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Presidential Address

Feeding 1.7 Billion

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Feeding the burgeoning population while simultaneously sustaining or improving limited natural resources is a major challenge before us today. So far production increase has been at the cost of depleting or degrading production resources, especially soil, water and biodiversity (plants, animals and microbes), which cannot be compromised with now and it has to be a simultaneous improvement. Doubling farmer's income and sustaining food and nutritional security calls for an integrated approach to various sectors of agriculture *viz.,* food grain crops, horticulture (fruits and vegetables) and forestry, livestock and fisheries, process engineering and machines as against our major tilt towards food crops over others till very recent past.

Agricultural Scenario

India today ranks second in the world in agricultural production as the leading producer of food grains, cotton, horticultural crops, 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 (ranked 11th and 12th), respectively. 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, registering a stupendous growth of $300 billion. A brief glance at Figure 1 is a perfect testimony to India's agricultural prowess: Simply put, the growth in Indian agriculture over the last 16 years was 350 per cent higher than the one achieved in the erstwhile period of 30 years (Shroff, 2019).

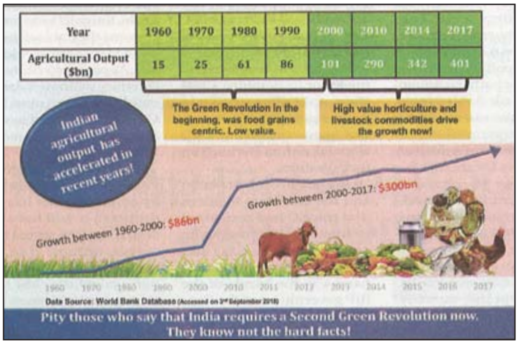

Figure 1: Growth in India GDP since 1960

The other point worth mentioning is that India is blessed with multiple factors, which are in its favour. With a high diversity of topography, climate and soil, India is inherently an agricultural powerhouse harvesting multiple produces, quite impossible for any other country in the world to emulate. India's cropping intensity is the highest in the world. The small-sized, family farms in India have imbibed a unique farming method, which is a mix and match of agriculture, horticulture, fish farming and livestock farming, cashing on the most cost-effective model of agriculture for other developing nations with small farms. India's multi-tasking farmers shift seamlessly from crop cultivation to animal husbandry, thereby remaining engaged throughout the year. By and large, it is the versatility that has catapulted Indian agriculture into the big league of food-exporting nations.

Population and Food Scenario

It is interesting to recall that the world population was 1 billion in 1800 AD; 2 billion in 1930 (next 1 billion was added in 130 years), 3 billion in 1960 (next 1 b in 30 years), 6 billion in 2000 (next 3 billion in only 40 years) and projected to be 10 billion$^+$ in 2100 (next 4 billion in 100 years). Major contribution to the population growth came from Africa, Asia and Latin America. Today considering its size, India is among the densest regions in the world. (Figure 2) and by 2050 India's population will be about 1.7 billion which will be the highest in the world and about 400 million more than China- the most populous nation today. How to feed them and preserve our finite production and life support resource systems are issues of highest concern. There is no way to postpone or ignore these any longer and have to be attended seriously.

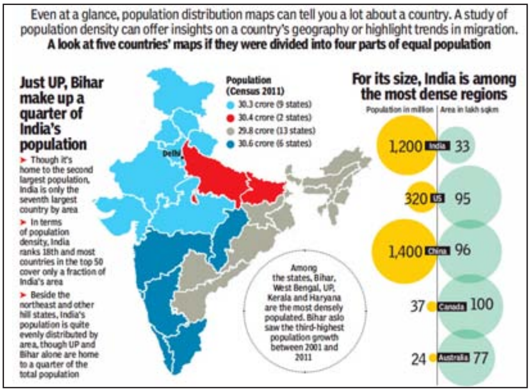

Figure 2: Population density in India

The Figure 3 below shows the population change in India since 1950 and the UN's projections of population by age bracket. Here we see that the number of children under the age of five (under-5s) peaked in 2007; since then the number has been falling. The number of Indians less than 15 years old peaked slightly later (in 2011) and is now also declining. These are landmark moments in demographic change. India's population will still continue to grow as a result of 'population momentum' – the effect often referred to by Hans Rosling and Gapminder as the 'inevitable fill-up' when young generations grow older. But we can now see an end to population growth: reaching 'peak child' anticipates the later 'peak population'. The

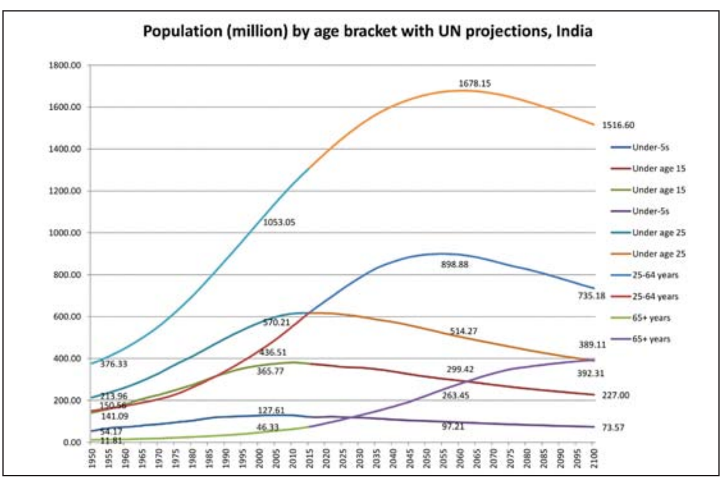

Figure 3: Dynamics of India's population in different age categories

number of children has peaked; total population will follow and reach its peak in four decades. In 1950, Indian population was only 376.32 million which is expected to overtake China and become the most populous nation in 2024. It is estimated that by 2030, Indian population would be 1.52 billion and approximately 1.70 billion by 2050. It is after 2060 that the population will stabilize and start declining.

Although 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 very intense. Food and nutritional security of India is threatened by issues like severe decline in the health and productivity of the soil 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.

By 2050, India needs to step up production of all agricultural commodities by around 30 per cent in food grains and to more than 300 per cent in vegetable oils to meet the needs of increased population and rising living standards (Table 1). To achieve this higher demand of agricultural commodities, the most suitable strategy seems to be improvement in productivity in different sectors, cropping intensity, adoption of best water and soil and land care management practices along with preservation of prime agricultural lands, water and biodiversity resources.

Table 1: Production and projected demand for agricultural commodities by 2050

Commodity	Present area (mha) (2018-19)$	Present production (mt) (2018-19)$	Projected demand (mt) (2050)@
Cereals	94.1	257.4	358.7
Pulses	29.2	24.0	46.3
Foodgrains	123.3	281.4	405.0
Vegetable oils	25.6#	32.1#	39.0
Sugarcane	5.2	380.8	660.0

Cotton*	12.2	30.1##	117
Vegetables	10.4	178.2	342.2
Fruits	6.5	93.0	305.3
Milk	--	163.7	401.4
Meat	--	7.4	13.8
Eggs (billion)	--	87.0	183.9
Fish	--	13.8	22.4

* Seed cotton production; $: 2nd estimate of crop production, # Annual oilseeds area and production, ## Million bales of 170 kg each. (*Source*: MoA&FW); (*Source*: @ Chand, 2012)

Currently, India is self-reliant in almost all the major agricultural commodities except oilseeds. Agricultural sector is also a net earner of foreign exchange. However, the share of agricultural export in India's total exports decreased from 13.9 per cent in 2012-13 to 12.3 per cent in 2016-17. It has been estimated that to meet the diverse demands of the population by 2050, land productivity has to be increased by 4 times, water productivity by 3 times and labour productivity by 6 times (Chand, 2012). All this has to be achieved with low carbon emission technology and the smallest of ecological footprints.

Area and Productivity of Different Crops

Significant land use changes have been observed in the last seven decades (Table 2). The area under rice and wheat increased sharply up to 1991 after which rate of increase slowed down. Area of maize continued to increase in a linear manner throughout the period. Area of sorghum and other coarse cereals showed continuous sharp declining trend, while that of pearl millet increased up to 1990-91 and declined thereafter. Total pulses and oilseeds area showed an increasing trend, although, individual crops like groundnut declined after 1990's, while soybean showed a phenomenal increase in area occupying more than 5 per cent of cultivated area of the country at present. Area of commercial crops like cotton and sugarcane also showed increasing trend. The productivity of all the crops showed an increasing trend during the last seven decades, although magnitude of increase varied among different crops and that during the period 1950-51 and 1990-91 was considerably greater than that during the period between 1990-91 and 2016-17.

Table 2: Area and productivity of different crops-temporal change

Crops	Area (mha)			Productivity (q/ha)		
	1950-51	1990-91	2016-17	1950-51	1990-91	2016-17
Rice	30.81	42.69	43.79	6.68	17.40	24.94
Wheat	9.75	24.17	29.58	6.63	22.81	32.0
Sorghum	15.57	14.36	5.62	3.53	8.14	8.12
Maize	3.16	5.90	9.63	5.47	15.18	26.89
Pearl millet	9.02	10.48	7.45	2.88	6.58	13.05
Other coarse cereals	9.92	5.58	2.31	4.08	9.00	17.50
Total Cereals	78.23	103.18	99.78	4.87	13.18	20.49
Chick pea	7.57	7.52	9.62	4.82	7.12	9.74
Pigeon pea	2.18	3.59	5.33	7.88	6.73	9.13
Total Pulses	19.09	24.66	29.44	4.41	5.78	7.86
Total Food -grains	97.32	127.84	129.22	5.22	13.80	21.29
Groundnut	4.49	8.31	5.33	7.75	9.04	13.98
Rapeseed and Mustard	2.07	5.78	6.07	3.68	9.04	13.04
Soybean	-	2.56	11.50	-	10.15	11.77
Total Oilseeds	10.73	24.15	26.17	4.81	7.71	11.95
Cotton	5.88	7.44	10.82	0.88	2.25	5.12
Sugarcane	1.71	3.69	4.43	334.2	653.95	690.0

During the last nearly seven decades, the proportion of area occupied by cereals declined from 61.1 per cent in 1950-51 to 48.7 per cent during 2016-17 while that of pulses remained stable (15.6% and 15.1%) during the same period (Table 3). On the other hand, area under oilseeds increased substantially from 8.3 per cent during 1950-51 to 13.2 per cent during 2016-17. The proportion of area occupied by sugarcane, cotton, fruits and vegetables also showed a sharp increase during this period.

Cropping and Farming Systems

The present cropping system is the cumulative result of past and present decisions by individual farmers, communities, government, and trade agencies. Farmers decide their cropping systems broadly in relation to a set of traditionally accepted rotations. The rotation is ordinarily adopted in relation to individual fields. These decisions are generally governed by various factors including production prospects, expected profit, resource base, household needs, experience, tradition, social and political compulsions etc.

During the past six decades, cropping intensity increased from 111 in 1950-51 to 141.6 in 2014-15, mainly due to rise in the gross irrigated area from 22.6 mha in 1950-51 to 95.8 mha in 2013-14 coupled with adoption of HYV and other production technologies. Though the available data do not reveal how much of prime agricultural land has been taken away for non-agriculture purposes but unplanned urbanization around towns and cities has led to conversion of large chunk, of prime agricultural lands into non-agricultural purposes. If one examines the past trends in cropping systems, it will be quite clear that expansion in area has occurred in favor of those crops which have either shown a higher growth rate of production due to technological development or whose relative prices with competing crops have moved in their favor or high growth rates in yields were combined with high prices resulting in sharp increases in their total profitability (Table 3).

Table 3: Extent (%) of different crops to total cropped area in India

Crop	1950-51	1990-91	2016-17
Rice	23.5	23.0	21.6
Wheat	7.6	12.9	15.4
Sorghum	11.8	7.6	2.2
Pearl millet	7.4	5.8	3.4
Maize	2.5	3.2	4.9
Total Cereals	61.1	55.5	48.7
Chickpea	5.9	4.0	5.0
Pigeon pea	1.7	1.9	2.3
Total Pulses	15.6	13.4	15.1
Total Foodgrains	76.7	68.9	63.8
Groundnut	3.3	4.5	2.3
Rapeseed & Mustard	0.8	2.8	3.6
Soybean	-	1.4	5.7
Total Oilseeds	8.3	13.5	13.2
Sugarcane	1.3	2.1	2.7
Condiments & Spices	0.9	1.3	2.1

Total Fruits	0.6	1.4	3.4
Total Vegetables	1.2	2.2	5.4
Cotton	4.3	4.1	6.3
Total Fibres	5.1	4.7	6.7
Other Crops	5.6	5.7	2.5
Total Cropped area (mha)	131.9	185.7	193.1

We often hear that productivity of crops over years has declined or plateaued, which is not correct if one looks at the data given in Figure 4 though there have been variations among different crops and commodities. This was possible because of innovations in crop varieties and other production technologies.

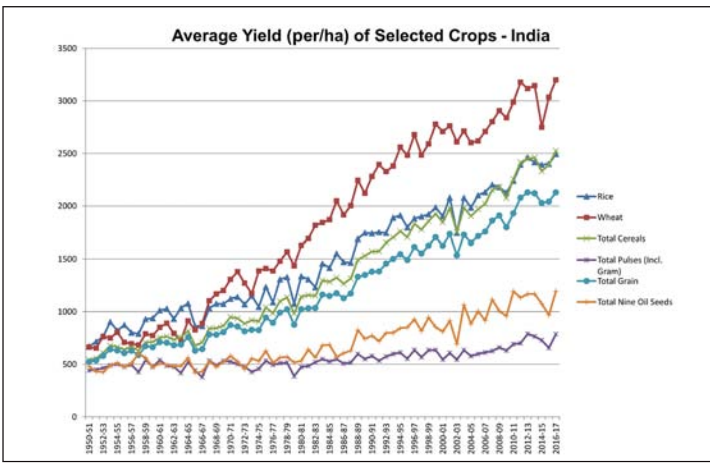

Figure 4: Average yield per hectare of selected crops – India

A socially desirable and appropriate cropping system should try to bridge the gap between demand and supply and help attain self-sufficiency in essential agricultural commodities in the long run, ensuring maximization of farm income. There could be divergence between actual cropping system and the socially desirable cropping system. But since farmers readily respond to the opportunities provided to them through various price and non-price signals, it should be possible to minimize this divergence between individual decisions and production targets for both domestic and export requirements through appropriate land use planning-based production and marketing system.

Under the conditions of agricultural production prevailing in India, farming is faced with inefficient scales of operation due to marginal and small size of farms and high vulnerability to climate related risks which are getting exacerbated on account of climate change occurrences. The situation necessitates incorporation of risk management approach to the production system. Integrated Farming System (IFS) offers such a comprehensive tool. This approach views farming in a holistic manner, and deploys resource management strategy to achieve economic and sustainable production, while preserving resource base and high level of environmental quality. This approach is particularly relevant for small and marginal farmers in poorly-endowed areas to secure a respectable livelihood on a sustainable basis. IFS also offers opportunities for secondary agriculture activities, enabling the farmers to take complementary benefit of farm enterprises in the entire value chain.

Special Agricultural Zones and Potentially Efficient Crop Zones

ICAR-NBSS&LUP has developed over time, criteria and methodology to identify special agricultural zones and potentially efficient crop zones for realizing high productivity of crops matching with the crop requirements and climatic and soil-site features. This approach will promote land use planning-based production and market system, improve the soil quality, raise the productivity and profitability and arrest the land degradation. To aid this approach, land resource inventory database of 1:10000 scale is most important input. This will also help in reducing area under different crops to realize the production targets by improving productivity and at the same time sparing substantial area presently under these crops for other uses.

Natural Resources

Soil and Land Resource

The shrinking size of farm holdings in India is a major constraint to agriculture growth. The land being used for agriculture has to cater not only to provide food and fiber for the human population but also feed and fodder for the 15 per cent of world's livestock population. The demand of the industrial sector for non-food items as raw material is also increasing at a fast pace like biofuels, bio-degradable substitutes for plastics, *guar* etc. The present land use pattern in the country shows that forestry and agriculture are the two major land uses, which occupy 71.8 mha (21.8%) and 140 mha (42.6%), respectively (Table 4). The area under agriculture has increased from 119 m ha in 1950-51 to about 140 m ha in 1970-71 and since then has more or less remained constant. During the same period, area under non-agricultural uses increased from 9.36 to 26.88 mha. On the other hand, the area under barren and uncultivable lands, land under miscellaneous tree crops and groves, cultivable wastelands and fallow lands other than current fallows has shown a significant decrease from 1950 onwards. This clearly shows that during this period, most of the barren, waste and fallow lands were either converted into agricultural lands or other uses or brought under forestry. However, there is hardly any scope to bring additional area under agriculture.

Table 4: Trends in land use pattern in India (mha)

Year Land unit	**1950-51**	**1960-61**	**1970-71**	**1980-81**	**1990-91**	**2000-01**	**2010-11**	**2014-15**
Geographical area	328.73	328.73	328.73	328.73	328.73	328.73	328.73	328.73
Forests	40.48 (12.3)	54.05	63.83	67.46	67.70	69.84	71.59	71.79 (21.8)
Not Available for Cultivation								
Area under non-agricul-tural uses	9.36 (2.8)	14.84	16.48	19.60	21.22	23.75	26.40	26.88 (8.2)
Barren and un-culturable land	38.16 (11.6)	35.91	28.13	19.96	19.51	17.48	17.18	17.00 (5.1)
Total	47.52	50.75	44.61	39.55	40.73	41.23	43.57	43.88
Other Uncultivated Land Excluding Fallow Land								
Permanent pastures & other grazing lands	6.68 (2.0)	13.97	13.26	12.00	11.41	10.53	10.30	10.26 (3.1)
Land under misc. tree crops & groves (not incl. in net area sown)	19.83 (6.0)	4.46	4.37	3.58	3.81	3.44	3.20	3.10 (0.09)

Culturable waste land	22.94 (7.0)	19.21	17.50	16.74	15.00	13.52	12.65	12.47 (3.8)
Total	49.45	37.64	35.13	32.31	30.22	27.50	26.15	25.83
Fallow Lands								
Fallow lands other than current fallows	17.45 (5.3)	11.18	8.73	9.72	9.66	10.51	10.32	11.09 (3.4)
Current fallows	10.68 (3.2)	11.64	10.60	14.83	13.84	15.34	14.28	15.09 (4.6)
Total	28.13	22.82	19.33	24.55	23.50	25.85	24.60	26.18
Agricultural Lands								
Net area sown	118.75 (36.1)	133.20	140.86	140.29	142.87	141.34	141.56	140.13 (42.6)
Total cropped area	131.89 (40.1)	152.77	165.79	172.63	185.74	185.34	197.68	198.36 (60.3)
Area sown more than once	13.15 (4.0)	19.57	24.93	32.34	42.87	44.00	56.12	58.23 (17.7)
Net irrigated area	20.85 (17.6)$	24.66	31.10	38.72	48.02	55.20	63.66	68.38 (48.6)$
Gross irrigat-ed area	22.56 (17.1)#	27.98	38.19	49.78	63.20	76.19	88.93	96.46 (48.3)
Cropping Intensity (%)	111.1	114.7	117.7	123.1	130	131.1	139.6	141.6

Source: Directorate of Economics and statistics, GOI; Figures in parenthesis are % to TGA; $ % in relation to NSA for Net irrigated area and #% in relation to total cropped area for gross irrigated area.

The per capita availability of land has declined from 0.91 ha in 1951 to 0.32 ha in 2001 and is projected to slide down to 0.23 ha in 2025 and less than 0.19 ha in 2050 (Table 5). As far as agricultural land is concerned, the per capita availability of land has declined from 0.48 ha in 1951 to 0.16 ha in 1991, 0.13 ha in 2001 and it is likely to decline further to 0.11 ha in 2025 and less than 0.09 ha in 2050. This decline in per capita land availability in the country is mostly on account of increasing population and, therefore it is important to examine the carrying capacity of the land under cultivation because there is no alternative other than intensifying agricultural activities to feed the huge population.

Table 5: Projected land resource and per capita availability

Land resource	Total maximum (mha) by 2050	Per capita availability (ha)			
		1951	2001	2025*	2050*
Total land area	328.73	0.91	0.32	0.23	0.19
Net sown area	150.00	0.48	0.13	0.11	0.09
Gross cropped area	250.00	0.37	0.19	0.18	0.14
Net irrigated area	87.00	0.06	0.06	0.06	0.05
Gross irrigated area	100.00	0.06	0.08	0.07	0.06
Forest area	75.5	0.11	0.07	0.05	0.04
Total green area	120.0	0.19	0.12	0.08	0.07
Total area that can produce biomass	270.0	0.75	0.26	0.19	0.15

Source: State of Indian Agriculture, 2009, NAAS Publication; *2025 and 2050 are projected

Land Holdings

The number of operational land holdings increased by 48 per cent in past five decades from 71 m in 1970-71 to 146 m in 2015-16 (Table 6). Among different land holding sizes, highest increase is in marginal category (64%) followed by small (48%) and semi-medium (22%). Contrary to this, number of holdings decreased by 70 per cent in large category and 31 per cent in medium category between 1970-71 and 2015-16. Consequently the operational holding size reduced from 1.5 ha to 1.08 during the corresponding period. How viable and profitable can this farm holding size be raises the question of sustainability?

Table 6: Decadal changes in number of operational holdings

Category	Number of operational holdings (millions)					
	1970-71	1980-81	1990-91	2000-01	2010-11	2015-16
Marginal (<1 ha)	36.20	50.12	63.39	75.41	92.36	99.86
Small (1-2 ha)	13.43	16.07	20.09	22.70	24.71	25.78
Semi medium (2-4 ha)	10.68	12.46	13.92	14.02	13.84	13.78
Medium (4-10 ha)	7.93	8.07	7.58	6.58	5.86	5.48
Large (>10 ha)	2.77	2.17	1.65	1.23	1.00	0.83
All sizes	71.01	88.88	106.64	119.93	137.76	145.73

Source: Agricultural Census, 2015-16

Fertility Status of Soil

A recent estimate based on available soil test data showed that soils of about 59, 36 and 5 per cent area are low, medium and high in available N, respectively. Similarly, soils of about 49, 45 and 6 per cent area are low, medium and high in available P, respectively; and soils of around 9, 39 and 52 per cent area are low, medium and high in available K, respectively. Not only is the inherent soil fertility poor and the nutrient input low but also there is a growing evidence of increasing deficiency of K and S, aggravated by the disproportionate/imbalanced application of higher doses of N in relation to P and K. The current gap between annual mining of major nutrients from the soil and inputs from external sources is about 10 mt, which is likely to grow further. This is one of the major causes of soil chemical degradation resulting in poor soil fertility and soil health. There is also a growing evidence of increasing responses to S in several crops including oilseeds, pulses and legumes and high-yielding cereals. Around 36.5 per cent of soils in India are potentially deficient in Zn, 13 per cent in Fe, 7 per cent in Mn, 4.2 per cent in Cu and 23 per cent in Bo (NAAS, 2015). The use efficiency of majority of nutrients is very low and considerable scope exists for their improvement.

The low values of nutrient use efficiencies, particularly micro-nutrient, *viz.* nitrogen (33-50%), phosphorus (15-20%), potassium (70-80%), sulphur (8-10%) and micro-nutrient (<5%) are indicators that it is easily possible to increase the efficiency through microbial consortia, method of fertilizer placement, foliar spray, site specific nutrient management, customized fertilizer, slow release fertilizer, nano-fertilizers, fertigation and development of new products and their timing. The current method of broadcasting fertilizers is very inefficient.

In recent years, due to rapid increase in industrialization and urbanization, the disposal of huge volumes of sewage and industrial effluents has become a source of pollution and contamination of soils, water and atmosphere. Although, the treatment of these sewage and effluents are regulated for safe disposal by pollution control boards, the contamination of soils and water bodies by discharge of untreated sewage and effluents containing heavy metals is a cause of great concern and an emerging threat to agriculture in the form of phyto-toxicity, biological health of the soil, contamination of water resources as documented from several case studies in India. Therefore, there is a need to strictly enforce the regulations under the aegis of pollution control boards.

In recent years, there has been acceleration in soil quarrying activities for brick industry and sand from river beds for construction which are causing serious damage to agricultural land and river courses. This human activity causes soil erosion, generates solid wastes, water logging and water management problems. All these factors contribute to degradation of the land. Brick industry uses top fertile soil, which is most important for crop production. In most of the brick kilns areas, soils are mined up to 3 meter. One of the estimates indicates that every year nearly 45,000 ha land is being diverted for brick making and with increased urbanization, and infrastructural development, area required for brick kilns may increase considerably.

Similarly, sand is in high demand in the construction sector. By 2020, 1.4 billion t/year of sand will be required in India. Illegal and unscientific sand mining is turning out to be one of the biggest ecological disasters in modern India. Exponential demand for sand has created several environmental problems as riverbed sand supply is not meeting the demand. In the last two decades, surface soils from tank beds, agricultural lands and village common lands have been excavated and washed to produce artificial sand around major cities and towns. Sand mining affects agriculture, water infiltration in the river bed and also leads to environmental problems. These activities have adversely affected the local economy, leading to conflicts among stakeholders. There is a need for strict enforcement of regulatory measures against sand mining and promote viable substitutes for bricks to meet the requirement of construction sector.

Soil as Ecosystem Service Provider

In addition to its role in crop production, soils provide several supporting and regulating eco-system services such as water retention and release, flood mitigation, water quality control through filtering of contaminants, de-toxication of waste, soil erosion control and sediment retention, enhancing soil stability and physical protection, conservation of biodiversity and climate change mitigation. This critical role that soil plays as a driver of ecosystem services has long been ignored. Since soil is going to play very significant role in meeting the SDGs, it is now an appropriate time to recognize the importance of this role and quantify its contribution so that an institutional mechanism is put in place for Payment of Ecosystem Services (PES) to the cultivators who adopt best management practices to improve the soil health.

India has the very formidable and challenging task of feeding 17.5 per cent of world's human population and 15 per cent of livestock population from a meagre 4 per cent of the global water resources. Among different sectors requiring water, irrigation accounted for 78 per cent in 2010 and is expected to account for 68 per cent by 2050 (Table 7). Agriculture has been and will remain the largest consumer of country fresh water resources.

Table 7: Sectoral water requirement in India (BCM)

Sectroal use	Year 2010			Year 2025			Year 2050		
	Low	High	%	Low	High	%	Low	High	%
Irrigation	543	557	78	561	611	72	628	847	68
Domestic	42	43	6	55	62	7	90	111	9
Industry	37	37	5	67	67	8	81	81	7
Power	18	19	3	31	33	4	63	70	6
Inland navigation	7	7	1	10	10	1	15	15	1
Environment ecology	5	5	0	10	10	1	20	20	2
Evaporation loss	42	42	1	50	50	6	76	76	7
Total	**694**	**710**	**100**	**784**	**843**	**100**	**973**	**1180**	**100**

Source: (NCIWRD, 1999)

If the international yardstick of 1700 m^3 per capita availability per annum of water is taken as a criterion, the whole country became "water stressed" in the year 2006 (Figure 5). Reported per capita availability of water was 1544 m^3 in 2011 and is likely to reach around 1100 m^3 in 2050 or earlier considering the wasteful ways of water usage at homes and farms. It may also be noted that per capita availability of <1000 m^3 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 even in 2010 (CWC, 2015).

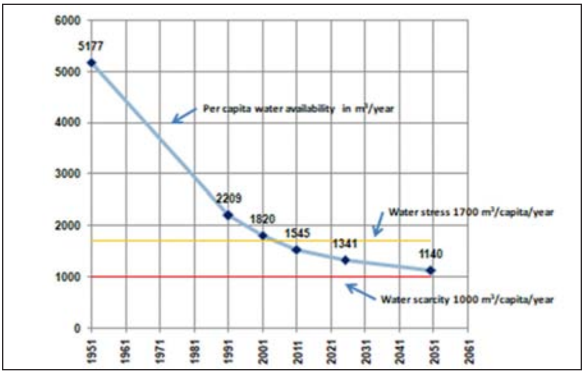

Figure 5: Change in per capita water availability since 1951.

Rain Water Resources

The normal annual precipitation in the country is estimated to be 400 million hectare-metres (mha-m) and most of the water received is in about 100 hours of rainfall in a year. Out of this, 115 mha-m enters surface flows, 215 mha-m enters the ground, and 70 mha-m is lost to evaporation. Only 25 mha-m is finally used through surface irrigation which constitutes mere 6 per cent of the total water available through rain. Out of 215 mha-m infiltrating into the soil, only 13 mha-m is utilized for groundwater irrigation and other uses. This again constitutes mere 6 per cent of the annual precipitation infiltrating into the soil, indicating the substantial potential for rainwater harvesting.

One of the reasons for the poor utilization of rainwater in India is its high concentration of rainfall over a few months and its uneven distribution. About 74 per cent of the rainfall is received during the south-west monsoon (June to September). As a result, the soil saturates, and much of the water flows away if no structures are made to check this flow. The uneven distribution also creates long dry periods when cropping is difficult if water is not retained or made available in some other way. Only 8 per cent of the country receives very high/assured rainfall of above 2000 mm, and another 20 per cent receives high rainfall of 1150 to 2000 mm. The rest of the country (72%), is in the low, dry, or medium rainfall range of less than 1150 mm, with 30 per cent area particularly dry at below 750 mm. Thus, in vast areas, supplemental irrigation is must for crop production. For sustainable use of groundwater, adequate rainwater recharge through percolation tanks and check dams and renovation of derelict ponds, tanks and lakes are pre-requisite.

Surface Water Sources

India has developed one of the largest irrigation infrastructures in the world, with more than 68 mha of net irrigated area (48%), which is next only to China. Irrigation development played a crucial role in ensuring food security. However, the average productivity in the irrigated systems (~3 t/ha) is considerably lower than the potential. 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, which stands at more than 25 mha. Top priority should be given to bridge this gap which is the main focus of the Accelerated Irrigation Benefits Programme (AIBP) now being pushed by GoI.

Water Use Efficiency

The conclusions of a study carried out on 35 major/medium irrigation projects in the country by (CWC, 2016) 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 8). The table also shows the high level of efficiencies attained by many of the major and medium irrigation projects, indicating that the current level management practices offer a huge potential in improving water use efficiencies.

Table 8: Water use efficiency of completed Major/Medium Irrigation Projects (Based on 35 projects in the country)

Parameters	% Efficiency
Conveyance Efficiency (CE)	**69**
*Major **	*91*
*Medium **	*86*
On Farm Application Efficiency (OFAE)	**55**
*Major ***	*80*
*Medium ***	*75*
Overall Water Use Efficiency (OWUE)	**36**
Major [@@]	*62*
Medium [@@]	*58*

Lowest CE:47 OFAE: 27 OWUE:13 *Source: CWC(2016)*

**Maximum level of conveyance efficiency observed in major and medium irrigated project.*

** Maximum level of on farm application efficiency observed in major and medium irrigated project.

[@@] Maximum level of overall water use efficiency in major and medium irrigated project.

At the planning stage, all irrigation projects have a provision of drainage systems but it is generally not implemented resulting in development of water logging and soil salinization. As a consequence, highly productive lands go out of cultivation in irrigation commands because of water logging and soil salinization. Adequate drainage systems, water quality monitoring of drainage waters and their reuse should be an integral part of irrigation projects.

Groundwater Resources

Development of ground water resources which was a low key affair in the earlier stages, is now contributing more than 60 per cent of the irrigation demand, and playing a critical role in ensuring food security. However, over-exploitation of groundwater has become a very serious cause of concern in most of the areas except eastern part of the country. Out of the 6607 assessed blocks, 4530 are safe while the rest are in the semi-critical (697), critical (217) and over-exploited (1071) category. By 2025, an estimated 60 per cent of India's groundwater blocks will be in critical/semi critical/ over-exploited categories. 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 declining trend continues and hence greater emphasis is given on artificial recharge of groundwater. Although, overall ground water development in the country is only 62 per cent, in some of the states like Delhi, Haryana, Punjab, Rajasthan etc., it has already crossed 100 per cent. Considering the low groundwater development in the eastern India and North-east, the Government of India has rightly decided to focus on this region under the programme aptly titled "Bringing Green Revolution to Eastern India" (BGREI).

The Pradhan Mantri Krishi Sinchai Yojna (PMKSY) is timely programme for holistic management of all the three categories of water resources at district level and provides convergence of different sectoral programmes on water. Thus, the gaps identified under Strategic Research and Extension Plan (SREGP) of the district will be covered in the preparation of District Irrigation Plan (DIP), which will be the compendium of all the existing and proposed water resource network system in the district for effective demand-supply management.

In this context, consideration of water productivity of crops as an indicator should form an integral part of crop diversification providing re-alignment of cropping pattern in the command area/watershed by alternating both high water demanding and low water demanding crops in rotation. However, this can be enforced by suitable regulatory measures for the optimum coverage of the chosen crops to increase land use efficiency and various water smart technologies for water saving.

Water Smart Technologies: Based on the research work carried out by ICAR-SAUs water savings associated with the various interventions has been quantified and are given below:

Proper scheduling of canals (matching supply with demand)	: 40-60%
Precision leveling through laser levelers	: 15-20%
Scientifically designed check basins/border strips	: 10-30%
Zero tillage	: 20-30%
Adoption of Pressurized Irrigation Systems	: 40-70%
Land configuration -Ridge/furrow or raised/sunken beds	: 20-25%

It is feasible to increase water use efficiency through precision leveling followed by adoption of scientifically designed check basins/border strips and land configuration *viz.,* ridge/furrow or raised/sunken beds, flood irrigation is being practiced. In other areas and identified crops use of micro irrigation system should be promoted in a big way. Field experiment has shown that even rice cultivation is possible with drip system with multiple benefits.

Waste Water Utilization

With the projected scenarios of water availability compounded by global warming, increasing urbanization and industrialization, huge volumes of waste waters will be generated. These waste waters would be of varying qualities depending upon the source, contamination level and quality of treatment before discharge. In India, the problems associated with wastewater reuse arise from its lack of treatment. On the whole, only 60 per cent of industrial effluent and 26 per cent of domestic sewage is treated at present. 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 has huge opportunity for waste water treatment and its use. It includes both sewage treatment and effluent treatment. At present, waste water treatment remains stuck at national average of 33 per cent. Therefore, there is enough scope for incentivizing and enforcing the treatment of sewage water and effluents to safe limits for reuse for various purposes. Waste waters can be treated and made suitable for irrigation very economically and are preferred by farmers because of the nutrients they provide.

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 for 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. The eco-system services that water provides are generally over looked. NBS can serve the triple goals of augmenting water availability, improving water quality and also reduce the risks related to water. NBS 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.

Water as an Ecosystem Service Provider

Apart from the role of water in providing provisioning service like production of food, fodder, fiber, fuel as well as agriculture, domestic and 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.

Horticulture-Challenges and Options

Diversification to horticulture has emerged as the best option for addressing nutritional adequacy, enhancing employment opportunities, farm income, use of natural resources and above all, emerging enterprises. The emerging trend worldwide and also in the country is indicative of a paradigm shift in dietary needs of the people, with rise in the income there is more demand of horticultural produce. In the scenario, where more than 300 million people are malnourished, and millions of people are below poverty line, there is need for improving quality of life through food and nutritional security.

Indian, horticulture development has many phases of growth, characterized by pleasantry, a hobby in pre-independent India, which moved further to adopt innovations in fifth phase of growth heralding Golden Revolution. Expanding horticulture demands knowledge, skills, and technologies for growing plants intensively to achieve efficient, profitable and competitive horticultural industry. The sector includes a wide variety of crops under different groups such as fruits, vegetables, root and tuber crops, mushroom, floriculture, medicinal and aromatic plants, nuts, plantation crops including coconut and oil palm. Government of India has accorded high priority for the development of this sector, particularly, since the VIII Plan-and beyond, which has impacted production, reaching to 314.67 mt, in 2017-18, from 96 mt in 1990-91, contributing 34.45 to the AGDP only from 11 per cent cropped area (Figure 6).

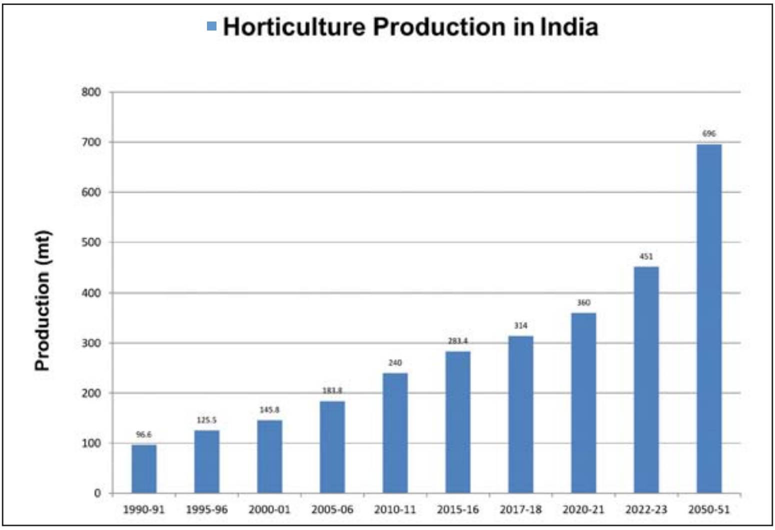

Figure 6: Progress in horticulture production over years

This trend of development in horticulture has been termed as Golden Revolution. However, challenges to feed growing population suiting to their dietary behaviour and nutrition requirements, is demanding science and technology led development, backed by enabling environments and resource utilization strategies. Change in dynamics of horticulture is now for health care through the use of horticultural produce for the treatment of many diseases, therapy, and environment services and above all to the improved quality of life of people living in rural as well as in urban area. The paradigm necessitates for knowledge empowered human resources, who can provide leadership in technology development and policy formulation to attract investment, and keep the pace of development. Horticultural crops is now playing a unique role in India's economy by improving the income of the rural populace and provide enormous opportunities to small and marginal farmers with higher return per unit of land than any other staple crops, beside overcoming vitamin and micronutrient deficiencies and is emerging as the main growth engine of Indian economy.

National Agriculture Policy (2000) categorically emphasized on integrated development of horticulture, which should be knowledge based, technology driven and farmers' centric. The policy also emphasized on rural institutions, reforms and development of infrastructure. There is no policy document for horticulture, but focus has been given on post-harvest management in the policy paper of food processing industries. Most notably policy change is related to storage, processing and marketing of horticultural produce. Backward and forward linked marketing with reform in agriculture produce marketing act, encouragement for contract farming are some of important policy changes which are likely to impact production, quality and competitiveness of horticultural produce. Other area of reform needed is in aggregating of land law, which can help in better investment as well as adoption of technology. To enhance the delivery there is a need for innovations in PPP mode for its better adoption in agriculture.

The main challenges to horticulture sector have been the investment and capital, access to technology and the initial learning curve to develop the required skills. An attempt to address many of the issues was made through mission mode approach to horticulture by launching of technology mission for development, to start with in North East in 1999, extending it to Himalayan states, in 2003 and to the whole country in 2005 as National Horticulture Mission (NHM), which continued as Mission for Integrated Development of Horticulture. Mission and National Programme on Micro-Irrigation ushered in horticulture revolution referred to as Golden revolution, in the country, providing opportunity for the farmers to enhance farm income and attract educated youth to farming, as horticulture proved to be economically rewarding and intellectually satisfying. In call of the nation for doubling farmers' income horticulture was identified to be a prime mover in achieving the goal.

With a surge in the middle and upper income group in the population, demand for fresh fruits and vegetables is bound to increase several fold. In this context, in addition to more food, the young, rich and urban population would demand diversified nutritious and safe food of high quality, and as a result of this there will be pressure on supply of horticulture produce. The report of committee on Doubling Farmers Income (DFI), 2018, estimated that by the year 2022- 23, production level of 451 mt has to be achieved. The report states that it can be achieved through 2.8 per cent increase in area and 3.1 per cent in productivity. It is evident that from the year 2000 to 2016 horticulture has growth rate of 5.8 per cent owing to technological changes, investment and policy environment. Many new technologies of seeds and planting material, drip and fertigation, greenhouse, hydroponics, marketing models and quality assurance through branding have been adopted and the success stories are replicated. Past trend shows that target of production envisaged in 2000, for 2021 is achievable, as we have reached to production of 314.67 mt in 2017-18. Thus, there are options of opportunities and challenges, which will need attention. The issues which require to be addressed are Innovation in technologies through institutional support as well as import of knowledge and technological backing for development through skills. Development strategies should be for cluster approach linked with post-harvest management and marketing, quality seeds and planting material, precision farming and smart horticulture, environmentally controlled horticulture, and enhanced ICT use to add efficiency to input management, knowledge transfer etc., and major emphasis to be given to value chain development and management for better profits.

Livestock and Poultry Sectors Development

India has made tremendous progress in the livestock sector as is evident from the fact that between 1951 and 2017-18, milk production enhanced from 17 to 176.35 mt (which is the highest in the world), meat production 7.37 mt, egg production 88.1 billion and fish production 0.75 to 10.8 mt. The change in the dietary habits of the Indian population has led to an increase of dairy products, eggs and meat. When it comes to enhancing income of farmers, livestock related interventions are one of the best interventions (DAHDF 2017-18). Dairy products will enhance livelihood, food and nutritional security and welfare of Indian population. It is estimated that over 70 million of the 140 million Indian households depend on dairy for their livelihood. Of these households, 75 per cent are small, marginal and landless milk producers, with average herd size of 2-8 animals.

India is the largest producer of milk in the world today and produces 18.5 per cent of the world's milk. This was possible because of technology development and innovations which led to more than 176 mt of milk production in 1917-18 from a very meagre production level of 17 mt in 1950-51 (Figure 7). This has resulted in increase in per capita availability of milk to 355 g/day as against the world average availability of 229 g/day and recommended per capita milk availability of 280 g/day for Indian population.

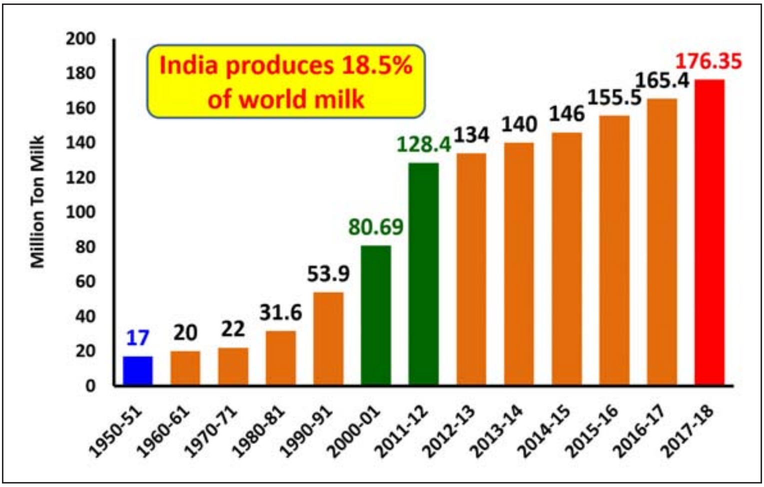

Figure 7: Technology and Innovation Led – Milk Production in India

Similarly, in areas of meat and egg production India has done reasonably well and today it is third largest exporter of meat next only to Brazil and Australia and largest exporter of buffalo meat (Figure 8). The state of UP

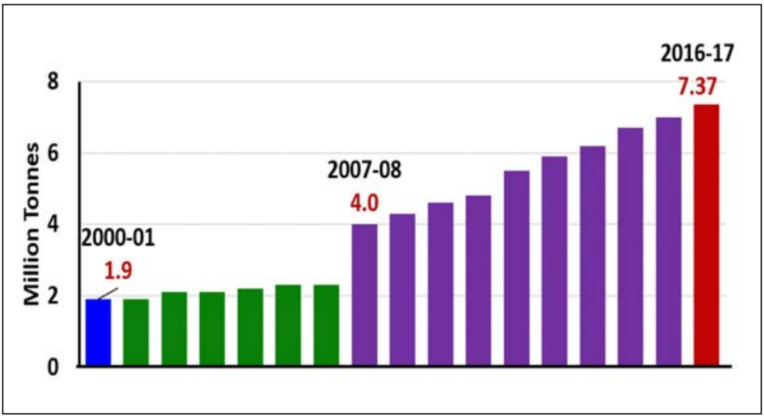

Figure 8: Meat Production in India

leads as far as export of buffalo meat is concerned. It is also important to note that of 7.37 mt, buffalo meat is 3.26 mt. Egg production which was only 39 billion eggs in 2000-2001 has shot up to 88 billion in 2016-17. In 1980-81, egg production was only 10 billion. Today India is third globally in egg production (Figure 9).

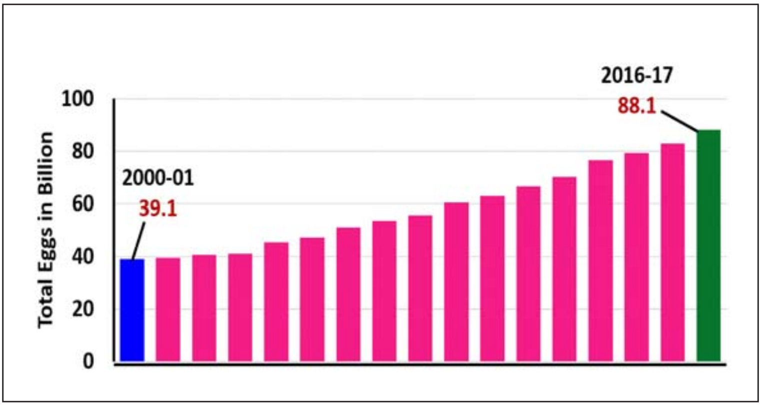

Figure 9: Egg Production in India

In the rainfed regions, it is the crop-livestock farming system which provides income and resilience to the small and marginal farmers and the rainfed/drought prone regions have the majority of the livestock population of the country (Figure 10).

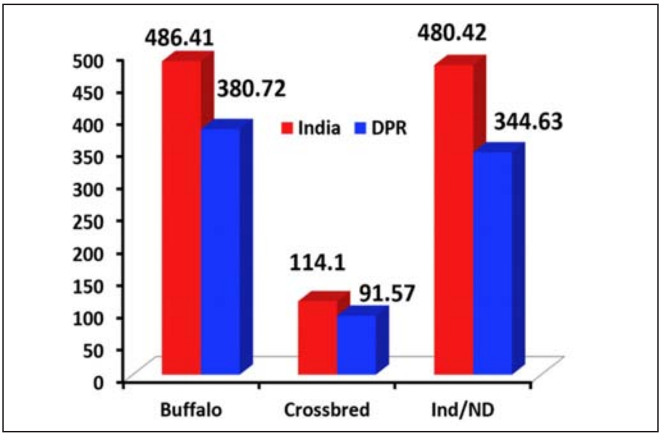

Figure 10: More Animals are in Drought Prone Region – Milch animals (in lakhs) in Indian vis-a-viz drought prones (DPR)

Feed is going to play a critical role in enhancing the productivity of the livestock. Unfortunately there is a huge gap in the availability of all feed components be it dry fodder (-39% deficit), green fodder (-36% deficit) and concentrates (-59% deficit). This aspects needs to be addressed on priority (Figure 11).

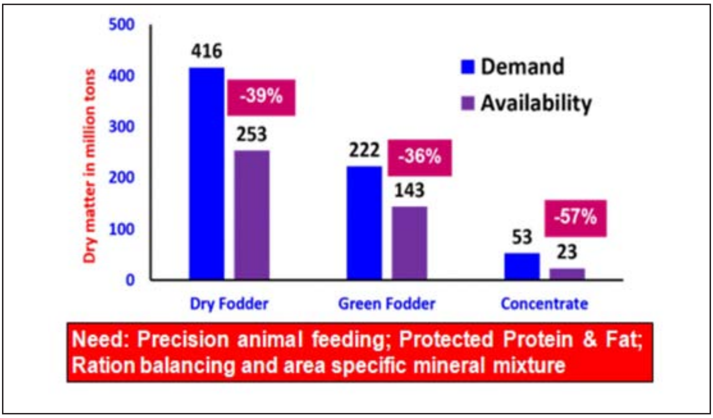

Figure 11: Feed and Fodder: Gap between Demand and Availability

By 2050 it is estimated that the milk demand would be of the order of 350-380 mt; herd size would be large (250), partly also as a consequence of small holders reorganizing themselves in producers companies; level of processing will go >80 per cent (70% in organized and 30% in unorganized); domestic producers will be linked to world market; and choice of diversified/ value added/ health dairy product will increase. There will be a need to emphasize on precision animal feeding and ration balancing, area specific mixture and feed/shelter management to reduce methane emission.

There is a need for transformation of Dairy Production from, Population Driven to Technology Driven; Highly Fragmented to Organized; Subsistence Type to Robust Commercial Models; Livestock Farm to Economic Unit; and Livestock Farmer to Livestock Entrepreneur. The important areas which need to be addressed in next two decades or so are the following:

- Cow side tests for diagnosis of sub-clinical mastitis, early pregnancy and ensuring metabolic disorder
- Development of electronic nose for estrus detection
- Reducing age at puberty in both male and female
- Technologies for sexed semen and sexed embryos
- Reducing the gap between demand and availability of male germ plasm
- Prediction of fertility of bull at calf-hood level
- Tools for selection of animals based on input efficiency
- Environment friendly waste disposal

- Increasing shelf life of milk and milk products
- Milk for pharma industry: exploiting milk as therapeutic
- Exploring the health attributes of non-bovine milk

Fisheries Sector Potential

Fish is known to provide high-value protein and a wide range of essential micronutrients, including various vitamins, minerals and polyunsaturated omega-3 fatty acids (FAO, 2012). Therefore, even in low quantities in the meal, fish is able to provide nutritional requirements at an affordable price. At present fish constitute 16.6 per cent of animal protein supply globally and 6.5 per cent of all protein for human consumption (FAO, 2012). Consumption of fish in India has also been increasing significantly day by day.

The total fish production in the country, from marine and inland sectors, has reached 13.8 mt in 2017-18. In 1950, the total fish production was 0.75 mt, it touched 11.4 mt in 2016-17 and it is expected to grow to 16.0 and 20.0 mt in the years 2025 and 2035, respectively. The country is now the second largest global fish producer. The export earnings from this sector have reached a new high of US$ 7.08 billion (Rs 45,107 crore) during the financial year 2017-18, with shipment of 1.38 mt of seafood, mostly frozen shrimp and frozen fish as the flagship items. The sector contributes about 0.9 per cent to the National Gross Value Added (GVA) and 5.43 per cent to the agricultural GVP (2015-16). With per capita current fish availability at 9.6 kg in the country, the country is yet to match the global fish consumption level of 20.3 kg. Further, with the addition of over 15 million population every year and gradual shift in the food habits oriented towards fish a safe protein source, it is evident that the demand-supply gap is going to grow in the years to come (Jena and Das, 2018).

Fishery sector therefore, occupies a very important place in the socio-economic development of the country. It has been recognized as a powerful income and employment generator as it stimulates growth of a number of subsidiary industries and besides being a foreign exchange earner. Most importantly it is a source of livelihood for a large section of economically backward population of the country. The main challenges facing fisheries development in the country have been in assessment of fisheries resources and their potentials in terms of fish production, development of suitable technologies for fin and shell fish culture, yield optimization, harvest and post-harvest operations and landing and berthing facilities for fishing vessels, augmenting export of marine fish products, generating employment and improving welfare of fishermen and their socio-economic status.

The multiple economic occupations not only bridge the often great seasonality in the abundance of fisheries resources, but also issues against risk of failing production in any one of these activities. Moreover, these complimentary persuits may in some cases determine part of the fisheries sector dynamics; for example, the supply of capital and labour of the fishing activity may evolve in close relation to agricultural activities undertaken by the household. The infrastructure developed for fisheries (feeder roads, landing sites and coastal havens, water retaining ponds) tend to trigger further economic development in other sectors such as tourism or agriculture. An important contribution of the sector is the employment opportunities it generates, especially in remote and marginal areas. And not only in fishing but also in boat building and maintenance, mechanical workshops for engine and gear, net making and repair, handling, processing, packaging and transport. In developing countries it is estimated that some 39 million fishers (including those engaged in production, harvesting and handling site based activities) are dependent for all part of their livelihood on fisheries. Together with their dependents, as many as 200 million people may rely on fisheries for their livelihood globally. In India, 14 million people are involved in this sector.

It is because of the paradigm shifts, significant impact has been seen over the years in terms of increasing contributions from inland sector and further from aquaculture. With high growth rates, the different facets, *viz.*, marine fisheries, coastal aquaculture, inland fisheries, freshwater aquaculture, and coldwater fisheries are contributing to the food basket, health, economy, exports, employment and tourism of the country. Today we are able to meet our domestic demand and have surplus for exports.

The potential innovations are in areas of harvesting technologies (type/ size of vessels and their methods of propulsion search technologies, methods of catching fish and bringing them to the board etc.); conservation technologies associated with monitoring and information intend to measure, control and monitor the direct harvesting impacts and the improvement of information, data on life history, movement and abundance of marine population and the quality of their habitat; development of new fish products and markets, market access; methods to grow more fish in captivity (innovations in feeds, improving the health of aquaculture animals etc.). Additionally, aquaculture developments need to focus on enhancing productivity through effective resources utilization, assured quality seed availability, appropriate nutrition & feed, fish health management, diversification, and adequate financial support coupled with insurance. On the policy front, market design, policy innovations with information collection, dissemination and evaluation and strategic planning, coordination and enforcement would be important measures to enhance fisheries sector and there by the rural economy especially of fish farmers.

Agro-forestry

Agro-forestry, an integral component of farming system, is vital for enhancing income and resilience to climate change. The promotion of sustainable agroforestry practices on a large scale is possible only through amalgamation of proactive farmer policies of the Govt. involvement of the industries, support services from NGOs and willingness of farmers (Sharma *et al.,* 2017). Agroforestry also provides services such as climate change mitigation (carbon sequestration), phytoremediation, watershed protection and biodiversity conservation. However, this needs development of an appropriate mechanism to reward the rural poor for the environmental services that they provide to society (Table 9).

Table 9. Total Domestic Demand for Various Commodities and Agroforestry Contribution in 2050.

Items	2010-11	Projected for 2025	Projected for 2050	Contribution from Agroforestry in 2050
Food grains (mt)	218.20	320.00	405.0	41.14*
Fruits (mt)	71.20	106.00	305.3	47.74*
Fodder (mt)	1061.00	1170.00	1545	154.50
Fuel Wood (mt)	308.00	479.00	629	308.00
Timber (mt)	120.00	171.00	347	295.00
Biodiesel (mt) required for 20% blending of diesel	12.94	22.21	37.92	30.34
Area (mha) required for TBOS	12.32	15.86	21.67	17.34
Agroforestry (mha)	25.32		53.32	

*Food-grains/fruits production from systematic agroforestry system viz. agri-silviculture agri-horticulture only considered

Agroforestry is perhaps the only viable option to achieve the recommended forest and tree cover of 33 percent of total geographical area of country. According to CAFRI (2015) by 2050, there is a scope of increasing the area under agroforestry by another 28.0 mha and thus a total of 53.23 mha or 17.5 per cent of country reported area under agroforestry. Most of this area will come from fallows, cultivable fallows, groves, degraded and wasteland. It also has the potential to change fortunes of small and marginal farmers and rural people by providing the resources to meet livelihood and food security along with the economic growth in the region (Singh and Dhyani, 2014).

Furthermore, agroforestry systems have potential to produce 100 million cubic meter timber/pulpwood for industrial and domestic use (Chavan *et al.* 2015), which would fulfill 65 per cent of the country's timber demand, 66 per cent of small timber demand, 70-80 per cent of plywood demand and 60 per cent raw material demand for paper pulp. In addition, it will produce 150 mt of firewood which is half of country's firewood demand. Likewise, 9-11 per cent of the green fodder requirements are met from the trees grown on the farms i.e. through agroforestry (Singh and Pandey 2011, CAFRI 2015).

Energy in Agriculture

The profile of energy consumption in the Indian agriculture has changed substantially, with a significant shift from animal and human labour towards tractor for different farming operations and electric and diesel pumps for irrigation. Quantitative assessment has indicated that in 1970-71, agricultural workers and draught animals contributed considerably to the total energy-use in agriculture (15 and 45%, respectively), while electricity and fossil energy together provided 40 per cent energy. Over time, the share of these energy inputs in agriculture has undergone a drastic change; the contribution of electricity and fossil energy together has gone up to 86 per cent and that of agricultural workers and draught animals has come down to 6 and 8 per cent, respectively. Estimates show that the all India average farm power availability at present is 1.35 Kw/ha, which needs to be increased substantially by promoting non-conventional energy sources so as to facilitate small holder's farm mechanization for efficient resource management (NAAS, 2015). Custom hiring center has proved very effective in providing the expensive machinery at an affordable charge to even small at marginal farms.

Use of ICTs and Emerging Technologies

The tremendous progress in information and communication technologies (ICTs) coupled with the rapid advancements made in GPS, Geographical Information Systems (GIS), simulation tools, sensors, drones, precision farming and remote sensing have opened up new vistas for land and water resources development and management and other sectors of agriculture. These tools should be an integral system of scientific management of irrigation networks, water distribution, soil health, crop planning and related operational activities as they will enable the system managers and land owners to take correct and timely decisions. Decision Support Systems (DSS) for real time monitoring and decision making with inputs from remote sensing and ground truth-based inputs can contribute significantly in efficient use of inputs and adopt precision farming techniques through ICT-enabled village knowledge centres and Krishi Vigyan Kendras (KVKs).

Artificial Intelligence (AI): AI is perhaps one disruptive technology which has the potential of impacting all aspects of our day to day existence. AI, however is not a new technology, its development was initiated more than 70 years ago (Turing *et al.*, 1952) and has been in use in many sectors particularly the industrial sector. But now as a consequence of almost unlimited computing power and lowering of data storage cost, AI based applications are on the fast track. It is as a combination of technologies which enable machines to act with higher levels of intelligence and emulate the human behavior. Globally, digital and AI technologies are helping solve pressing issues across the agriculture value chain. The relative role of each technology in creating impact is dependent on the nature of the work, and the issues at hand. India has ~30 million farmers who own smart phones, which is expected to grow 3 times and 315 million rural Indians will be using internet by 2020. An Accenture study reported that digital farming and connected farm services can impact 70 million Indian farmers in 2020, adding USD 9 billion to farmer incomes. These are not futuristic scenarios, they are already on ground today, enabled by a vast digital ecosystem which includes traditional original equipment manufacturers, software and services companies, cloud providers, open source platforms, startups, R&D institutions and others. Future growth is interdependent on the close partnership among these players.

In 2016, approximately 50 Indian agricultural technology based startups ('AgTech') raised USD 313 million. For the first time, this sector is seeing widespread participation by startups. Intello Labs, for example, uses image-recognition software to monitor crops and predict farm yields. Aibono uses agridata science and AI to provide solutions to stabilize crop yields. Trithi Robotics uses drone technology to allow farmers to monitor crops in real time and provide precise analysis of their soil. SatSure, a startup with roots in India, uses machine language techniques to assess images of farms and predict economic value of their future yield.

Microsoft in collaboration with ICRISAT developed an AI Sowing App powered by Microsoft Cortana Intelligence Suite including Machine Learning and Power BI. The app sends sowing advisories to participating farmers on the optimal date to sow, the best part–the farmers don't need to install any sensors in their fields or incur any capital expenditure. All they need is a feature phone capable of receiving text messages. The advisories contained essential information including the optimal sowing date, soil test based fertilizer application, farm yard manure application, seed treatment, optimum sowing depth, and more. In tandem with the app, a personalized village advisory dashboard provided important insights into soil health, recommended fertilizer, and seven-day weather forecasts. In 2017, the program was expanded to touch more than 3,000 farmers across the states of Andhra Pradesh and Karnataka during the kharif crop cycle (rainy season) for a host of crops including groundnut, ragi, maize, rice and cotton, among others. It is reported that the increase in yield ranged from 10 to 30 per cent across crops.

Blue River Technology has designed and integrated computer vision and machine learning technology that enables farmers to reduce the use of herbicides by spraying only where weeds are present, optimizing the use of inputs in farming–a key objective of precision agriculture.

Crop diseases or pest infestation in the crops can be accessed by an image on a farmer's phone and determine the product quality in real time, without any manual intervention. Farmers just need to know the operation of app in their phone. This will help farmers in their product grading.

Predictive Agricultural Analytics: Farming practices advisories are limited due to lack of access to scientific understanding of crop lifecycle, pests, quality metrics and the latest micro-fertilizers use. Supply chain efficiencies–real-time data analysis can be used for efficient and smart supply chain. These modern techniques are the future of the Indian agriculture. They capture complete information about the commodities (growing information, pre- and post-harvest, transportation, warehousing etc.) and proactively advice farmers on sowing, pest control, harvesting etc.

Bio-Security and Safety: Bio-security and safety has become a very vital issue in today's world from threats like gene-piracy, cross-border movement of vector-borne diseases, alien invasive weed species and pests. Environmental and safety aspects of nano-technology derived products, GM crops are issues which need to be addressed before large scale use can be recommended.

Robotics in Agriculture: There are real problems in modern agriculture. Traditional farming methods struggle to keep up with the efficiencies required by the market. Farmers in developed countries are suffering from a lack of workforce. The rise of automated farming is an attempt to solve these 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 smart phone, 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. “Robocop”, for example, uses computer vision to detect plants as it is pushed by a tractor. It then automatically does the spaces between plants to uproot the weeds. Other weeding robots use lasers to kill the weeds.

Urban Agriculture, Automated Vertical Farming, and Hydro-and-Aquaponics: The urban population is expanding globally, and yesteryear's food system will soon be suboptimal for many of the mega-cities swelling with people. The future of food depends on technology that enables us to get more food out of fewer resources. The next generation food production system will include urban agriculture, automated vertical farms, aquaponics / hydroponics, *in vitro* meats, and artificial animal products. With new technology, the future agriculture could change drastically. Many products will flop, but others will take a firm hold in our supply chain and become culturally acceptable and economically viable. Urban agriculture will allow moving food production from rural to urban areas, reduce transportation costs and allow fresher food to be delivered to the growing urban population. In 2015 alone, some 9.9 per cent of the world population was engaged in some level of urban agriculture, producing about 17 per cent of the world's food. Most of this activity, is small scale and often sustenance farming. This is changing as technology is allowing more compact agricultural infrastructure. Using automated vertical farms advances in digitization and automation; automated vertical farming has proven to be 100 times more productive per acre than traditional farming.

Nano Technology Applications

Nanotechnology applications have the huge potential to change 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:

- Nanoporous zeolotes for controlled release and efficient amount of water, fertilizer etc.
- Nanocapsules for delivering of herbicide, vector and managing of pests.
- Nanosensors for detecting aquatic toxins and pests.
- 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.
- Nanostructured metals can be explored in decomposition of harmful organics at room temperature.
- Smart particles can be useful in effective environmental monitoring and purification processes.
- Nanoparticles as a novel photocatalyst.
- Waste water treatment.

The Way Forward

The farming of the future will be technology based and a paradigm shift is needed in our approach towards intensified sustainable agricultural production system. Even today, there is a significant gap between the potential yields and the farm level yields which needs to be bridged urgently. We need to focus on the followings:

1. Large scale adoption of resources use efficient technology with a provision for incentives to promote their wider use.
2. Field tested Integrated Farming System Models (crop-livestock-agri-horti-forestry) relevant to the average farm holdings, focusing on small and marginal farmers for different agro-ecosystem, must be upscaled in a mission mode with assured market linkages and MSP. Formation of producer organizations should be promoted and the complete chain from farm to fork addressed. IFS models can take care of the diverse needs, nutritional security, livelihood enhancement and climate resilience.
3. The two vital natural resources, soil (land) and water provide a host of ecosystem services in addition to the provisioning services like food production. An institutional mechanism needs to be put in place for Payment of Ecosystem Services (PES) so that their sustainable management in guaranteed.
4. The Government of India has committed in the Paris 2015 meeting, to reduce the GHGs emission intensity by 33-35 per cent of 2005 level by 2030. A strong policy support is needed to meet this commitment as well as achieving Land Degradation Neutrality by 2030.
5. The dietary changes of the Indian population is showing a significant increase in the consumption of meat, eggs, dairy and fishery products. All these commodities would require factoring in for their water, land and other inputs including feed and fodder.
6. A national mission on precision agriculture including livestock & fisheries needs to be set up, which focuses on utilization of modern tools and technologies like Remote Sensing, Drones, Sensors, Decision Support Systems, Robotics, Artificial Intelligence, Internet of Things (IoT), Biotechnology (CRISPER, Gene Editing) etc. So that "More from Less for More" is ensured for the 1.7 billion Indian by 2050.

7. Organic farming must be promoted in big way in rainfed, hilly and tribal regions, districts/blocks with very low or negligible fertilizer use, and north-eastern states. It is essential to have a holistic approach for organic farming with emphasis on organic inputs for pest, disease and weed control. There is also an urgent need to have adequate processing and value addition system in place for organic produce as demand for safe, healthy and nutritious food is increasing and a niche market (domestic and international) exists.
8. Post harvest management policy is needed to:
    - establish agro-processing centres with warehouse/storage facilities for raw and processed products with marketing logistics in each panchayat.
    - decentralize storage of grains, fruits and vegetables with public and government partnership at block level adjacent to these agro-processing centres currently,
    - enhance funding for post-harvest research and development,
    - open entrepreneurship development training and incubation centres in each district for rural youth, and
    - launch a dedicated campaign for educating all stakeholders involved from farm to fork to minimize the loses in the supply chain.
9. Use of renewable/alternative forms of energy like solar and wind based application instead of fossil fuels need to be pushed in a big way as the energy use in agriculture in India is still low compared to other developing countries.
10. Availability of labour is going to be a major handicap in future. Mechanization, custom hiring centres, gender friendly small farm implements that can cater to resource, poor farmers must be promoted by the Government for bringing in efficiency, reducing drudgery and cost of cultivation.
11. Adequate and dedicated funding should be provided for high end research on futuristic technologies like nanotechnology, climate adoption and mitigation options, enhancing soil & water use efficiency, robotic, AI, etc.

References

Agricultural Census 2015-16 (2018). Agriculture Census Division Department of Agriculture, Co-Operation & Farmers Welfare Ministry of Agriculture & Farmers Welfare. Government of India.

CAFRI Vision 2050. Central Agroforestry Research Institute, Jhansi, India, 2015.

Chand, R. (2012) Agricultural R&D for next generation-ICAR vision 2050. AU Vice-Chancellor and ICAR Directors Meet)

Chavan, S.B., Keerthika A., Dhyani, S.K., Handa, A.K., Newaj, R., and Rajarajan K. National Agroforestry Policy in India: a low hanging fruit. Current Science. 2015; 108(10):1826-1834.

CWC (2015). Water and related statistics, Water resources information system directorate information, system organization, Water planning and projects wing, Central Water Commission: p 161.

CWC (2016). Summary report on water use efficiency studies for 35 irrigation projects. Central Water Commission, Govt. of India, p:126.

DAHDF (2017-18). Annual Report, Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture & Farmers Welfare, GoI.

Directorate of Economics and Statistics (2018); Ministry of Agriculture and Farmers Welfare, Govt. of India.

FAO (2012). Food and Agricultural Organization, Annual Report, Fisheries and Aquaculture statistics.

Hannah, Ritchie. (2019). Population by age bracket with UN projection, India, Ourworldindia.org

Jena, J.K. and Das, P.C. (2018). Assuring fish demand of India by 2030 through aquaculture development: Issues and Strategies, Indian Farming 68(10).

NAAS (2009). State of Indian Agriculture, National Academy of Agricultural Sciences.

NAAS (2015). State of Indian Agriculture - Energy, National Academy of Agricultural Sciences.

NCIWRD (1999) Report of the National Commission for Integrated Water Resources Development, Ministry of Water Resources, Vol. I, 542 p.; BCM=Billion cubic meter

NITI Aayog (2018). National Strategy for Artificial Intelligence, Discussion Paper.

Shroff, R. (2019). India: An Agricultural Powerhouse. The Sunday Guardian, May 12-18, New Delhi.

Sharma, P., Singh, M.K., Tiwari, P., and Verma, K., (2017). Agroforestry systems: Opportunities and challenges in India, Journal of Pharmacognosy and Phytochemistry, SP1: 953-957

Singh V.S. and Pandey, D.N. Multifunctional agroforestry systems in India: Science-Based policy options. RSPCB. 2011; 4:1-34.

Singh, A.K. and Dhayani, S.K. Agroforestry policy issues and challenges. In: Agroforestry Systems in India: Livelihood Security & Ecosystem Services (eds.) J.C. Dagar, A.K. Singh and Arunachalam A. Springer, India. Advances in Agronomy. 2014, 367-372.

Singh, V.S. and Pandey, D.N. (2011). Multifunctional agroforestry systems in India: Science-Based policy options. RSPCB. 4:1-34.

Targeted in document perspective of horticulture, Ministry of Agriculture 2000, Target made in respect of DFI, (2017). Estimated with assumption of changes, dietary needs, urbanization, population growth, income and trend in growth, 2011, report submitted to planning.

Turing, A., Braithwaite, R., Jefferson, G. and Newman, M.H.A. (1952). Can automatic calculating machines be said to think? The Essential Turing Chapter 14, Oxford University Press, Oxford, pp. 487-506.

Verma, P., Bijalwan, A., Dobriyal M.J.R., Swamy S.L., Thakur, T.K. A paradigm shift in agroforestry practices in Uttar Pradesh, Current Science. 2017; 112(3):509-516.

Visual Capitalist (2019). If India's population was split into four equal parts, Times of India, April 10, New Delhi.

WWAP (2018). The United Nation's, World Water Development Report, 2018, Nature Based Solutions for Water, Paris, UNESCO.