India is still debating the cultivation of GM crops like soybean and mustard that have been in global market for more than two decades now. The GM mustard developed by Delhi University scientists is held up for socio-political consensus while the country is importing GM soya oil to the tune of 4.5 mt, 0.3-0.5 mt of GM canola and consuming domestically produced GM cotton seed oil to the tune of 1.5 mt constituting a total GM oil component of nearly 5-6 mt out of 21 mt annual edible oils consumption. In fact, there are some countries, who are planning their oilseed crop cultivation only to meet India's requirement. The import composition is dominated by palm oil followed by soya oil, canola and sunflower oil. Palm oil import reached almost 80 per cent of the total oil import but now is reduced to 60 per cent in recent years. It is also interesting that India imposes the differential import duty structure on the crude and refined palm oil. In 2016, out of 8.3 mt of palm oil import the share of crude palm oil was 5.7 mt while the refined palm oil was 2.6 mt. The import of other edible oils varies, depending upon the prevailing prices internationally. Although the overall import of vegetable oils during the oil year 2016-17 was lesser to some extent owing to good monsoon for Kharif oilseeds crop, the issues of climate change looming large on the agricultural production will certainly upset the production potential at any time in future and self sufficiency in vegetable oil appears to be a dream unless some effective steps are taken on production and policy fronts.

Table 2. Comparison of average yield of different edible oils in India with other edible oil producing countries (tonnes/ha)

Average Yield (Tonnes/ha)				
Crop	India	World	Highest	Country
Soybean	1.10	2.5	2.9	Brazil
Groundnut	1.24	2.2	4.5	USA
Mustard	1.25	2.0	3.9	Germany
Sesame	0.55	1.5	2.2	China
Safflower	0.58	1.6	2.1	
Sunflower	0.70	2.5	3.5	

Source: Agricultural Statistics at Glance 2015-16

The performance of oilseeds sector has never been as good as cereal crops in India like wheat and rice. Somehow there was never a breakthrough in the productivity of oilseeds crop neither through the genetic enhancement nor from other production technologies. There is no significant increase in area, production and productivity of oilseed crops during 2001-02 to 2015-16 (Table 3). A large number of oilseeds crop that are grown in India, some are conventional but a few have been non conventional. Majorities are the annual crops but some oil sources are also from perennial crops. However, major contribution to annual oilseeds production comes from three annual crops; soybean, groundnut and rapeseed-mustard. Global average productivity of soybean, groundnut and mustard are 2.5, 2.2 and 2.0 tonnes/ha against India's yield of 1.1, 1.24 and 1.25 t/ha respectively. Indian studies have shown that average yields average yields of soybean, mustard groundnut, rapseed, sesame, and sunflower can be enhanced to 1600, 2000, 1820, 750 and 950 Kg/ha, respectively with appropriate technology transfer, policy and price support, as judged from the transferable yield gaps.

Table 3. Area, Production and Yield of Oilseed Crops for the period 2001-2016

Years	Area (mha)	Production (mt)	Productivity (kg/ha)
2001-02	22.64	20.66	913
2002-03	21.49	14.84	691
2003-04	23.66	25.19	1064
2004-05	27.52	24.35	885
2005-06	27.86	27.98	1004
2006-07	26.51	24.29	916
2007-08	26.69	29.76	1115
2008-09	27.56	27.72	1006
2009-10	26.96	24.88	958
2010-11	27.22	32.48	1193
2011-12	26.31	29.80	1133
2012-13	26.48	30.94	1168
2013-14	28.05	32.75	1168
2014-15	25.59	27.51	1075
2015-16	26.13	25.30	968

Sources: Agricultural Statistics at Glance 2015-16

14.3 Strategies of Improving Productivity and Profitability

14.3.1 Technology application and adoption

Development of new hybrids and varieties using double haploid approach, marker-assisted breeding/selection and other biotechnological approaches to solve viability (sunflower and soybean) and seed production issues should receive top priority amongst the researchers. Encourage network research involving private and public institutes nationally and globally towards development of products with identified market partners and also consolidate research funding from various sources (ICAR, DBT, DST and from international sources). Focusing on product development for water and nutrient use efficiency, mitigating monsoon withdrawal and terminal drought and other related climate variability issues, eco-friendly biotic stress management, value chain improvement and developing health tagged varieties, developing specific nutrition and micro-irrigation schedules based on soil health, fertility and physical properties (soil test based, site specific nutrient management and length of growing period) and developing new cropping systems for profit (apiculture in mustard, sunflower and niger, thalamus from sunflower, petals from safflower and eri silk from castor) based on market access. Focus on soybean and mustard for research and development is likely to pay more dividends for edible oil than groundnut. Undisputedly, sesame is the next crop on which we need to invest time and money for rich dividends. There are several approaches of transgenic and molecular breeding being adopted internationally. Noticeably, GM soybean and GM canola account for nearly 104 mt or 94 per cent of 110 mt of global trade in soybean and canola, 15 mt or 22 per cent of 70 mt of global edible oil trade and 64 mt or 80 per cent of 80 mt of global animal feed trade. Transgenic technologies have been a major success in oilseed crops. The successful example of Bt cotton is before us as it has indirectly contributed to 10 per cent growth in oil availability in India. The timely approval of GM mustard hybrid and deregulation of barnase–barstar technology will be a milestone decision to strengthen Indian brassica research and accelerate the process of deploying genetic gains. The impact of commercial release will have resounding effect on the entire GM research in country as due to its delay, scientists are demoralized and discouraged to research on new technologies, which are developed by many public sector research labs in India. From drought tolerance to biotic stress and fatty acid composition, research on transgenic oilseed crops is in advance stages. The scientists are awaiting green signal from the planners for commercializing the technologies.

In fact there are several proven production technologies, which have potential for upscaling. For example soil and water conservation practices and rain water harvesting, vertical mulching in vertisols, zero tillage practices for mustard, sunflower and linseed in paddy fallows, use of broad bed furrows (BBF), quality seed production and expansion of drip irrigation are a few but very successful technologies that can enhance the yield of oil crops from 10 to 40 per cent. It has been shown that micro-irrigation in oilseed crops alone enhanced the productivity in all the oilseed crops from 16 to 45 per cent. In case of nutrition, it has been observed that only 35 per cent of the nutrients needs are met in current practices. Continuous mining of nutrients from soils also makes the crops vulnerable to micronutrient deficiencies. Nearly 75 per cent soils are deficient in Sulphur, which can be met by replacing DAP with SSP. Yet another issue that is not fully resolved in cultivation of these crops is SRR because the seed chain is often missing in crops like groundnut, safflower, linseed, sesame and soybean.

14.3.2 Cultivable area expansion

Oilseed crops are stagnant over the years in respect of area in spite of several opportunities to expand cultivable area. These crops can be grown as intercrops in some states (Table 4_A), in nontraditional areas (Table 4_B), and also in rice fallows (Table 4_C). Nearly 12 mha area is available under rice fallows, leaving some for pulses; some area would certainly be available for oil bearing crops.

The green revolution effect has resulted in intensive cultivation of rice-wheat (R-W) rotation in the entire North Indian irrigated belt particularly Punjab, Haryana and Utter Pradesh. This system being an assured in respect of output and income, many other states like MP, Chhattisgarh, and even canal irrigated areas of Rajasthan are following rice–wheat rotation. However, it has come to notice that the R-W system is deteriorating the soil, environment and water availability. Oilseeds and pulses are considered as excellent sources of crop diversification. In Kharif, rice can be replaced with soybean in most of the areas. Similarly in Rabi, cultivation of largely mustard and to some extent linseed can be cultivated as substitute to wheat. Such diversification has distinct advantages for halting the ill effects of R-W system and also meets the demand of vegetable oil of the country. Experimentally it has been proved that there is a possibility of Rabi castor cultivation in Tamil Nadu and Karnataka as it requires very limited water.

There are 33 cotton growing districts where the productivity is just half of the national average i.e less than 300 Kg lint per ha. These districts are basically rainfed and cover nearly 45 per cent of the total cotton area. Some of these districts can be identified for cultivation of sesame, soybean and sunflower.

Table 4. Proposed Areas for Oilseeds Expansion

A. Intercropping system

Crop	Specific area	Potential area (mha)
Soybean	Maharashtra, Telangana & Karnataka	0.70
Groundnut	AP, TN, Karnataka, UP (Bundel.), Gujarat, Maharashtra, MP, Rajasthan, Bihar, Punjab, NEH, Kerala	2.80
Rapeseed-Mustard	UP, Bihar, Rajasthan, MP	0.95
Castor	Telangana, TN	0.50
Sesame	AP, TN, Karnataka	0.80
Sunflower	Karnataka & Maharashtra	0.50
Safflower	AP, Maharashtra, Karnataka, MP, CG	0.50
Linseed	UP, MP, Gujarat, Rajasthan, Maharashtra	0.80
Total		7.5

B. Non-traditional areas

Crop	Non Traditional Areas	Potential area (mha)
Soybean	Maharashtra, Rajasthan, Telangana, Jharkhand, Gujarat, NEH	2.00
Groundnut	UP (C&W), Gujarat, WB, Assam	0.51
Rapeseed-Mustard	Karnataka, Rajasthan (S), Ratlam (MP) & Vidarbha (Maharashtra)	0.30
Sunflower	West Bengal, Bihar and Odisha	0.30
Sesame	NEH	0.50
Safflower	Gujarat, MP and CG	0.10
Castor	TN, Haryana, Karnataka & Odisha	0.50
Linseed	NEH	0.03
Niger	AP, Karnataka & TN	0.05
Total		4.39

C. Rice Fallows

Crop	Area of rice Fallows	Potential area (mha)
Soybean	Punjab	2.00
Groundnut	TN, AP, Odisha, WB, Goa	0.50
Rapeseed-Mustard	UP, AP, Odisha, WB, Goa	1.50
Sunflower	AP, Karnataka, Odisha and WB	0.50
Sesame	WB, Odisha, Gujarat, TN, AP	1.00
Linseed for Utera situation	CG, WB, Odisha, Bihar, Assam	1.00
Total		1.00

14.3.3 Effective technology transfer

In spite of several efforts to bring harmony and coordination among the public institutes such as central research institutes, state agricultural universities (SAUs) and state departments, ground realities are not matching with expectations. Major funds released to the state departments for development activities do not have appropriate linkage for technology transfer with the universities and local research institutes. Among the improved variety/hybrid options to farmers from private and public bred products based on local tests are not largely available from the universities or central research institutes.

Access to newly released public bred products is major issue, though licensing process initiated recently did not make much headway in oilseeds group. Community managed seed systems needs a fresh look. Productivity improvement in oilseed crops can be achieved by some known technologies such as improving seed replacement ratio, large scale adoption of new varieties, dead furrow contour cultivation, paired row planting and reduced or zero tillage, herbicide based integrated weed management (IWM) for effective weed management in all soil types, adoption of integrated pest management (IPM) modules with bio-intensive approaches, providing micro-irrigation infrastructure at critical stages can be useful in increasing the productivity of all the oilseed crops (Table 5). A long term study reported a existing yield gaps, ranging from 24 to 41 per cent between farmers practices and improved technology, and 6 to 70 per cent between improved technology over the average yields of these crops. Several small interventions such as seed pelleting for lowering seed rate, cluster based oil extraction and marketing in nontraditional areas, enabling small farm mechanization and custom hire services, leveraging ICTs for dissemination of knowledge/technology transfer largely through mobile and short video films in public access, development of model farms and contract farming, educating farmers with proper input and technology supply, yield can be doubled in about a million hectare under cultivation. Sesame and safflower are potential profitable crops with technology readily available and has potential to replace several unprofitable Rabi crops facing moisture stress.

Table 5. Outreach of Technologies- Realizable Productivity and yield gaps (2010-15)

Crop	Improved technology yield (Kg/ha) (IT)	National Average yield (Kg/ha) (NAY)	Increase in yield due to IT over NAY (per cent)
Groundnut	2264	1439	57
Soybean	1603	1182	36
Rapeseed mustard	1692	1181	43
Sunflower	1742	700	149
Sesame	536	447	20
Safflower	1061	567	87.1
Niger	406	313	29.7
Castor	2032	1647	23.4
Linseed	1090	484	125.2
Average	1541	1019	51.3

Source: Reddy, A.V., 2017. Production Problems and Way Forward for Enhancing Productivity: Sunflower, Sesame, Niger, Safflower and Linseed, Presentation at Strategy workshop, NAAS

14.4 Protocol for Quick Dissemination

Following interventions and cropping systems protocols can contribute to increasing oilseeds production in all major edible oil crops in India;

- Use of ridges-furrows or BBF in all rainfed cultivated area with sowing on the onset of monsoon
- Use of bio-fertilizers such as Rhizobium, Azotobacter, Azospirillum, PSB, SSB & Mycorrhiza etc., which at lower cost supplement Nitrogen up to 40 Kg N per ha and up to 25 kg P per ha
- To achieve the optimum plant population per ha, it is essential to use seed priming, hardening techniques and also as per the requirement either thinning or gap filling has to be done
- Use Neem, Sulphur or Coal tar coated urea for enhancing the nitrogen (N) use efficiency
- Under extremes of natural resources & investment limitations, it is natural to follow integrated farming system model on small holdings to have assured income from oilseed crop based cropping
- Weed management is a critical issue especially in the initial growth stages and need to be adopted either mechanically or using the herbicides

- Weather forecasting and forewarning system to be used for determining the operations and also the pest and diseases early detection is must to reduce the heavy losses

- Boron application has been recommended for sunflower which has shown to increase the yield by 15-25 per cent across several locations and hence it should be a compulsory package of practice in the schedule of cultivation of sunflower.

14.5 Ongoing Initiatives of Government of India

The strategies for enhancing the productivity (and profitability) of oilseed based production system are prepared for the annual oilseeds and for oil palm in the country. The interventions/ strategies proposed in oilseeds are time tested with scale neutrality that can be grounded for enhancing the productivity of the oilseed based production systems with necessary institutional support/ handholding. The proposed strategies are categorized under four situations as follows.

1. Increasing seed production and distribution of newly released varieties
2. Low cost technologies with high impact on productivity resulting in higher income
3. Technologies with high impact that involve reasonable investment with high return on investment (ROI), with emphasis on eco-friendliness, high input use efficiency, and
4. Strategies with emphasis on quality improvement and value addition leveraging technologies with a bearing on the employment through skill/ entrepreneurship development.

The newer opportunities to explore non-traditional seasons and regions for crops are also projected that have proven success for area expansion and integration into major cropping systems.

The Government is aware that there exists a tremendous potential for enhancing the yield of nine oilseed crops by adopting the technologies already available. This contention is based on the results of 23,118 frontline demonstrations (FLDs) (2010-2015) conducted on nine oilseeds crops under real farm situations in different agro-ecological conditions of India over a period of five years. The productivity (yield) gap between improved technology and farmers' practices ranged from 21 per cent in sesame to 149 per cent in sunflower (Table 5).

Bridging yield gap across oilseeds can increase oilseeds production significantly that would concomitantly reduce the dependence on imports of vegetable oil besides realising higher profitability to oilseed farmers.

To boost production of oilseeds, the GoI started a National Mission on Oilseeds and Oil palm (NMOOP) for Oilseeds & Oil palm development programmes in the country in 2014-15 and continued up to 2017-18.As per the decision of Cabinet Secretary regarding merger/ conversions or linkage of Schemes/ sub Schemes/ programmes, etc. having similar components such as incentive for seed, demonstration, and farm implements including efficient water application tools covered under NFSM and Oil seeds was merged under revamped National Food Security Mission (NFSM) from the year 2018-19. The Objectives of NFSM-Oilseeds & Oil Palm are as below:

- Increase in production and productivity of vegetable oils sourced from oilseeds and Oil palm. It aims to augment the availability of vegetable oils and to reduce the import of edible oils by increasing the production and productivity of oilseeds from an average production of 29.79 million tonnes and productivity of 1122 kg/ha during 12th plan period to 36.10 million tonnes and 1290 kg/ha, respectively by end of 2019-20 (MM- I)

- Effort will be made to achieve additional area of 1.05 lakh hectare under oil palm cultivation during 2017-18 to 2019-20. With additional area of 1.05 lakh ha under Oil Palm during next three years i.e. up to March, 2020, total area of about 4.20 lakh ha, will be achieved (MM-II)

- An area of 7480 ha will be covered under plantation of 09 Trees Bearing Oils (TBOs), namely, Olive, Mahua, Kokum, Wild Apricot, Neem, Jojoba, Karanja, Simaroba and Tung during next 03 years i.e. upto March, 2020 (MM-III).

The three mini Missions are progressing well and should be able to meet their targets.

14.5 Policy Instruments for Improving Edible Oil Economy

Efforts are needed to implement the Minimum Support Price (MSP) along with bonus for enhancing the net income of the oilseed farmers. In spite of a regular enhancement in MSP of oilseed crops, lack of a defined procurement policy does not encourage the farmers to take up the cultivation of these crops. Like rice and wheat procurement system operated in North Indian States, an assured purchase of the produce would stimulate oilseeds producers to expand area and adopt improved technologies for better yields. Attempts for price realization based on the oil content can enhance the net income of the oilseed farmers. However, the efforts of linking price with oil content have largely proved disadvantageous to farmers (particularly in mustard) for various reasons of setting unrealistic standards and implementation of oil content estimation in the markets. Edible oils, except coconut and palm oil, were kept under Open General License (OGL) and import duty was substantially reduced. The heavy imports of edible oils had a cascading effect on edible oil economy. Import duty was 12.5 per cent on crude oils, 20 per cent on refined oils and 30 per cent on raw material (sunflower and rapeseed) for crushing. The industry association (SEA) demand is to raise the import duty on refined oils to safeguard the interest of farmers and higher capacity utilization of refiners, which currently operate at 40 to 50 per cent of the capacity only. In order to overcome the shortage of raw material for crushing and feed, the industry had suggested to encourage import of oilseeds by lowering duty to 5 per cent from 30 per cent at present and reduce the duty on oilcake, rice bran and oil bearing materials from 15 per cent to nil to make their import commercially viable to encourage value addition and employment within the country. However these policies in long run have discouraged to grow these crops as they did not find their cultivation remunerative. The fluctuating and counter directional policies with respect to imports and domestic prices have left the stakeholders unsure of any long term planning by both the producers and processors. The Government of India has recently made some welcome corrections in the import policies of vegetable oils such as enhancing the import duty on crude as well as refined edible oils by 40-100 per cent. This will be encouraging to growers to take up cultivation of edible oil crops as they would be much competitive to cereals in dryland areas. Every option of risk mitigation like easy availability of inputs and credit, MSP and assured procurement, crop insurance, policies linking farmers to markets, buffer stock options and their commodity price stabilization schemes and free technical guidance need to be put in place for oilseeds sector on priority if the country has to reduce its foreign reserves on the import of edible oils.

Accelerated progress and focus on enhancing the profitability, stability, and sustainability of the major oilseed crops based farming systems rather than productivity focus alone of each crop is likely to yield long term benefits. Policies always favored the oil consumer by checking price rise but they have not been kind to the oilseed producer, the farmer.

14.6 Recommendations

Recognizing that oil economy of the country is dependent on import of vegetable oil, it is essential to make special efforts to boost productivity and production of domestic oilseed crops for enhancing local availability of the edible oil. The participants of the strategic workshop on "Vegetable Oil Economy and Production Problems in India" deliberated on several issues pertaining to, the means of enhancing production, availability though research, extension and key policy instruments for MSP, import structure and developing effecting value chain linkages. Major recommendations are summarized below:

Regulate the import of edible oil through appropriate inventions in policy as has been done for the current oil year. The vegetable oil should be viewed beyond the export & import balance with the goal of achieving self-sufficiency to a greater extent. The domestic availability should be viewed in the context of improved livelihood, farmers' profitability and for processing industry of the country.

The mechanism of minimum support price (MSP) though available is not in operation inmajor oilseed producing states. Therefore ensuring the market intervention for effectiveimplementation of MSP through procurement of oilseeds in case of fall in open market prices is needed.

The potential of public-private partnership (PPP) through linkages in all aspects of production, processing, marketing needs to be harnessed. PPP model can be useful in several aspects of oil economy such as seed production, forward-backward linkages for processing, value addition, contract research in niche areas, contract farming and joint ventures for higher order derivatives and specialty products and so on. Therefore it is essential to create an enabling environment for private participation in such areas.

The export of oil meals for animal feed and castor oil has to some extent plugged the import bill of vegetable oil. However the policy of exporting oil meal may not be desirable in long run as the domestic animal industry is deprived of high value feed to increase the milk and meat production. There are also arguments that instead of importing crude or refined oil, why not import oilseeds so that the local crushing industry also prospers and at the same time oil cake as animal feed is also made available. However policies that balance all these factors could be formulated through PPP mode.

Greater emphasis on innovations and application of new techniques of genetics and biotechnology need to be harnessed to achieve quantum jump in productivity. Use of transgenic in soybean, cotton rapeseed-mustard and maize has been globally accepted and currently 83 per cent soybean, 75 per cent cotton, 29 per cent maize and 24 per cent canola grown in the world are transgenics. India need to take a bold and defined stand based on science to allow the technology use in edible oil crops. Indian scientists have already succeeded in developing GM mustard, which has been thoroughly assessed and approved by the regulatory committee and waiting for the political green signal. Similarly, GM groundnut resistant to biotic and abiotic stresses, sunflower resistant to viruses, safflower and castor transgenics are being developed in the Indian public sector institutions. They need to see the light of the day and waiting for the first GM oilseed crop, mustard to get clearance so that others can follow.

Research priorities should focus also on developing short duration genotypes for better adoption to climate change and in rainfed situations through integration of modern tools of biotechnology such as marker assisted selection and transgenic breeding supplementary to conventional breeding.

Institutional convergence would be a key to effective transfer of technology in oilseed sector. For this strengthening the linkages between the research and extension is required where the linkage of NARS-KVK needs to created for validation, upscaling and transfer of research outputs with accountability.

Model Oilseeds Technology Farms developed through mission funding at State levels and managed by ICAR and KVK's would be torch bearer for technology, showcasing as has been successfully done during green revolution period for transfer of technologies of rice and wheat.

Develop contingency seed banks at selected districts either through seed village concept or in PPP mode. Seed production in private sector is already being done in soybean, hybrids of sunflower, mustard and castor. There is need to encourage private participation in groundnut and other minor oilseed crops.

Promote oilseed cultivation in nontraditional areas, rice fallows and in off seasons. They could be best substitutes for diversification in rice-wheat belt. Eastern regions offer good scope for expansion of area. The entire dryland cultivation offers an opportunity for intercropping with cereals, cotton and pulses.

Large scale production of small machinery though Government support is necessary to improve adoption of farm machinery in oilseeds cultivation. There are now excellent examples of group farming in many States where the system of common machinery hiring is adopted because of shortage of labour. These are giving good results. Government should catalyze such processes to promote farming especially with small farm holders.

Oilseed crops also offer opportunities for additional income through various products like table purpose groundnuts, sunflowers & safflower petals, linseed fibre and omega-3 substitutes which can be exploited so that back ward linkage in production can occur.

Oil palm cultivation should be extended in some areas where it can give higher yield. Simultaneously processing facilities should be promoted so that this could be a good source of oil for the total vegetable oil pool.

Promote scientific processing of cotton seed for higher recovery and to get high protein retention (42 per cent) compared to traditional processing (22 per cent). Cotton seed contains nearly 21-24 per cent edible oil but the current cultivars have only 17-18 per cent. There are genotypes where oil is the primary product and fibre is secondary with no gossypol. To meet the oil demand such cotton cultivars offer a good source. Also it is recommended that processors should improve the efficiency of extraction of oil through solvent extraction for hard seeds and expeller extraction for soft seeds.

Currently, there is no linkage between the oil expeller industry and producers. A model of sugarcane available can be followed for oilseeds too. The oil industry should go in to contract with farmers for assured supply of raw material at predetermined prices which will encourage farmers to take up cultivation on modern footing. The industry should also be involved in supporting the technology generation and dissemination.

14.7 Follow the Success Story of Pulses

Pulses are a major source of dietary protein in India, especially for the majority low-income households, besides being rich in essential minerals, vitamins and fibres. Producing 14 to 18 million tonnes during 2000 to 2014, India has been the largest producer of pulses in the world. But, the demand has increasingly outstripped the supply until 2017, necessitating imports of about 3-5 million tonnes, the largest in the world, costing nearly 2.5 billion US dollar annually, let alone the erratic price rises. Keeping in view the growing costly imports, thin global market, and volatile prices, India had to become self-sufficient in pulses, and NAAS felt that the needed projected production of 24 million tonnes could be achieved within 2 to 3 years.

Accordingly, NAAS organized a Strategy Workshop entitled Towards Self-sufficiency of Pulses in India on 7-8 April, 2016 to deliberate the challenges, opportunities and prospects (Strategy Paper 2). Critically analyzing the current and projected situations of production, consumption, and trade, in light of the technological, socio-economic, market, and agro-ecological domains, the Workshop, prepared a detailed strategic framework and comprehensive district-wise action plan for 19 of the pulses-producing provinces, including Madhya Pradesh, Uttar Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Rajasthan, which jointly accounted for 77 per cent of the national pulses production. All stakeholders at the national, provincial, district and village cluster levels judiciously implemented the Action Plan and rendered India pulses self-sufficient in the next two years, currently producing 24-25 million tonnes and maintaining a comfortable buffer stock. The success should dynamically be fortified.

Conclusion

Edible oil Industry is one of the most important industries of agriculture sector in India. The country plays an important role in the global edible oil market, accounting for 10-12 per cent share of consumption, 6-8 per cent share of edible oil production and 12-14 per cent share of world's edible oil imports for the oil year 2015. India is fourth largest oil seed producing country in the world after USA, China and Brazil. Of the nine, soybean, groundnut and mustard are the main oilseed crops grown in the country. The growth of edible oil consumption and increasing population coupled with limited availability of oilseeds and fluctuating yields resulted in continuous demand-supply gap, which is being met by imports. Further, the imports of vegetable oils are subject to change in custom duty rates between crude oil and refined oil which do affect the domestic producers and refiners. Apart from the custom duty structure the edible oil industry is also susceptible to the policies of exporting countries.

The oilseed production is constrained by several factors like grown on depleting soils, deprived of nutrition, water and other inputs. Nearly 64 per cent of these crops are grown as rainfed and hence occasionally suffer from drought under erratic rainfall. The cultivation also suffers due to low adoption of improved cultivars and modern technologies. Unorganized marketing, price fluctuations and inoperative minimum support price (MSP) mechanism make the oilseed cultivation an unattractive proposition. Also Government policies should be so designed that they are more in favour of producers and domestic refiners than the consumers alone. Though the duty differential between crude and refined palm oil increased in recent years, edible oil sellers are finding it more convenient to import refined palm oil and sell it in the domestic market thus placing the edible oil units to operate at hair line margins or in worst case scenario wherein the units are small the operations have become unviable. The performance of the companies in edible oil sector for medium term period will depend upon the demand of crude palm oil in India post recent increase in import duties on refined oils, movements of domestic edible oil prices, and profitability margins from the specialty-fat business with comprehensive product range, including bakery shortening's, chocolate and confectionary fats, ice cream fats and a range of cooking oils.

For pulses we must rigorously follow the strategy which has already paid rich dividends, and repeat this success story in vegetable oil. For oilseeds while the trade and tariff policies are important, science, technology and innovation must play the driving role in more than doubling oilseeds productivity during the next 5-10 years, by genetically enriching the seeds for productivity as well as stress tolerance. Simultaneously, there is scope for enhancing oilseeds area by increasing cropping intensity. To meet the total vegetable oil requirement of about 39 million tonnes in 2050, the total vegetable oilseeds availability should be about 120 million tonnes. Should India pledge to cut down the import to only 30 per cent of the total domestic need, we will need to locally produce 27 million tonnes of vegetable oils by producing about 81 million tonnes of oilseeds from the present level of about 30 million tonnes. The feasible pathway to achieve this goal is complementary doubling of average yield to about 2 tonnes/ha and increasing the area from current level of about 27 million ha to about 40 million ha by 2050. The target set is attainable only by synergistic collaboration of all stakeholders. We should also have a view whether the present level of per capita consumption of 18 kg/year is medically advisable.

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Chapter 15

Regulatory Aspects of Utilization of GM Crops and GE Technology for Food & Nutrition Security, Climate Resilience, and Improving Farmers' Income

15.1 Introduction

This chapter is essentially a reproduction of the NAAS recommendations contained in its policy brief papers entitled "Biosafety Assurance for GM Food Crops in India" and "To Accelerate Utilization of GE Technology for Food and Nutrition Security and Improving Farmers' Income", with minor modification and a few additional facts, for consideration of all stakeholders, especially the regulatory authorities to liberate science to serve society.

The chapter underpins the baseless, ill-informed, unscientific and illogical opposition of genetical engineering, GM organisms and other proven safe products arising from new sciences and innovations, and the recalcitrance of the policy makers and the governments in delivering the proven safe products/technologies to the farmers and end users along the value chain are denying India not only from achieving comprehensive food and nutritional security, climate resilience and accelerated sustainable agricultural development, but are also thwarting development of cutting-edge technologies, and innovations and the development of human resources and institutions, thus denying India to emerge as a New India.

15.2 Bio-safety Assurance for GM Food Crops in India (NAAS Policy Paper 52)

Genetically modified (GM) crops are the product of introduction of one or more well characterized genes in a crop plant using recombinant DNA technology. The genes introduced may belong to either a distant species or a closely related species or the same species. Based on their proven merit, the global acreage under GM crops swelled from 1.6 million hectare in 1996 to 148 million hectare in 2010. In India, Bt cotton today occupies nearly 9.5 million hectare, 86 per cent of the country's total cotton area.

Yet, there is a strong opposition to the commercialization of GM crops in India and several other countries on the perceived grounds of their health and environmental unsafety. Whereas, from the deliberations of innumerable national and international symposia it has emerged that, while it is almost impossible to prove that the GM crops are completely safe, all experimental evidences and commercialization experiences during the last 15 years have revealed no risks.

In order to critically examine the current biosafety issues and the prospects of benefiting from the GM technology, the National Academy of Agricultural Sciences organized a Brainstorming Session on Biosafety Assurance for GM Food Crops in India on June 22, 2011. The main stakeholders – noted scientists and representative of public and private sectors and NGOs had participated. Based on detailed analyses of the available evidences, the

Session concluded that GM technology is a powerful tool and the transgenic varieties of various crops so far commercialized are safe.

Since the GM approach is a dynamic process, it should be continuously enriched scientifically and evolved in a transparent and socially inclusive manner. This invaluable document addresses all issues of concern and contains science-based recommendations and concrete actions for safe, inclusive and judicious harnessing of the GM technologies for accelerated and sustained crop production. The Session made the following observations and recommendations.

The GM technology is a powerful tool for developing future crop varieties with in-built genetic resistance to various biotic and abiotic stresses for reducing crop losses and enhanced input use efficiency, yield potential and quality traits. Their use will be crucial for the food and nutritional security of the country and therefore research on them must be continued with the aim of developing safer, more productive and nutritious food crops. However, this should be done in a more transparent and socially inclusive manner for wider public acceptance. Also, concerns of the opponents of GM technology should be addressed to allay the public concerns on food, environmental and economic security.

There is also scope for developing a range of GM food crops by transferring genes from one food crop to another or back into the same crop after suitable modification for enhanced or reduced expression levels. This concept is being promoted in Europe as 'Cisgenic' technology, which is a variant of the transgenic GM technology but has negligible food safety risk, and therefore may face less opposition/criticism.

The issue of bio-safety should not be a matter of individual opinion and undue fear or overconfidence. Therefore, the food and environmental safety of the specific GM crop events must be actually evaluated by the experts before their commercial release to the farmers. A very good system is already in place in India for this purpose. It was shown that the present bio-safety evaluation system in India follows all the international bio-safety norms and standards and is one of the most stringent [1]. However, national capacity needs to be enhanced to handle a large number of samples expected with increasing number of new transgenic events.

All GM crop events will not require the same level of biosafety evaluation. The level of biosafety concern increases when genes are transferred from distant species to which humans and farm animals do not have prior exposure as food or feed. Therefore, the bio-safety is to be evaluated on a case-by-case basis and it will not be scientific to make generalized statements about the biosafety of all GM plants.

Regarding the concern for loss of crop biodiversity due to introduction of GM food crops, the danger is no more than many traditional varieties of wheat and rice going out of cultivation due to introduction of high yielding semi-dwarf varieties during nineteen hundred sixties and seventies, the so called era of Green Revolution. But this is a real concern and a way has to be found to compensate the farmers, who choose to participate in the process of *in situ* conservation of biodiversity of crop varieties. As far as possible, such diversity must be collected and deposited in the national gene bank at the earliest for the purpose of gene discovery and allele mining activities.

Another biosafety concern that has been widely discussed is the transfer of introduced gene to wild species through pollen. In this connection, a number of studies have been conducted and it was found that pollen flow does take place. However, this would not have much consequence unless a selection pressure is applied to the wild species leading to increase in the gene frequency [5, 25]. The consequences of gene transfer via pollen should be evaluated on a caseto-ase basis and due precaution must be ensured.

The development of resistance in the insects against insecticides and that in the weeds against herbicides has also been widely discussed. It has been recognized that the development of such resistance is a normal phenomenon even during conventional plant breeding, and should be treated in the same manner

A major point of concern among the farmers is also the monopolistic control of seed business by MNCs (multi-national companies), leading to sometimes exorbitantly higher cost of seeds [31, 35]. The solution to this problem is to encourage competition among the GM seed companies and even more importantly to have mission-mode programs for the development of GM seeds in the public sector, which has yet to deliver a popular GM crop product. This may be partly due to insufficient support and lack of mission-mode approach for the development of GM technology in the public sector.

Access to seed of approved GM crops is another concern. Therefore, the government should make a policy for procuring the seeds of useful GM food crops and make them available to the needy farmers at an affordable cost in the same way as it does for fertilizer and diesel subsidy. In fact, future GM food crops with enhanced nutrient use efficiency will require less fertilizer, thus reducing the input cost of cultivation for the farmers. Similarly, GM technology is also seen as a solution to the energy crisis by producing more efficient GM crops for biofuel

Currently our preparedness for risk assessment research is inadequate to provide scientific support to the regulatory process. Therefore, a **"National Institute of Bio-safety and Bio-Security"** should be created with state of the art infrastructure, human resource and research programs for conducting frontier research, capacity building in this field and providing policy support and technical advice to the government on this issue. Presently, although we have a good bio-safety evaluation system using standard protocols, there is very little basic research being conducted on the various aspects of the GM food crops in India. The risk assessment should also include the so called issue contamination needing of separation of GM food from non-GM foods and horizontal gene transfer etc. as advocated in the Occasional Paper of the Rajya Sabha Secretariat.

Education is a key to allay undue fear of GM food crops in the minds of public due to successful misinformation campaign by certain organizations. The public needs to be educated properly about the facts regarding both food safety and economic benefits of the GM food technology [14]. However, this will be more effective if the government promoted the GM crops developed by the public sector or that purchased from the private sector in the public interest, and is not perceived as a proxy to the multinational seed companies.

A major deficiency in India is also the lack of PPP (public-private partnership) for joint development and ownership of the GM food crop products. The products are coming almost entirely from the MNCs due to small size of the Indian seed companies *vis-s-vis* their R&D expenditure. This sometimes leads to lower public confidence particularly in the large section of poor farmers with limited resources for procuring agricultural inputs.

15.3 Action Plan for the Development and Utilization of GM Food Crops

In view of the long gestation period for the development of useful GM crop events, and the high cost of research and development, there seems to be a need to have a sound biosafety evaluation and regulatory infrastructure. Following plan of action is suggested for this purpose:

15.3.1 Bio-safety Evaluation and Regulatory Mechanism

- The government should enact the proposed Biosafety Regulatory Authority of India (BRAI) legislation at the earliest for a single window regulation of GM crops. It should have a transparent time-bound decision making, similar to a citizen's charter, for rejection or acceptance of the GM crop events taking care of all the public concerns

- ICAR should take a proactive role in the conduct and monitoring of biosafetycum-evaluation trials as stipulated in the revised RCGM guidelines, so that no time is lost in bringing the elite GM crop material to the farmers

- We need to strengthen the public sector laboratories conducting bio-safety evaluation and also promote establishment of accredited private sector bio-safety labs for crops and food products because we expect deluge of GM crop events in the coming future and our physical and administrative infrastructure should be commensurate with the demand

- We need to strictly enforce the regulation on the ground because a good "Regulatory Act", if poorly implemented will bring disrepute to this wonderful technology. For example, experimental GM crop events should not land at farmer's hand for widespread cultivation before they are approved by the regulatory authority

- GM crop events need to be classified, based on the perceived bio-safety risks and the level of regulation should be calibrated accordingly. For example, a gene coming from a food crop or another edible life form being transferred to another food crop need not go for an elaborate toxicity and allergenicity testing. Similarly, a protein coming from a distant source like soil bacterium but already tested extensively for toxicity and allergenicity, need not be tested again and again for this because it will unnecessarily delay the deployment of a benign gene for the benefit of society

- We need to develop a mechanism for fast track clearance of GM crops with no perceived bio-safety risks, on the basis of the above categorization and biosafety evaluation

- It may not be necessary to subject a GM crop to fresh bio-safety testing and evaluation process, or undergo bridge biosafety study, if it has resulted either from pyramiding of more than one approved GM events into a single variety or due to transfer of an approved event from one genetic background to another elite genetic background through molecular marker technology

- We need to initiate research on integrated pest resistance management through gene technologies and crop management

- We need to start studies on the potential of herbicide tolerant crop adoption on tillage practices

- It is necessary to implement on priority and preferably in a network mode research studies on reproductive biology and potential impact of gene flow in native crops

- Program should be initiated to inform and educate the policy makers, farmers and public about merits of GM crops for food security and potential benefits and risks of GM crops on biodiversity

- Steps should be taken to harmonize the policies at the level of State and Central Governments so as to minimize the hindrance in conveying the benefits of proven pro-poor technologies to the farmers

15.3.2 Pre- and Post-release Monitoring and Evaluation of GM Crops

- Set up mechanisms for pre- and post release monitoring of cultivation of GM crops as a part of the BRAI to see that recommended practices are followed. This should be accompanied with the feed-back with respect to the accountability of the GM crop seeds

- Have provision for adequate punishment for violation of specific guidelines built into the BRAI Act

- We also need to initiate research on analysis of the impact of GM cotton adoption in India on (i) cotton genetic diversity, (ii) economic gain to the cotton farmers and (iii) development of insect resistance to the Bt gene.

15.3.3 Accessibility of Approved GM Seeds to the Farmers

- Strengthen the publicly owned national and State seed corporations for making the approved GM seeds available to the farmers at an affordable price

- Fix MRP for the approved GM seeds so that no one is allowed to charge exorbitant price. The Government may consider to include all seeds including GM seeds under the category of the essential commodities in order to regulate the price of seeds

- If required the seed prices may be subsidized to ensure affordability to the farmers in a way similar to the fertilizer and diesel subsidies. This will be required only if the cost of seed development and production is actually very high

- Enact the long awaited 'Seed Bill' legislation for effective regulation of seed business in India while retaining the right of farmers to save seed.

15.3.4. Research and Development including PPP

- Although considerable work has been done in the public sector with respect to the development of GM crop events, these have not reached to the farmers. Hence, DBT and ICAR should consider establishment of separate Task Forces focusing on GM crops in a coordinated approach

- We also need to constitute a Task Force of experts for in-depth analysis and prioritization of the crops, traits and genes for developing GM crops

- Start mission mode projects for the development of elite GM crop events in the selected crops for selected traits in the public sector institutions with adequate financial support and monitoring of progress. There is need to strengthen selected institutions with proper tissue culture and transgenic greenhouse facilities with assured power supply

- Sufficient grants should be provided for out-sourcing of bio-safety evaluation and regulatory approval of the elite events developed by the public sector institutions to competent professional services

- Encourage private companies to take up joint R&D projects with the public sector with the aim of developing GM products with joint IPR protection. The products can then be commercialized by the seed companies (both private and public) on the basis of reasonable sharing of benefits

- Added emphasis needs to be given on non-controversial and attractive GM crop events. For instance, the new (stronger) Golden Rice events need to be transferred to elite commercial cultivars with added features of better iron and zinc uptake, critical for the biosynthesis of β-carotene to vitamin-A. These could be used very effectively to garner public support for the GM food crops technology

- Initiate GM crop projects for traits that will have positive impact on crop diversity. For instance, improvement in yield, adaptation, nutrition and consumer acceptability of “orphan crops” would provide attractive options to the farmers for crop diversification.

15.3.5 Education and Public Awareness

- Devise curricula for schools and universities incorporating modern concepts ofgenetic modification of crops and societal needs

- Encourage interface of students, scientists and teachers; develop suitable models and modernize lab

- oratory infrastructure for demonstration and skill development in the area of GM crops

- Sensitize extension personnel on the usefulness of GM crop technology. Krishi Vigyan Kendras (KVKs) should be equipped to undertake this exercise

- Train and educate the farmers at village/district level by inviting them to special training programs and demonstrate GM technology on the fields by frontline demonstrations (FLD)

- Connect to e-chaupals, radio and TV shows for education on benefits of the GM crop technology

- Strengthen genome/DNA clubs under the Agriculture Technology Management Agency (ATMA)

- Prepare spokespersons and media outlets to interface with public and policy makers and also arrange “Road Shows” and “Workshops”

- Prepare fliers of frequently asked questions (FAQs) and their answers in Indian languages and distribute them widely. Knowledge-based articles/reviews also need to be published from time-to-time, particularly in popular science journalsand newspapers. (Bring out DVDs on GM Crops both in English and other Indian languages).

15.4 Utilization of GE Technology for Food & Nutrition Security and Improving Farmers’ Income

Towards building New India, India’s agriculture must be transformed to be more productive, profitable, health-friendly, climate smart and environmentally sustainable. To meet these challenges, the country has no option but to use all the available and emerging tools and technologies. Genetic engineering (GE), also known as GMO technology, is one such technology, which has shown great promise in improving crop productivity, best exemplified by the outstanding success of *Bt*-cotton in India.

As India is one of the wordst affected countries by the climate change, genomics should be used to deliver climate-change ready crops. Whiel working on germplasm collections including CWR, the genetics community can map Climate change relevant traits should be mapped with the help of high-throughput genotyping and phenotyping platforms in a faster and more cost-effective manner. Next generation breeding approaches including (GS) and Genomic Editing (GE) can use the new germplasm and technological advances to develop climate change lines. Such breeding materials should be widely shared so that the advances can be translated into delivery higher genetic gains in farmers' fields through location-specific selection of climate change ready crops in a cost-effective and rapid manner.

The Green Revolution notwithstanding, in the last two decades (1996-2015), the global area under GE crops has increased over 100 folds, from 1.7 to 179.7 million hectares, benefitting nearly 18 million farmers. Of these 18 million farmers, 90 per cent were small, resource-poor farmers in developing countries. In 2015, of the 28 countries2 planting GE crops, 20, were developing countries, covering more than 50 per cent global area under the GE crops. These crops have provided enormous environmental and economic benefits. A global meta-analysis has shown that *"on average, GE technology adoption has reduced chemical pesticide use by 37 per cent, increased crop yields by 22 per cent, and increased farmer profits by 68 per cent"* 3. Between 1996 to 2014, GE crops have helped in increasing crop production valued at US$150 billion and improving environment, "by saving 584 million kg a.i. of pesticides; in 2014 alone, reducing CO2 emissions by 27 billion kg, equivalent to taking 12 million cars off the road for one year; conserving biodiversity by saving 152 million hectares of land; and helped alleviate poverty for ~16.5 million small farmers and their families totaling ~65 million people, who are some of the poorest people in the world"

Regulatory approval is an essential requirement for commercialization of GE crops, to ensure the biosafety of the GE crops, their products, and the associated technologies. India's multi-tier regulatory system is one of the most robust regulatory systems in the World, to address the biosafety and environmental issues, which are considered to be the main impediments in public acceptance of GE crops. Under the 'Rules for Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms/ Genetically Engineered Organisms or Cells 1989', of the Environment Protection Act, 1986, six competent authorities, i.e. the Recombinant DNA Advisory Committee (RDAC), Institutional Biosafety Committees (IBSC), Review Committee of Genetic Manipulation (RCGM), Genetic Engineering Appraisal Committee (GEAC)6, State Biotechnology Coordination Committee (SBCC) and District Level Committee (DLC) have been established. While the RDAC has advisory role, the IBSC, RCGM and GEAC have functions to regulate GE products, including the GE crops, the SBCC and DLC are involved in monitoring. The GEAC is the apex body constituted by the Ministry of Environment and Forests and Climate Change.

15.4.1 Major Regulatory Hurdles

Following the moratorium on *Bt* brinjal on 9th Feb. 2010, there was a setback to GE research and the country continues to debate on the relevance of GE crops in India, in spite of the success of *Bt*-cotton clearly showing environmental and socioeconomic advantage of growing GE crops. Recently, the environment for GE research has improved as the Government of India has taken positive steps and allowed field trials of several GE events. Of these, GE varieties of three crops carrying important traits – mustard for hybrid seed production, cotton with stacked resistance to insect and tolerance to herbicide, and brinjal for insect resistance - are ready for commercial release14. However, introduction of the requirement of 'no-objection-certificate (NOC)' from the State Governments, for conducting confined field trials, has emerged as a major hurdle in moving forward.

It is high time to release and commercialize the GE varieties, which have been tested to be biosafe, to extend the benefit of growing these varieties to the farmers, consumers and the environment without further delay. This will also help in giving fresh push to the utilization of the available technology for improving our crops by introducing desirable traits for protecting environment and health of the consumers and extending economic gains to the farmers.

Since the introduction of *Bt*-cotton in 2002, the regulatory system in India has undergone changes necessitated by the experience of cultivation of *Bt*-cotton. Notably, the regulatory system has evolved in line with the improvements in biosafety and environmental safety as recommended in the guidelines of the WHO, FAO and OECD. However, there is a strong need to provide enabling regulatory and policy framework to make the regulatory system efficient and effective to accelerate utilization of the GE technology for the benefit and economic empowerment of resource-poor farmers. This can be achieved by –

a) Renaming the GEAC again as a Genetic Engineering Approval Committee and authorizing it to approve multi-location testing of the biosafe GE varieties

b) The Indian Council of Agricultural Research (ICAR) should take the responsibility of multilocation testing of the GE varieties, approval for environmental release by the GEAC, on the pattern followed for multi-location trials of the non-GE varieties

c) There is an urgent need to establish the Biotechnology Regulatory Authority of India (BRAI) *to promote the safe use of modern biotechnology by enhancing the effectiveness and efficiency of regulatory procedures.* Until the time Parliament approves creation of autonomous BRAI, the RCGM and GEAC should have full time chairpersons as recommended by SAC to PM, and the GEAC should function like a statutory body and make final decision on approval of the GE event for environmental release

d) A policy decision may be taken by the MoEF&CC, through Gazette Notification, that the 'NOC' by the State Governments for 'confined field trials' is not required, particularly as there is no such provision in the biosafety guidelines

e) Apart from restructuring of the regulatory system, there is also a strong need to re-examine and harmonize biosafety requirements on case to case basis, to reduce the cost of regulation.

15.4.2 Emerging New Options

Application of emerging -omics technologies will further strengthen regulation in the country's multi-tier regulation system, of novelty, potential hazard, and environmental exposure to provide greater assurance that no unintended differences have been introduced by any breeding process used in the development of GE crop varieties. Moreover, innovations in the future would be more effective, efficient and devoid of biosafety issues of any kind.

15.4.3 GE Crops are as safe as their non-GE counterparts

During the two decades of the use of GE crops for food and other purposes, no risks, related to human health and environment as well as the related issues have been encountered15 16. This view has also been supported by the 107 Nobel Laureates in their letter to the Governments around the world, saying that the GE crops are "… as safe as, if not safer than those derived from any other method of production"17 A recent extensive study by the three science academies in the US examined the positive and negative claims on the effect of GE crops to environment and human health. The study found "little evidence to connect GE crops and their associated technologies with adverse agronomic or environmental problems." For example, there is a general perception that the use of GE crops leads to loss of biodiversity. The US study found no 'substantial' reduction in on-farm biodiversity, and to the contrary, 'sometimes their (GE crops) use resulted in increased biodiversity'. The study also found clear association of the use of *Bt* crops with a decrease in the use of insecticides by the farmers. In an extensive study in India, an average of 82.8 per cent decrease in insecticide sprays on *Bt* cotton was found in the three major cotton growing states – Andhra Pradesh, Maharashtra and Punjab19. Development of resistance in pests resulting from use of sub-lethal doses of pesticides or over use of single pesticide is a natural phenomenon. Similarly the evolution of resistance to *Bt* toxin has been found to be associated with the use of GE crop varieties expressing low doses of *Bt* toxin or non-planting of refuges. Evolution of resistance to herbicide in weeds was also found to be associated with the overuse of a single herbicide (US Study, 2016). Such resistances can be easily checked by appropriate regulations and monitoring of the GE crops, and encouraging farmers to use integrated and sustainable pest management approaches.

A decade of EU-funded GE research did not find any adverse effect of the GE crops on health and environment as compared to traditionally bred varieties 20. Similarly, the US study (2016) found no evidence that would suggest a higher risk to human health from consuming GE foods compared to consuming the non-GE counterparts. On the contrary, the US study found some evidence that GE insect-resistant crops have had beneficial effects on human health by reducing insecticide poisonings and decreasing exposure to mycotoxins.

Overall, the US study found no evidence of cause-and-effect relationships between GE crops and environmental problems. However, the complexities involved in the assessment of long-term environmental changes often made it difficult to reach definitive conclusions. That is illustrated by the case of the decline in monarch butterfly populations. Detailed studies of the population dynamics of monarch butterfly carried out as of 2015 did not demonstrate an adverse effect related to the increased use of glyphosate, although there was still no consensus among researchers that the use of glyphosate on milkweed did not cause a reduction in monarch populations. The studies in India have shown that the activity of honey bees is not hindered by *Bt*-cotton.

15.4.4 GE Crops for the small-scale farmers

The GE crops have been found equally useful for both the large- and small-scale farmers but the small-scale farmers are more likely to be successful with GE crops when they have 'access to credit, extension services, and markets and to government assistance in ensuring an accessible seed price'22. The success of *Bt*-cotton in India can also be attributed to the extension services, availability of inputs at reasonable cost, credit and markets.

Initial push for the development of GE crops was driven by large investments in research and technology development by the private sector institutions, but in the future, public-sector institutions have to play a much greater role, particularly for developing GE crops of interest to small-scale farmers. This change is expected, as the returns from investments in research will not be sufficiently attractive for private-sector investment.

15.4.5 Need to promote GE technologies for improving farm incomes

The 2010 moratorium on the release of *Bt* brinjal and subsequent hurdles for field testing of GE crops adversely affected the morale of scientific community in the country and decelerated research on GE crops, and students intake in biotechnology. The trend must change, by creating an environment and improved funding, to support GE technologies for the development of crop varieties in sync with traditionally bread varieties for resistance to biotic and abiotic stresses and to improve their nutritional content and productivity. Such varieties will help in hunger alleviation and improving farm incomes.

15.4.6 Need to Create Public Awareness

One of the non-scientific barriers in the way of promoting GE technology is the erroneous public perception that - the GE technologies are the monopoly of multinational companies. A survey conducted under the auspices of the Phase II Capacity Building of Project on Biosafety of the Ministry of Environment, Forest and Climate Change23, has shown that the public sector institutions – research institutes, general universities and agricultural universities - in the country are playing important role in the technology and product development of over 100 economically important plants.

The main target crops of these institutions are rice, cotton, tomato, brinjal, maize, tobacco, banana, chickpea, pigeon pea and wheat. The first five of these crops are also the target crops of the Indian private sector, mostly in collaboration with the public sector institutions. A number of GE events for insect resistance and drought tolerance have reached the stage of field testing. These R&D efforts are being directed not only to develop GE plant varieties of current relevance to Indian agriculture but also to address the emerging challenges, particularly the adverse impact of climate change, to ensure sustainable agricultural growth. Productivity constraints in crops, that are of particular relevance to small farm holders, such as pulses and millets are also receiving significant attention, to help in achieving food and nutrition security.

The points repeatedly raised by the opponents of GE technology include, (i) food safety of

of super weeds, and (v) farmers' suicides. The studies reported above clearly show that the GE foods are safe, that there is no adverse effect of GE crops on biodiversity, that development of resistance in pests is no different from the normal natural phenomenon, and there is no evidence of development of super weeds. The problem of farmer's suicide is complex and there is no direct evidence that GE crops lead to farmer's suicides.

The other issue that has been debated and discussed greatly in India is the use of herbicide tolerance (HT) trait in GE crops. This issue has also been a matter of concern in countries where HT has been commercialized for over two decades, such as the USA. Analysis made by the US Study25 noted the change in the classification of glyphosate from Group 2B (possibly carcinogenic to humans) to Group 2A (probably carcinogenic to humans) by the IARC of WHO, but concluded on the basis of the European Food Safety Authority's evaluation that "glyphosate is unlikely to pose a carcinogenic risk to humans". Similar conclusion was arrived at by the Canadian Health Agency and the Environmental Protection Agency, that glyphosate does not interact with human systems related to estrogen, androgen, or thyroid. While acknowledging the existence of "disagreement among expert committees on the potential health harm that could be caused by the use of glyphosate on GE crops and in other applications", the US Study concluded, based on the available evidences, that "no differences have been found that implicate a higher risk to human health safety from these GE foods than from their non-GE counterparts"

Weeds are a major 'pest' of crops in India (www.nrcws.org). Since HT technology is shown to be safe to human beings as well as environment, use of this technology is an unavoidable agronomic requirement in rain fed crops like maize, soybean, chickpea, mustard, cotton, wheat, etc., to help in improving productivity of such crops. Herbicide tolerant rice is a boon for direct seeded/aerobic rice production which, of necessity, is expanding fast.

Recent initiative of the Government of India to develop "Guidelines" to make GE products available to the farmers expeditiously and at a reasonable price is an important step, but it needs careful planning to ensure that in the long term the licensing system would not be detrimental to GE research and development. Development of GE crops requires much greater investments compared to the investments for developing new varieties of plants through conventional breeding. No organization would be able to invest such resources under conditions restricting appropriate returns due to the proposed compulsory licensing system. Moreover, it is difficult to assess accurately and fairly the "trait value" before the GE variety is grown on a large scale on farmers' fields. Unless individuals and organizations which invest in achieving this goal are fairly rewarded our efforts to improve agricultural productivity may get seriously jeopardised in the long run.

15.5 Recommendations:

We, the Fellows of the NAAS, representing the scientists of the national agricultural research system of India seek Government of India's urgent intervention to promote research and development of GE crops, so that this useful technology is successfully harnessed for addressing the current and emerging challenges of Indian agriculture. To achieve this objective we recommend the following policy interventions by the Government of India:

1. We must double the productivity of our farms to meet the zero hunger challenge of the United Nations by 2025. Such an increase will be possible only through the judicious use of all the available farm technologies, including the GE technologies. It is high time to approve environmental release of the GE varieties, which have been tested to be bio-safe, to extend the benefit of growing these varieties to the farmers and consumers without further delay

2. Recent approvals by the GEAC (MoEF&CC) allowing confined field trials (CFTs) of some GE crop varieties is a positive step showing intent of the Government to promote GE technologies. However, the hindrance continues due to the introduction of an extra step of obtaining NOC from the States for conducting CFTs of GE crop varieties. This provision is counterproductive for GE research, and it must be dropped as the GEAC examines the biosafety issues from a national perspective, and there is no provision of such a step in the regulation of CFTs of GE plants in India

3. There is a strong need to strengthen the regulatory system for improving efficiency to accelerate utilization of the GE technology. (a)The GEAC should be renamed back as 'Genetic Engineering Approval Committee'. (b) The GEAC should function like a statutory body vested with the authority to take final decision on approval of the GE event for environmental release. (c) The Indian Council of Agricultural Research (ICAR) should take the responsibility of multilocation testing of the GE varieties, approval for environmental release by the GEAC, on the pattern followed for multi-location trials of the non-GE varieties. An efficient regulatory system, is essential so that the fruits of creative work of our young scientists reach the end users – the farmers, at a fast pace, and the objective of the Government's 'lab-to-land' is attained for the biotechnology sector

4. There is an urgent need for greater investment to develop well trained quality human resource for basic and applied research and infrastructure development to give push to GE technology in active partnership with the public and private sector institutions, to ensure inclusive access to improved technologies among all the farmers - small or large. Increased

investment and a forward-looking and efficient regulatory system will also ensure harnessing the full potential of the emerging GE technologies, which show the promise to substantially change the future crop production because of the precision in genetic transformation. For example, application of the gene-editing technology, named CRISPR, is expected to be a powerful tool for developing precision crops at a fast rate

5. We must develop a strong public awareness programme on the issues related to GE technology, to put restrain on creation of erroneous public perception, based on unsubstantiated information. For example, the recent epidemic of white fly in North India has no connection with the commercialization of *Bt*-cotton. Only and only rigorously science-based information should be considered in formulating biosecurity measures so that baseless unfounded fears or apprehensions do not stall proven path breaking technologies from reaching the farmers and other stakeholders who need them the most (Pental, 2019)

6. Recent initiative of the Government of India to develop "Guidelines" to make GE products available to the farmers expeditiously and at a reasonable price is an important step, but it needs careful planning to ensure that in the long term the licensing system would not be detrimental to GE research and development, and promotion of public-private partnership

7. Seventeen noted biotechnologists, S. Datta, G. Padmanaban, R.S. Paroda, A.K. Tyagi, N.K. Singh *et.al.* in their most recent joint paper entitled "India needs genetic modification technology in agriculture, Current Science, August 2019, have appealed as below:

"The genetic modification technology is definitely one of the options to ensure food and nutrition security in the country, including biotic and abiotic stresses. The obsession with endless debates on Bt-cotton is scuttling initiatives to explore modern technologies in other areas such as saving fertilizer use and utilizing photosynthetic efficiency for greater productivity. It would not be appropriate to discard the technology based on propaganda without a scientific basis. This is discouraging even for research students to get into the area on gene modification in agriculture. It is not a good augury for a developing country like India, with aspirations to ensure food and nutrition security to over 1.3 billion people and more than 500 million livestock (excluding poultry).

One needs to assess rationally on a case-to-case basis and adopt the most appropriate technology. We are also clear that each case has to be assessed based on the source of transgene, trait to be introduced, path of gene expression, phenotypic expression, effect on the environment, safety trials required and economic viability in relation to other technologies available. The public-sector institutions have a major role to play in the development of GM crops, so that the interests of farmers and public are top priority.

Challenges would always arise in sustaining productivity, and scientists should have the space and access to address the concerns and come up with newer solutions. No one is championing to dispense with regulatory issues of safety to health and environment. Our regulatory bodies follow one of the strictest protocols for evaluation. There is always scope for improvement and more innovative ways of informing and involving the farmers and public in the development and use of modern technologies. While scientists can develop the technologies and experts can work out an appropriate regulatory regimen, the political decision to accept GM crops/plants, whether it is a case of bringing a gene from outside or precisely changing an existing gene, on a case-to-case basis, is essential. To start with, on a rational scientific basis, it is time to deregulate Bt genes in use, based on a huge amount of data attesting to their safety, and lift the moratorium on Bt-brinjal cultivation. This is also in tune with the recommendation of the National Academy of Agricultural Sciences (India), which states 'It is high time to approve environmental release of the GE varieties, which have been tested to be bio-safe, to extend the benefit of growing these varieties to the farmers and consumers without further delay.

It is time for India to employ and adopt genetic modification technologies for improved agricultural productivity and profitability, and contributing to sustainable food and nutrition security. Ambivalence and indecision will hurt us deeply, and ultimately the country would be the loser."

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Chapter 16

Transforming Agricultural Education

16.1 Agricultural Universities Harbinger of Green Revolution

Human resource capital is the greatest treasure of a nation, and ever-enrichment of this treasure must be the foremost resolve of all nations. Globally, education, research, and extension systems, particularly in agriculture and food systems, have been instrumental in bringing transformational changes in a dynamic mode to ensure livelihood security for all for all times. During the past 50 years or so, driven by technology changes, in synergy with policy and institutional changes, particularly through the Green Revolution processes, the number of poor, hungry and undernourished had decreased significantly in most developing countries.

Yet, globally nearly 800 million people are hungry and over 2 billion are malnourished. Generally the total factor productivity (TFP) growth has slackened and farmer-non-farmer income inequity has widened. On the other hand, the food demand by 2050 is projected to almost double, and is to be realized in an environment-friendly sustainable manner from the shrinking land, water, and biodiversity resources. The challenge is further exacerbated due to proverbial uncertainties of the fast changing climate and markets. The global agricultural research, education, and extension system would thus need to transform dynamically to undertake quality research for development.

In India, the thrust on creating trained quality human resources in the Agriculture Sector through the countrywide establishment of State Agricultural Universities (SAUs) in the 1960s onwards, along with the deemed universities, had ushered in the Green Revolution, followed by White, Yellow, and Blue Revolutions. The National Agricultural Research, Education and Extension (NAREE) system, one of the largest in the world, had congruently generated the needed scientists, teachers, researchers, technologists, technologies and technology transfer systems to transform India from Ship-to-Mouth situation to the Right-to-Food status. Similar developments have taken place in China, Brazil and other developing countries.

16.2 Transforming Agricultural Education to Reshape India

The Rainbow Revolution notwithstanding, India’s agrarian progress during the past few years has slackened and serious asymmetries exist in science – led growth of agriculture, farmers’ income, and food and nutrition securities. These asymmetries are aggravated due to the volatilities in climate change and markets, and the declining natural resources. This not so satisfactory state of India’s food and agriculture system and agrarian economy could partly be attributed to the decline in quality of agricultural education, *viz* erosion of basic sciences from agricultural curricula, extensive inbreeding, serious skill gaps, and poor employability of agriculture graduates. Thus, bridging these gaps in the availability of quality human resources must be a high national priority.

16.2.1 Gaps in India's Agricultural Education System

The NAAS XIth Agricultural Science Congress on "Transforming Agricultural Education for Reshaping India's Future" organized at Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, 2013, had identified the following gaps and constraints in India's agricultural education system:

- Low priority to agricultural education as a career option, consequently the gross enrolment was only 0.03 per cent

- Declining quality of students, poor quality of education due to obsolete and inadequate equipment, laboratory, farm and library facilities, leading to knowledge deficit all along the value-chain, particularly in new and emerging areas, such as biotechnologies, nanotechnology, informatics and communication, and more so in the private colleges

- Depleting number and quality of faculty members, lack of faculty competence in frontier and emerging areas, limited emphasis on refresher training, faculty improvement and incentives; dwindling faculty in SAUs with majority chunk of the posts remaining vacant

- Disconnect among agricultural education, employment, and industries' requirements; lack of adequate skill, entrepreneurship and experiential learning; overall poor employability of the graduates

- Outdated curriculum delivery mechanisms; increasing irrelevance of Home Science colleges and curricula

- Poor inclusion of basic sciences in agricultural curricula; low appreciation of transforming STEM (Science, Technology, Engineering and Mathematics) into STEAM, where A stands for Agriculture

- Extensive inbreeding and associated depressions; low access of agricultural education to rural students, especially to the tribals and socially-deprived communities

- Inadequate academic rigour in existing curricula, which are short in informing and sensitizing the students and faculty about the seriousness of the stubbornly high incidences of hunger, under-nutrition, poverty, inequality, fast degrading natural resources - land, water and biodiversity, and high vulnerability to climate change and market instabilities

- Inadequate and declining investment and financial resources in agricultural universities/colleges; opening of new universities without matching resources; unmindful splitting of agricultural universities, and poor resources planning

- Poor governance, system's inability to take full advantage of modern tools of management for efficient governance (e-governance); widening disconnect amongst education, research and extension; isolation from international exposure and poor internalization of relevant international trends and developments, and
- Lack of evaluation, monitoring, impact assessment, accountability and incentive systems.

16.2.2 Addressing the Asymmetries in Agricultural Education and Development

Towards resolving the above asymmetries and transforming India's agricultural education system, and sharing the global experiences, the Congress had made the following recommendations comprising new approaches and actions:

- Embrace agricultural education for development (AE4D) as an integral component of the national agricultural policy to ensure adequate, consistent and predictable investments in agriculture, especially education, research and extension in creating a world-class agricultural university system attuned to face local, national and international challenges and opportunities over short, medium and long terms
- Ensure and institutionalize transparent governance, autonomy, meritocracy, dynamic assessment of human resource requirement, judicious allocation of resources, transparent and effective flow of funds, transparent examination and student enrolment system, effective implementation, monitoring, evaluation, accountability and responsibility based system (measure to manage)
- Minimize inbreeding and splitting of universities, promote national integration and institutional linkages, pay focused attention to standards, norms, and accreditation, strengthen basic sciences and emerging sciences components in agricultural education and research; create centers of excellence and institutes for agricultural education, science, knowledge, research, technology and innovation in an interdisciplinary and multi-faculty mode
- Strengthen and streamline Centre-State partnership, identify national and state level public and private sector leaders with differentiated but reiterative responsibilities to work on the design and implementation of reforms and to develop a strong inter-ministerial and inter-departmental cooperation mechanism
- Revamp teaching/learning processes and methodologies to attract best of talents and blooming young minds for nurturing them leading to a nation-wide programme on "Youth for Leadership in Farming", and ensure faculty competence and strength
- Strengthen/initiate/institutionalize skill development, entrepreneurship and experiential learning programmes, and duly promote non-formal education and vocational training to enhance employability of the graduates, and

- Support development of an active and continuous long-term relationship-based international cooperation, rejuvenate and dynamically strengthen initial very successful collaborations, such as between Indian SAUs and US Land Grant Universities, and launch need-based South-South and South-North collaborations.

16.3 The Bhubaneswar Declaration on Indian Agricultural Education

The National Academy of Agricultural Sciences (NAAS) - the national think tank for agricultural research and education for development, in close collaboration with the Indian Council of Agricultural Research (ICAR) – the nation's apex body for higher agricultural education, organized its XI Agricultural Science Congress on "Agricultural Education: Shaping India's Future", Bhubaneswar, 2013. It was attended by more than 500 delegates, including several world leaders in agricultural education from India and abroad. The Congress had identified the following gaps and constraints in the Indian agricultural education system.

- Low priority to agricultural education as a career option, consequently the gross enrolment was only 0.03%; rising unemployment and poor employability of the graduates - 43% of graduates and 25% of post-graduates being unemployed

- Declining quality of students, poor quality of education due to obsolete and inadequate equipment, laboratory, farm and library facilities, leading to knowledge deficit all along the value-chain, particularly in new and emerging areas, such as biotechnologies, nanotechnology, informatics and communication, and more so in the private colleges

- Depleting number and quality of faculty members, lack of faculty competence in frontier and emerging areas, limited emphasis on refresher training, faculty improvement and incentives; dwindling faculty in SAUs with majority chunk of the posts remaining vacant

- Disconnect among agricultural education, employment, and industries' requirements; lack of adequate skill, entrepreneurship and experiential learning

- Outdated curriculum and curriculum delivery mechanisms; poor inclusion of basic sciences in agricultural curricula; low appreciation of transforming STEM (Science, Technology, Engineering and Mathematics) into STEAM, where A stands for Agriculture

- Extensive inbreeding and associated depressions; low access of agricultural education to rural students, especially to the tribals and socially-deprived communities

- Inadequate academic rigour in existing curricula, which are short in informing and sensitizing the students and faculty about the seriousness of the stubbornly high incidences of hunger, under-nutrition, poverty, inequality, fast degrading natural resources - land, water and biodiversity, and high vulnerability to climate change and market instabilities

- Inadequate and declining investment and financial resources in agricultural universities/colleges; opening of new universities without matching resources; unmindful splitting of agricultural universities, and poor resources planning

- Indifference to the needs of women, especially women students, scientists and farmers, and increasing irrelevance of Home Science colleges and curricula

- Poor governance, system's inability to take full advantage of modern tools of management for efficient governance (e-governance); widening disconnect amongst education, research and extension; isolation from international exposure and poor internalization of relevant international trends and developments

- Lack of evaluation, monitoring, impact assessment, accountability and incentive systems

16.4 Ongoing Reforms and Innovations in the Agricultural Education System

Quality assurance in higher agricultural education in the country has been pursued by ICAR/DARE/SAUs through policy support, accreditation, framing of minimum standards for higher agricultural education, academic regulations, personnel policies, review of course curricula and delivery systems, development support for creating/strengthening infrastructure and facilities, improvement of faculty competence and admission of students through All India competitions. Following the Bhubaneswar Declaration/Recommendations, ICAR's Fifth Deans' Committee restructured the course curricula to underpin relevant practical skills, entrepreneurial aptitude, self-employment, leadership qualities and confidence among graduates, attracting and retaining youth in agriculture, which among other things, will be helpful in implementing the new initiatives of the government, viz., Make–in–India, Start-up-India, Skill India, Digital India, etc.

Our New India must be innovation-driven during this "Decade of Innovation in India", as we foster innovation, importance of cost effective, location specific, and affordable innovation along the value chain and of new extension system have been highlighted in the revised curricula. Further, the Deans' Committee has also considered the international dimension of agricultural education in context of technological, socio-economic, environmental, and livelihood security, and sought to achieve global level academic excellence and relevance. The updated curricula thus provide academic legitimacy to the new and emerging issues of food and agricultural system, and contextualize the new pursuits.

In order to harness regional specialties and to meet region specific needs, certain optional courses such as Coastal Agriculture, Hill Agriculture, Tribal Agriculture etc have been formulated. Many new courses have been recommended to be introduced and instituted in emerging fields like GIS, Precision Farming, Conservation Agriculture, Secondary Agriculture, Hi-tech Cultivation, Specialty Agriculture, Renewable Energy, Artificial Intelligence, Mechatronics, Plastics in Agriculture, Dryland Horticulture, Introductory Nanotechnology, Agro-meteorology and Climate Change, Waste Disposal & Pollution Abatement, Food Plant Regulations and Licensing, Food Quality, Safety Standards and Certification, Food Storage Engineering, Food Plant Sanitation and Environmental Control, Emerging Food Processing Technologies etc. Courses on Personality and Leadership Development, Yoga Practices and Human Values & Ethics are new additions in the list of non-credit courses.

The Bhubneshwar recommendations have invigorated ICAR to strengthen faculty & student amenities, curriculum delivery, development of facilities for UG practical's, computer labs, updation of professional/technical competence of para-professional staff/administrative staff, students study & educational tours, support to deans, library strengthening, and skill development. The 'Student Exchange Programme' between colleges located in different agro-climatic zones is being promoted towards skill development in the graduating students for specialized jobs in view of market needs and demands. Appreciating that education goes beyond classrooms and age groups, it is hoped that besides additional units of Earn While Learn Program for students, Demonstration cum Production Centres will emerge for training students, field workers of Government Departments, NGOs, and community leaders in income generation skills.

16.4.1 World Bank Project on Agricultural Higher Education – A Great Support to Capacity Building and Enriching Knowledge Platforms

The Bhubaneswar Declaration had triggered the ongoing World Bank supported National Agricultural Higher Education Project (NAHEP), which is strengthening capacities of faculty and other staff at all levels. Various trainings, such as induction training for scientists at entry level, overseas training for global exposure in key emerging areas, and structured trainings for heads of departments, comptrollers, faculty, technical and financial staff, pertaining to their specific needs, are being strengthened.

The NAHEP will further strengthen linkage of the national system with global knowledge economy, and also help undertake International Experiential Learning. Suitable twinning arrangements with foreign universities could be explored for sharing innovative pilots for agricultural education, research, and technology dissemination. These initiatives will help further strengthen institutional reforms to emphasise learning-centred education, faculty and teaching facilities upgradation, and partnership with private industries.

16.4.2 Fifth Deans Committee Boosted Academic Legitimacy of Curricula Transformation to Enhance Employability of Agricultural Graduates, Attain World Class Quality, and to Build Leadership to Meet the SDGs

Seeking judicious adoption of the provisions of ICAR Model Act by all the SAUs, the Deans' Committee has designed a framework for preparing Detailed Project Reports (DPRs) for establishment of new colleges. This move should greatly enhance the standards and harmonize the curricula quality across the country. Several new initiatives for aligning Indian agriculture curricula with the current national needs and initiatives and with international trends are also under implementation.

In compliance with the Student READY programme launched by the Hon'ble Prime Minister on 25th July, 2015, the Committee has designed one year program in all the UG disciplines comprising (i) Experiential Learning, including International Experiential Learning wherever feasible; (ii) Rural Agriculture Work Experience; (iii) In Plant Training/ Industrial Attachment; (iv) Hands-on Training (HOT) / Skill Development Training; and (v) Students Projects.

In its various congresses, brainstorming sessions and policy advocacy meetings, the Academy has elaborated the academic legitimacy and contextuality of contemporary developments and helped internalize them into our university curricula. New developments such as Biotechnology, Nanotechnology, Precision Agriculture, Renewable Energy, Big Data and Analytics, alongwith the Rural Entrepreneurship and Awareness Development Yojana (READY), Experiential Learning Programme (ELP), Rural Agricultural Work Experience (RAWE), and the Agricultural Science Pursuit for Inspired Research Excellence (ASPIRE) programme have been duly emphasized.

Further, in view of the increasing importance of climate change, market competitiveness, information technology, entrepreneurship, and graduates employability, students of all the disciplines will now need to be taught courses on Environmental Studies and Disaster Management, Communication Skills and Personality Development, Information and Communication Technology, Entrepreneurship Development and Business Management, Agricultural Informatics, and Economics and Marketing. Keeping in mind the latest scientific developments impacting food and agriculture systems, considering new societal demands, and in line with current national policy thrust, new courses and degrees in B. Tech. (Biotechnology), B.Sc. (Hons) Sericulture, B.Sc. (Hons) Community Science (Home Science rechristened) and, B.Sc. (Hons) Food Nutrition and Dietetics have been launched.

Following the recommendation of the Deans' Vth Committee, all degrees in the disciplines of Agricultural Sciences have been declared as professional course degrees, which include undergraduates in: Agriculture, Agriculture Engineering, Biotechnology, Dairy Technology, Fisheries, Food Technology, Forestry, Community Science (Home Science), Food Nutrition and Dietetics, Horticulture, and Sericulture.

16.5 Paradigm shifts in Agricultural Education Programs

16.5.1 From Land Grant to World Grant

Accounting for 17 per cent of world's population, over 30 per cent of smallholder farmers, hardly 2.5 per cent of the land and 4 per cent of world's water resources, India greatly impacts and gets impacted by the state of global food, agriculture and natural resources system. Thus, the Committee had underpinned that major global initiatives and foresights must be kept in mind while developing leaderships in agricultural sciences. Accordingly, it had suggested that the system should move from the Land-Grant to a "World Grant" pattern. The new curricula, courses and contents have accordingly been designed to duly inform the students of the new global initiatives, such as Global Green Economy; Knowledge Economy; Global Zero Hunger Challenge; UN International Year themes *viz.* International Years for Pulses, Family Farms and Smallholder Farmers, Soil and Water; Sustainable Development Goals, 2030; and International Agriculture and Development Challenge, 2050.

16.5.2 Contextuality of More from Less From More Coupled with Sustained Growth

The mantra of More from Less for More (MLM) had steered the Committee to drive the national educational systems to undertake business unusual to achieve (i) sustainable intensification and diversification of production and zero waste to meet demand for nutrition and food quantity and quality, (ii) 100 per cent increase in smallholder productivity and income, ensuring desired profitability, social justice, and attractiveness to agriculture as a profession, and (iii) ecosystem services that improve water quality and quantity, soil health, carbon capture, and biodiversity.

The NAAS's Roadmap on Agricultural Education and related Brainstorming Session had underpinned that the graduates are required to possess professional capabilities to deal with the concerns of sustainable development (productive, profitable and stable) of agriculture in all its aspects, as stipulated under the Sustainable Development Goals (SDGs). Further, there is need for agricultural graduates to possess knowledge, skills, including "soft skills" e.g. written and verbal communication ability, and also entrepreneurship to provide a class of village-based services such as advisories on new innovations, markets and avenues of development assistance for corporate and contract farming. Industry and universities partnership is essential if industry is to obtain well-trained agricultural professionals in cutting edge technologies for international competitiveness.

16.5.3 From STEM to STEAM

Higher education is emerging as an international service, and there is a growing concern the world over about quality, standards, and recognition. Prioritizing the quality of higher education services by implementing or strengthening quality assurance measures is a strategy for increasing global stature. Although, the Indian Government has decided to recast the country as "knowledge economy", purportedly by making higher education a top national agenda item and creating world-class universities, most of our universities are performing sub optimally and the quality of human resource and research outcomes have been compromised. Strategic funding and quality improvement programs are urgently needed to reverse the deterioration process. Towards universalizing agricultural education the Vth Deans' Committee had recommend that Agricultural (A) should further be enriched by putting it in the middle of Science, Technology, Engineering, and Mathematics (STEM), thus transforming STEM into STEAM, as suggested by a Land Grant University in USA.

16.5.4 Towards Quality and World Ranking of Agricultural Universities

As we know, the highly ranked leading universities are reshaping the nations and the world, and have shown that the level of knowledge domains, meritocracy, governance, transparency, and international partnership underpin the quality of science, innovations, technologies, human resources, and competitiveness. Since quality education is the lifeline of progress, national developments can be viewed through the lens of education, research, technology and innovation. Unfortunately, none of the Indian universities are in the top 100 ranked universities of the world. The NAAS took initiative to prepare a ranking framework for agriculture universities and has designed a set of indicators/parameters for ranking of Indian Agricultural Universities, keeping in mind Indian context, particularly the educational aspirations, needs, employability, and livelihood security. As the ICAR institutionalizes the outcome/impact assessment and accountability pathway process, ranking of universities should be its foremost activity to be pilot-tested and hopefully all the agricultural universities and colleges will ultimately be part of the ranking process.

In the academic ranking of world universities in 2017, two China universities appeared in the top 100. Comparing Indian situation with China, we find that during the past 20 years China had initiated several administrative system reforms and launched dedicated projects, including the Project Double First-Class Agricultural Union. In 2016 there were 82 independent agricultural and forestry colleges and universities, and the total number of students in agricultural sciences was 529,836, which was about 1.54 times that of the students in 2005. In 2018 four agricultural universities ranked within the top 800 in Times' World University Rankings, and six agricultural universities were in the 1000 top of the U.S. News Global University Rankings, and four agricultural universities including China Agricultural University, Nanjing Agricultural University, Huazhong Agricultural University and Northwest A&F University had more than one field of study in the Essential Science Indicators (ESI) % citation ranking. China's higher agricultural education has thus made great achievements in reform and development, and played a pivotal role in promoting China's agrarian economy.

Through brainstorming sessions and other consultative processes, NAAS has promoted other new approaches towards building qualified human resources, for instance, the Massive Open Online Courses (MOOC) in NARES. Individual universities should develop custom-designed MOOCs to meet the skill requirements of their students, as desired under the Skill India initiative.

Further, the NAAS has prepared a roadmap for mentoring, emphasizing the need for matching the experience and wisdom of mentor with the learning needs of mentee. If properly administered, the process would benefit our institutions to build bridges across the hierarchy levels, empower change management, enhance work ownership and sharing of responsibility, and expansion of learning ecosystem and good practices etc. This would result in enhanced transfer of skills, knowledge, products, technologies, and services. The potential mentors could be given orientation training to enable them to undertake mentoring in a systematic way so that the mentoring so achieved could be properly evaluated.

Mentoring all stakeholders, from the ground to the top level, by experienced and successful mentors should become a part of the teaching-learning process in the NARES. The Department of Science and Technology (DST) is already mentoring students through its Innovation in Science Pursuit for Inspired Research (INSPIRE) program and the Ministry of Human Resources Development (MHRD) is funding such incentives under the program called Global Initiatives of Academic Network (GIAN). The Handbook of Mentoring and Performance Audit prepared by the DST and MHRD could be used as a starting template for the agricultural system. The Department of Agricultural Research and Education (DARE), ICAR and NAAS may institutionalize implementation of the agricultural education roadmap prepared by the Academy. Willing NAAS Fellows may participate in the initiative to encourage younger colleagues for excellence in agricultural sciences.

16.5.5 Promoting SAUs Congruence with Corporate Social Responsibility

Towards promoting appreciation of social engineering to build a New India, the Academy took note of on-going relevant projects, such as the Bill and Melinda Gates Foundation (BMGF) initiatives on promoting science with a human face and had recommended establishment of Model Innovation Centres at selected SAU campuses. These should link farmers, agriculture, and food systems, agribusiness and digital communication in a real-world situation to trigger new exciting opportunities, particularly for the young innovators in harnessing best of the science and technology in serving farmers to save and transform farming.

The Academy has strongly recommended that incubation centres should be created in research university campuses, which will incubate new ideas and stimulate and trigger young minds to innovate. Several of such innovations will find practical applications and synergise the university-industry linkage including joint appointments, and enrich the research and academic stream. With such a setup, a good number of students shall be working as interns with the companies, thus gaining invaluable hands-on experience that will jump start their careers. The incubators for start-up companies will help convert innovations into commercial businesses thus boosting the Startup India initiative.

Education for Agriculture in the 21st Century and the Third Generation Universities should have the goal that every agricultural graduate becomes an entrepreneur. Business Management has thus been mainstreamed in major applied courses, e.g. Seed Technology, Dairy Technology, Fish Technology, Food Processing etc., besides establishing new Faculties or Departments of Agricultural Business Management. NAAS has recommended that Private companies and cooperatives which are manufacturing and distributing agricultural inputs and related products should, other things being equal, give preference to such agricultural graduates for employment and granting licenses and dealerships.

16.5.6 Monitoring, Evaluation and Judicious Implementation

As the planners and managers strive to meet the challenges and uncommon opportunities, we may use the following check-list to assess outcomes and impacts of various educational programmes:

- Whether our agricultural education system is prepared to produce such leaders who would navigate us through the changing water and render our universities world-class?
- Do the staff and students have real-world experience as part of learning and could our graduates essentially become job creators rather than job seekers, and realize demographic dividend?
- Are we ready to change the Land Grant System to the "World Grant System"? How relevant are the existing teaching and skill development programmes and institutions?
- Is our agriculture backed by basic sciences and best of practices to convert STEM into STEAM?
- Are we prepared to adopt "business unusual" and "disruptive innovations" to effect the much needed changes in our agricultural education system, including centre-state congruence - the hub-spoke model?
- Do we have the necessary quality financial and other resources, commitment and political will to lead India to be a major knowledge hub in the world geared towards an all-time Zero Hunger World?

Affirming the above, ensuring effective implementation of the suggested policy and quality measures should render agriculture as an intellectually more stimulating discipline and an economically rewarding profession to attract talent and investment. The academic and economic legitimacy thus provided to contemporary challenges and opportunities should inspire the youth to find agriculture, agribusiness, agriculture related service sector, and the pursuit of agricultural science and technology generation as an attractive vocation, career and profession. The agriculture thus transformed would transform the agrarian economy, especially the farmers' socio-economic condition, leading to a Farmer Happy New India. The transformed universities will become a preferred destination for foreign students and will render the Governments "Study in India" initiative a great success.

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Chapter 17

Monitoring, Evaluation and Impact Pathways Analysis

17.1 Importance of M&E System

India has developed one of the world's largest agricultural research, education, and extension systems for development. The efforts have been instrumental in ushering in the Green and ultimately the Rainbow Revolution transforming the country from a ship-to-mouth situation to a sizeable food exporter. These changes had increased agri-food production 5 to 10 times between 1965 and 2015 and greatly reduced poverty, hunger and undernutrition.

Despite the unprecedented developments and experiencing high (7 to 8%) GDP growth rate for the past decade or so, enigmatically, the country is still home to about one-fourth of the world's hungry and more than one-third of the world's undernourished, stunted and wasted children. The problem is exacerbated due to volatilities of climate change and market uncertainties. Moreover, the developments were associated with agro-ecological degradation, unsustainability, inefficient use of resources resulting in lower and sluggish TFP. This was primarily due to poor implementation, monitoring, and evaluation of programs and projects.

Often the technologies and approaches developed by the science, technology and innovation system were not judiciously adopted by the farmers, resulting in adverse side effects, namely, inefficient use of inputs and natural resources, deteriorating soil health, water quality, and underground water reserves. Obviously, the business as usual will not enable the country to meet the Sustainable Development Goals. New strategies, result frameworks, implementation pathways, and mid-course corrections, if needed, will have to be adopted to meet the goals.

In today's world of scarce public funding and greater accountability, governments, donors and research managers are increasingly demanding assessment of the socioeconomic returns to their investments in Agricultural Research, Education and Extension Systems (AREES). This information is needed not only to show that Universities and research organizations have the capacity to help increase agricultural production and alleviate poverty, but also is essential to justify allocation of limited resources to AREES. Research organizations, worldwide, are under increasing pressure to undertake impact assessment of their research activities and to better integrate the social, economic and environmental considerations in research planning and implementation to help attain the SDGs.

17.2 Criteria for Evaluating Development Investment and Assistance

The following criteria should be used for evaluating different activities and investments for achieving desired development goals:

Relevance: The extent to which objectives are relevant and consistent with the requirements of beneficiaries/stakeholders, emphasis on demand-driven.

Effectiveness: The extent to which an intervention attains its objectives.

Efficiency: Efficiency measures the outputs—qualitative and quantitative – in relation to the inputs. It tells if the most efficient process has been adopted.

Impact: Positive and negative changes produced by the intervention, directly or indirectly and intended or unintended, the output-outcome-impact congruence and synergy.

Sustainability: The benefits of the activity should continue even after donor funding is withdrawn, the program should be able to build resilience to risk as well as imbibe environmental and financial sustainability.

17.3 Ten Steps to Building a Results-Based M&E System

Linda and Rist (2009) outlined ten steps in building and sustaining effective monitoring and evaluation for development evaluation training which is equally applicable for AREE programmes. These steps are reproduced here under:

17.3.1 Conducting a Readiness Assessment

It is a way of determining the capacity and willingness of universities and research institutes to construct a result- based M&E system.

17.3.2 Agreeing on Performance Outcomes to Monitor and Evaluate

It is important to generate an interest in assessing the outcomes and impacts the organization or government is trying to achieve, rather than simply focusing on implementation issues (inputs, activities, and outputs).

17.3.3 Developing Key Indicators to Monitor Inputs, Outputs, Outcomes and Impact

Indicator development is a core activity in building an M&E system and drives all subsequent data collection, analysis and reporting. The methodological issues in creating credible and appropriate indicators are not to be under estimated.

17.3.4 Gathering Baseline Data on Indicators

The measurement of progress (or a lack of it) towards outcomes begins with the description and measurement of initial conditions being addressed by the outcomes. Collecting baseline data essentially means taking the first measurements of the indicators to find out "where are we today?" A performance baseline is information (qualitative or quantitative) about performance on the chosen indicators at the beginning of (or immediately prior to) the intervention.

17.3.5 Planning for Improvements Setting Realistic Targets

It is the final step in building the performance framework and establish targets. Most outcomes and nearly all impacts in international development are long term, complex, and not quickly achieved. Thus, there is a need to establish interim targets that specify how much progress towards an outcome is to be achieved, in what time frame, and with what level of resource allocation. Measuring performance against these targets can involve both direct and proxy indicators as well as the use of both quantitative and qualitative data.

17.3.6 Monitoring for Results

As mentioned, a results based monitoring system tracks both implementation (inputs, activities, and outputs) and results (outcomes and impacts). Each outcome will have a number of indicators, each of which will have a target. In order to achieve those targets, there are a series of activities and strategies that need to be coordinated and managed. To be successful, every monitoring system needs to have ownership, management, maintenance and credibility.

17.3.7 Role of Evaluations

Although monitoring systems are important, it is to be emphasized that the role evaluation plays is vital in supplementing information on progress toward outcomes and impacts. Whereas, a monitoring will tell us what we are doing relative to indicators, targets, and outcomes; evaluation will tell us whether: Are we doing the right things (strategy)? Are we doing things right (operations)? Are there better ways of doing it (learning)? Evaluation can address many important issues that go beyond a simple monitoring system.

17.3.8 Reporting Findings

Analysis and reporting of M&E findings is a crucial step in this process, as it determines what findings are reported to whom, in what format, and at what intervals. Thinking carefully about the demand for information at each level of the organization, as well as the form in which that information will be most useful, and at what stage(s) of the project/program, the findings need to be reported is crucial.

17.3.9 Using Findings

The crux of an M&E system is not in simply generating results based information, but in getting that information to the appropriate users in the system in a timely fashion so that they can take it into account (as they choose) in the management of the projects, programs, or policies. Development partners and civil society have important roles in using the information to strengthen accountability, transparency, and resource allocation procedures.

17.3.10 Sustaining the M&E System within Organization

There are six critical components crucial to the construction of a sustainable M&E System: (1) Demand for M&E information (2) Clear roles and responsibilities for collecting, analyzing and reporting performance information (3) Trustworthy and credible information (4) Accountability (5) Capacity of the organization in terms of technical and managerial skill to perform M&E and (6) Incentives to encourage the use of performance information. Each of these components needs continued attention over time to ensure the viability and sustainability of the system.

17.4 Analysis of Impact Pathways of Research on Agriculture – IMPRESA approach:

An IMPRESA (The Impact of Research on EU Agriculture) study has made the recommendations as reproduced below:

Ex-ante research impact assessment

- *Plan early for impact, at the outset of the research design:* Importance of additional social competences; anticipation of uses.
- *Involve key stakeholders (including private sector) at an early stage in* the research: Stakeholder mapping is a useful tool.

Maintaining impact focus within project implementation

- *Consider impacts in mid-term project reviews:* External reviews; opportunity to revise options for outcomes and impacts.
- *Provide project resources for 'soft factors':* Trust, network and capacity building; help of professional communication agencies and lead farmers.

Ex-post impact evaluation

- *Enrol researchers into a new 'culture of impact':* Motivation!
- *Where appropriate, conduct an ex-post Participatory Impact Pathway Analysis:* Long enough after the end of the project.

Managing research calls and funding frameworks

- *Build flexibility into calls for projects to allow for new stakeholder perspectives:* Changing circumstances, e.g. concerning markets and policies.
- *Design funding frameworks to gain early involvement of the private sector:* Prior to design of the projects; tensions and possible trade-offs between long-term public and short-term private interests.
- *Monitor research output with data collection tools and protocols at early stage:* Effective information management systems needed.

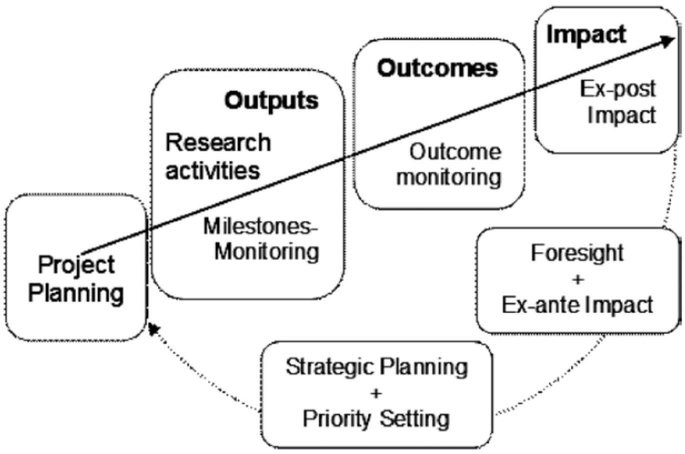
17.5 CCAFS Effort to Establish Impact Pathways

Climate Change and Agriculture and Food Security (CCAFS) programme of the CGIAR, in South Asia, headquartered in New Delhi, has recently been institutionalising the Impact Pathway approach in the national and regional programmes. The approach allows establishment of explicit pathways to outcomes and impact, and a sense of shared purpose among implementers. The approach helps identify and consolidate synergies among programmes and better understand the needs of end users and next users.

The impact pathway approach, as depicted below, is likely to provide a vision of the following questions:

- What was the situation like before the programme started? What were the unmet needs and requirements of next users and end users?
- What are the next users now doing differently?
- How are programme outputs disseminating (scaling out)?
- What political support is nurturing this spread (scaling up)?
- What are the end users doing differently?
- What are the benefits they are enjoying as a result of the programme?
- Are some end users groups benefiting more or less than others?

Figure 1. Impact Pathway Framework



Source: Adapted from CCAFS

India and CCAFS in partnership can derive significant mutual benefits. For instance, there are the areas in which CCAFS has been working in some parts of India and there is a good scope to out-scale and upscale CCAFS Climate Smart Village (CSV) initiative in several parts of the country through the National Initiative on Climate Resilient Agriculture (NICRA) programme. Likewise, CCAFS has been implementing index based insurance in Vaishali district, Bihar of India and there is ample scope for collaboration in this sector with

Agricultural Insurance Corporation (AIC). CCAFS has been partnering with IFFCO Kishan Sanchar Limited (IKSL) in providing agro-advisories in climate smart villages in Bihar and IKSL will further expand areas for this work. On request, the IKSL will assist in piloting similar activity in other countries in South Asia.

The PM urged the CMs and other stakeholders to focus on development and announced panel of CMs to drive reforms for the farm sector ultimately making India a US$ 5 trillion economy by 2024. He urged the states for a collective fight against poverty, unemployment, drought, flood, pollution, corruption and violence. The committee on farm sector will take a holistic approach on agri-food system reforms.

He referred to the governance system characterized by performance, transparency, and delivery – an aspect strongly advocated by NAAS. Empowerment and ease of living have to be provided to each and every Indian and the goals which have been set for the 150th anniversary of Mahatma Gandhi should be accomplished by October 2, and the goals set for 2022 at 75th anniversary of Independence.

"Onground implementation of schemes is vital" emphasized the Prime Minister and urged members to help create a government set-up which works and has the people's trust. States should recognize their core competence and work towards raising GDP targets.

NICRA can emerge as an international model and can establish partnership with other international programmes, such as CCAFS for undertaking training on downscaling climate scenarios and climate analogues; applying Decision Support System for defining R&D priorities, capacity building and data sharing; evolving protocols and toolkits for climate smart villages; and conducting case studies on mainstreaming climate resilient agricultural activities into regional development plans.

17.6 Strategy and Results Framework (SRF) of the CGIAR

Reviewing the impact of CGIAR research and technologies on global food security and contribution to the SDG, outlined by the United Nations, in particular to reduce poverty, to improve food and nutrition security for health, and to improve natural resources and ecosystems services, the Consultative Group feels that they cannot simply tread the usual familiar paths in tackling these problems. Aligning its vision of a world free of poverty, hunger and environmental degradation, CGIAR's 2016-2030 Strategy and Results Framework (SRF) defines as to how CGIAR will build on its past successes and investments and find new and creative solutions to barriers to success by harnessing new opportunities. The SRF targets globally 150 million fewer hungry people, 100 million fewer poor people, and 190 million ha less degraded land by 2030. The system will focus on four most critical consecutive themes:

- Mitigating and adapting to climate change risks and shocks
- Ensuring gender and youth equity and inclusion
- Strengthening the policy and institution enabling environment

- Developing the capacity of national partners and beneficiaries.

The New SRF will focus on three System Level Outcomes (SLOs) and their Intermediate Development Outcomes, comprising: UN Zero Hunger Challenge, Nutrition for Growth Compact, Global Alliance for Climate Smart Agriculture (GACSA)'s commitment, IUCN's Bonn challenge on Landscape Restoration and the Convention on Biodiversity's Aichii Targets.

The specific System Level Outcomes (SLOs) and the corresponding Intermediate Development Outcomes (IDOs) are listed below:

SLO 1 – Reduced Poverty

IDOs i) Increased resilience of the poor to climate change and other shocks
ii) Enhanced smallholder market access
iii) Increased incomes and employment
iv) Increased productivity.

SLO 2 – Improved Food and Nutrition Security for Health

IDOs v) Improved diets for poor and vulnerable people
vi) improved food security
vii) Improved human and animal health through better agricultural practices.

SLO3 – Improved Natural Reserves and Ecosystem Services

IDOs viii) Natural capital enhanced and protected, especially from climate change
ix) Enhanced benefits from ecosystem goods and services
x) More sustainability managed agro-ecosystems.

To reach the above targets the CGIAR will focus on the following eight research practices:

- Genetic improvement of crops, livestock, fish ad trees
- Agricultural systems approach to optimize economic, social, and environmental co-benefits
- Gender and inclusive growth, creating opportunities for women, youth and marginalized people
- Enabling policies and institutions to improve performance of markets, services, and resistance of poor people
- Natural resources and ecosystem services, reverse environmental degradation and enhance productivity
- Nutrition and health, dietary diversity, nutritional content and biosafety, and enriching value chains
- Climate smart agriculture-adaptation, mitigation, and productivity

- Nutrition diversity, genetic resource conservation, evaluation for nutrition traits and their use.

17.7 NAAS Recommendations

The National Academy of Agricultural Sciences organized a Brainstorming Session on Monitoring and Evaluation of Agricultural Research, Education and Extension for Development (AREE4D) in 2015 and reviewed the global effort in this area, especially the CGIAR and European Systems. The session reiterated that M&E of AREE is becoming a significant challenge as donors and funding agencies are keen on outcomes and impacts of the funding. Further, it emphasized that towards achieving Agenda 2030 and the defined targets, it is a must to have a science-based highly efficient M&E system to track the progress, and to take corrective actions if needed, to achieve the targets and the goals. These developments have resulted in increased demand for expertise in M&E. The participants of the brainstorming session representing various organizations deliberated and are in favor of constituting M&E in NARES to promote accountability, improvement in the quality and rating of the institutions. The BSS made the recommendations:

- All the stakeholders need to be sensitized on the benefit of M&E relating to strategic planning, implementation and assessment of technical/ scientific contribution mainly from the point of improvement of mandated activities
- All the activities such as prioritizing, planning, monitoring and evaluation of programmes and projects should be addressed cumulatively at University/Institute level as well as at the individual project level, through the M&E cell. It is ideal that M&E Cell is chaired by Vice-Chancellor/Director and apart from others should include representatives from faculty, students and Alumni
- M&E unit should be a multidisciplinary team inclusive of social scientists. At present, most personnel of M&E cell are not exposed to the theory and principles of M&E. Their capacity building is necessary
- M&E should use both qualitative and quantitative indicators to measure the outputs, outcomes and impacts. Hence, for an effective monitoring and evaluation a Management Information System (MIS) is needed. Accordingly, depth and quality of data need to be improved
- Impact assessments should not be directly limited to measurable impacts; but should also seek to capture the complexity and non-linear nature of agricultural AREE. It should be integrated into complex social, economic and political dimensions
- In M&E, we need to clearly understand the weak links in the research-to-impact pathways; between priority setting, targeting, outputs, outcomes, and impact. AREE outputs are cumulative and evolutionary- new finding is partially a product of all previous findings. Also, AREE outputs have lag periods that will take several years – capturing the temporal attribution of AREE is a challenge
- The model adopted for CGIAR research programmes is apt for NARES as well

- M&E cell should undertake periodic surveys to assess and document status of technological advances, its adoption and mapping of emerging trends in technology
- It is necessary that environmental impacts form a part of the assessment. The outcomes in the case of environmental projects can be classified into immediate outcomes, intermediate outcomes and ultimate outcomes
- Valuation of natural resources and environmental impacts of agricultural technologies has been a challenge since often market failure and imperfect markets, which lead to distorted prices / returns, fail to capture the true total economic value. In such a context, non-market valuation techniques need to be popularized in M&E framework
- Indicators for ecosystem valuation should be designed and widely used for Monitoring agro-ecological sustainability.
- Impacts of environmental projects are lagged (temporal and/or spatial), that can lead to either positive or negative externalities. There is a need to identify over time and space, the tangible and intangible costs and benefits of the environmental project/s. Within each of the environmental research areas there are output, outcome and impact indicators, including cross-cutting ones such as employment and technological advances
- The social impacts including ethical and cultural aspects need to be captured and accounted in the evaluation.
- M&E should capture improvement in the quality of teaching, increase in the employability of the graduates and the rating of the institutions on well defined and accepted norms
- Steps need to be initiated for development and institutionalization of indicators to measure quality of education and extension
- A combination of indicators such as evaluation by superiors, peer evaluation, student evaluation and self-evaluation should be well developed and included in the M&E efforts
- For the Frontline Extension System (mainly KVK system), Annual Review Workshop conducted by the Zonal Project Directorate, and Scientific Advisory Committees of the KVKs are much useful to review the work performance and to plan the next year technical programme.

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