POLICY PAPER 56

Sustaining Agricultural Productivity through Integrated Soil Management

NAAS

NATIONAL ACADEMY OF AGRICULTURAL SCIENCES, NEW DELHI
DECEMBER 2012

Sustaining Agricultural Productivity through Integrated Soil Management

NATIONAL ACADEMY OF AGRICULTURAL SCIENCES, NEW DELHI

December 2012

CONVENER : Dr A. Subba Rao, Director, Indian Institute of Soil Science, Bhopal

CO-CONVENER : Dr J.K. Saha, Principal Scientist, Indian Institute of Soil Science, Bhopal

EDITORS : Dr C. Devakumar
: Dr P.K. Chhonkar

REVIEWERS : Dr I.P. Abrol, Dr Rajendra Prasad, Dr Deepak Sarkar and Dr S.M. Virmani

CITATION : NAAS 2012. Sustaining Agricultural Productivity through Integrated Soil Management. Policy Paper No. 56, National Academy of Agricultural Sciences, New Delhi. 24 p.

Published by Mr H.C. Pathak, Executive Secretary on behalf of
NATIONAL ACADEMY OF AGRICULTURAL SCIENCES
NASC, Dev Prakash Shastry Marg, New Delhi - 110 012
Tel: (011) 25846051-52; Fax: (011) 25846054
Email: naas@vsnl.com; Web site: http://www.naasindia.org

Preface

Soil is a wonderful gift of nature as being the basis of terrestrial life and performs important functions like storing and cycling nutrients for plants, filtering & buffering of various organic and inorganic compounds for providing potable groundwater, harbouring and sustaining biological diversity etc. Although the soil has evolved through millions of years of weathering and is sustaining various forms of terrestrial life, its management has become an essential component of strategy for sustenance of ever-increasing population and development pressure. Under the pressure of increasing food, fodder, feed, fibre and fuel production, soil has been used as medium of plant growth with considerable reliance on external supply of major nutrients, irrigation water, plant protection chemicals etc., without taking care of their impact on their capacity to carry out different functions. As a result, soils of various agro-ecological zones, particularly under intensive cultivation have developed fatigue with declining factor productivity, particularly of plant nutrients. Adoption of inappropriate policies and cropping systems alongwith faulty soil management has also resulted in accelerated soil erosion, groundwater quality deterioration, emerging micronutrient deficiencies, and adverse impact on soil biodiversity and physical properties, resulting in about 104 million hectares of land in our country as degraded. The situation is further complicated with emerging pressures of climate change, diversion of agricultural to non-agricultural uses, faulty disposal of effluents and wastes from cities and industries, international pressure of controlling GHG emissions, rising cost of fertilizers, etc.

With the above backdrop, the National Academy of Agricultural Sciences organized a Brainstorming Session on '*Sustaining Agricultural Productivity through Integrated Soil Management*' on October 10, 2011. Nearly 25 leading experts from different branches of soil science, water, microbiology, crop production and rainfed & dryland agriculture had participated. From comprehensive discussions among the experts, it emerged that there is an urgent need for effective soil protection and land use policy and establishment of framework for monitoring of soil quality in order to save our precious soil resources from degradation. Integrated nutrient management, balanced fertilization, recycling of organic wastes, sequestration of carbon in soil and plant system, reclamation of chemically degraded land, remediation of degraded and polluted soils etc. were highlighted as some of the major strategies for integrated soil management in different agro-ecological regions of the country.

This Policy Paper suggests research and policy priorities which must inform our policy makers, scientists and farmers about the integrated soil management towards achieving accelerated and sustainable agricultural productivity.

I compliment Convener, Dr A. Subba Rao, Director, Indian Institute of Soil Science, Bhopal (IISS), and Co-convener, Dr J.K. Saha, Principal Scientist, IISS, for convening the session. Our thanks are also due to the 'brain stormers'.

(R.B. Singh)
President, NAAS

Sustaining Agricultural Productivity through Integrated Soil Management

1.0 PREAMBLE

Soil is the living outer layer of our planet, a basic natural and non-renewable resource which serves as a medium for plant growth and a habitat where animals and other micro-organisms live. It forms a main component of the terrestrial ecosystems upon which our well-being and prosperity is dependent. India is bestowed with diverse soil groups due to variability in parent materials, land topography and climatic conditions in different regions (Table 1) [1]. Soils of our country have been grouped under major soil orders [2], namely Vertisols (27.96 m ha), Aridisols (14.07 m ha), Ultisols (8.25 m ha), Mollisols (1.32 m Ha), Alfisols (44.45 m ha), Inceptisols (130.37 m ha) and Entisols (92.13 m ha). Each soil group as well as sub-group has a distinct physical and chemical properties influencing soil-water–plant continuum and thus contributing to distinct advantages and constraints in various operations of crop management resulting in differential productivity.

Enhancement and maintenance of soil productivity is essential to the sustainability of agriculture and for meeting basic needs of rising population. India supports approximately 17% of the global population and 11% of the world's livestock population on merely 2.5% of the world's geographical area, adding immense pressure on agricultural land. In this context, some important issues that need to be addressed are:

(i) Are the soil resources adequate to meet the food demands for rapidly increasing human population?

(ii) What are the potentials and constraints of soil resources?

(iii) Is generic technology available that can be adopted to soil and site specific conditions for sustainable management of soil resources?

The scope of increasing land area for producing food is very limited. Bringing of marginal lands under plough is very risky and may pose threat to fragile ecosystem. Hence, meeting food demand mostly depends upon supply of plant nutrients and water as well as capacity of soil to perform various functions related to nutrient cycling and rhizospheric environment. The availability of plant nutrients is becoming scarce due to rise in cost and that of water has always remained uncertain due to

Table 1. Area under broad soil groups

Major soils	Area (in '000 ha)		% to total geographical area
Alluvial soils	1,02,823.59	1,02,825.99	31.28
Peat soils	2.40		
Coastal alluvial soils	10,049.07		3.06
Black soils	54,564.05		16.60
Red soils	85,474.96		26.00
Brown forest soils	540.02		0.16
Laterites	18,093.51		5.50
Terai soils	161.35	2,423.12	0.74
Hill soils	2,261.77		
Mountain meadow	60.14	163.98	0.05
Sub-montane	103.84		
Desert soils	26,283.40	26,332.53	8.01
Sand dunes	49.13		
Glaciers	1,402.22		0.43
Mangrove swamps	114.28	491.71	0.15
Creeks and lagoons	0.09		
Beaches	0.92		
Salt waste	36.92		
Water bodies	339.50		
Gullied land	0.20	3,078.64	0.94
Rock land	830.18		
Rock outcrops	2,248.26		
Others	23,281.26		7.08
Total	**3,28,721.06**		**100.00**

Source: [1]

its dependence on climate. The situation is getting worse due to competition from other sectors and changing climatic pattern and also due to deteriorating soil quality because of increased anthropogenic activity. Numerous studies have documented decline in soil productivity, produce quality, groundwater quality as well as loss in soil biodiversity as a result of these factors [3-9]. It is a matter of great concern that degraded lands form more than 57% of the total reporting area against 17% in the whole world. Hence, pressing need has arisen for managing our precious soil resources for improving and sustaining its various functions so that demand for quality food is met and quality of environment is improved. Previously, agricultural research focused primarily on a specific soil function i.e., medium of crop growth and hence, emphasized on management of soil and inputs for enhancing plant nutrient supply. However, in the era of rapidly degrading environment due to increased interference by man, role of soil in various environmental processes such as sink and source for pollution is emphasized in various fora for policy making. Thus, for higher quantity and better quality of food and fodder production from diversified farming system as well as for better quality of environment, there is a need for better management of our soil resources by integrating all our efforts related to improving and sustaining its functional quality.

2.0 MAJOR EMERGING THREATS TO THE SOIL RESOURCES OF INDIA

There are several natural degrading processes like desertification, erosion, salinization etc. However, anthropogenic activities have not only accelerated these degrading processes, but also created new types of threats which can be broadly categorized into four areas:

2.1 Land and soil diversion

As population expands and urbanization spreads, less area per capita becomes available under cultivation with consequent reduction in agricultural production. This happens in two ways; viz., (a) removal of top soil for brick making and for other construction activities, and (b) sealing of soil for housing, road or other infrastructure. About 7% of the geographical area, for which land-use statistics is available, is used for non-agricultural purposes, this area is estimated to be increasing at the rate of 0.3 million ha / year.

2.2. Chemical pressure

a. Entry of contaminants into soil via polluted air, rain and water

Pollutant chemicals enter into the soil body through various processes, for example, air-borne pollutants enter the soil body from emissions from industries, power plants, vehicles, radioactive and toxic chemical fallouts during disasters; gas-dust releases into the atmosphere under high temperature technological processes (e.g. power plants, metal smelting, the burning of raw materials for cement, etc.), waste incineration and fuel combustion. In India, about 100 million tonnes of pollutants are being added to the atmosphere annually through burning of fossil fuel and industrial emissions causing considerable air pollution. Coal combustion in thermal power plants releases 100-110 t Hg/year, which finally gets precipitated on soil body. Polluted surface water and groundwater add several harmful chemicals into the soil body when used for irrigation. More than 35 billion liters of urban waste water and 25 billion liters of industrial wastewater are released everyday, a significant part of which enters into agricultural land as irrigation carrying different pollutants. In-take of potential carcinogenic and non-carcinogenic persistent organic pollutants (POP) like polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB) and other organic pollutants from contaminated soil may occur via ingestion, and inhalation or dermal (skin) exposure to contaminated soil/dust. Tilling of dry soil can result in ingestion of small but measurable amounts of soil.

b. Entry of contaminants via synthetic fertilizers, composts and amendments and pesticides

Some of the pollutants are constituents of extensively used agrochemicals like fertilizers (e.g. Cd through phosphatic fertilizer), pesticides (organic pollutants) etc. and enter into the rhizosphere when these are used for higher production and economic return. A study at Indian Institute of Soil Science, Bhopal indicated high concentration of heavy metals (Cd, Cr, Cu, Pb, Ni and Zn) in composts manufactured in many cities of India from mixed municipal solid wastes. These heavy metals may accumulate in soil with repeated applications.

c. Illegal disposal of solid and liquid wastes

Illegal release of pollutant-loaded industrial effluents on the agricultural land is destroying soil fertility around several industrial areas of the country, compelling the inhabitants to change their livelihood from farming to industrial labour.

d. Entry of contaminants via polluted groundwater

As a result of intensive exploitation, concentration of pollutants like As is increasing in the groundwater of many parts of India. Contribution of As contaminated food to its toxicity in humans in these areas has been highlighted by several researchers. High concentration of Se in soil is also reported from some pockets of Indo-Gangetic Plains (IGP). In some of the districts using high doses of fertilizer, higher levels of NO_3^- in groundwater has been recorded indicating probable contamination from injudicious use of N fertilizers.

e. *Salinization and alkalinization*

About 6.73 million ha of country's land is affected by salt related problems (salinization and alkalinization). Large areas irrigated by canals face both waterlogging and salinity. In the Gandak and Indira Gandhi Canal command areas, the annual rise of groundwater has been 43-83 cm. According to an estimate by Central Arid Zone Research Institute (CAZRI), Jodhpur, 60 per cent of these command areas will develop drainage and salinity problems in 100 years. Many industries like textile mills, paper mills, tanneries, electroplating industries, agro-industries release high amount of salts in water bodies through effluents. Having high mobility (particularly Na^+ and Cl^-) through soil, salts have also been found to contaminate groundwater in and around the industrial areas. Considerable portion of such salts contaminate agricultural land when salt loaded effluents, surface water and groundwater are used for irrigating crops thereby, degrading soil structure and decreasing crop productivity.

f. *Nutrient imbalance*

Degradation of soil health has also been reported due to long-term imbalanced use of fertilizer nutrients. Although overall nutrient use ($N:P_2O_5:K_2O$) of 4:2:1 is considered ideal for Indian soils, the present use ratio of 6.8:2.8:1 is far off the mark. This imbalance nutrient use has resulted in wide gap between crop removal and fertilizer application. Long-term experiments, in India has in general showed that P and K status in soils at all centres has gone down when only N was applied. The partial factor productivity of fertilizers during the last three and half decades showed a declining trend from 48 kg food grains/kg NPK fertilizer in 1970-71 to 10 kg food grains/kg NPK fertilizer in 2007-08 (Fig. 1) [10, 11]. Moreover, widespread deficiencies of micro- and secondary nutrients in crops are being reported from different parts of the country; one of the reasons being their non-inclusion in nutrient management programmes. The number of nutrient-elements deficient in Indian soils increased from just one in 1950 to nine in the year 2005-06 which might further increase by the year 2025 if the imbalanced fertilization continues. In contrast, relatively high concentration of phosphorus has been reported in some intensively cultivated irrigated areas.

2.3 Physical pressure

a. *Compaction of soil*

Excessive use of heavy machinery for cultivation and harvesting causes compaction of soil with consequent reduction in porosity, available moisture content and increase in resistance to root penetration. Increase in bulk density under rice-wheat cropping

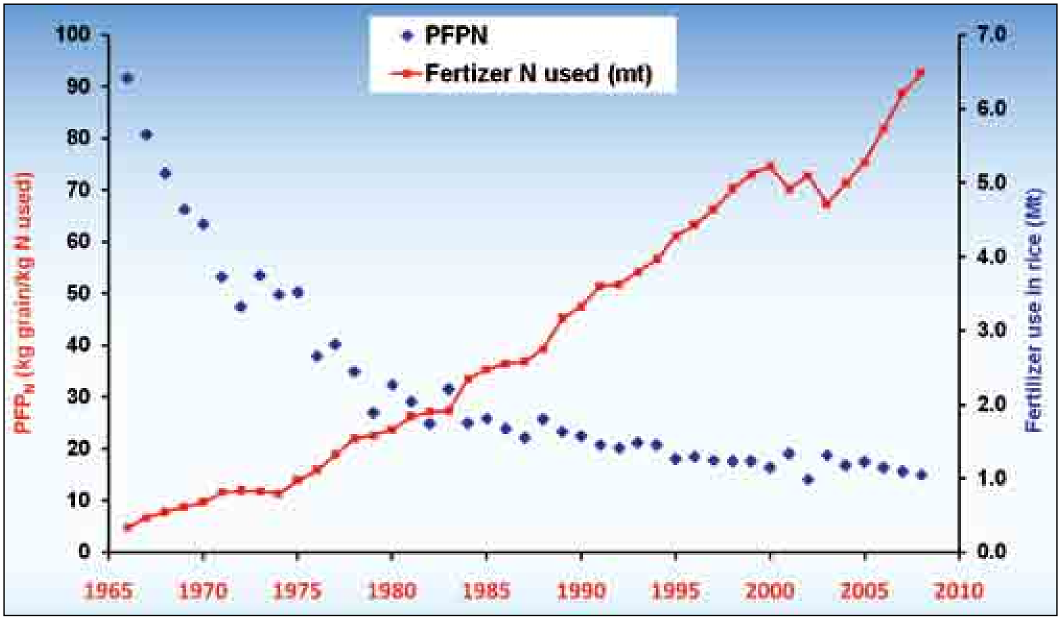

Fig. 1. Fertilizer N use and partial factor productivity (kg grain/kg N applied) in rice from 1965 to 2008

Source: [10, 11]

system in IGP is a concern. Intensive cultivation in conjunction with low organic input is also responsible for loss of soil structure and consequent compaction.

b. Erosion loss of top-soil

Inappropriate soil management, unsuited to the location like tilling along the slope, lack of crop cover during heavy rainfall etc. is responsible for accelerated soil erosion with consequent loss of land productivity. According to an estimate, more than 85 million ha of geographical area is subjected to water and wind erosion. Because of different processes like slaking and dispersion, mechanisms of soil structural collapse and degradation vary climatically and from one soil type to another. In addition to terrain deformation, erosion also takes away tonnes of nutrients to sea. Crop productivity loss due to soil degradation (from erosion) is estimated at 272 million tonnes worldwide at 1996 production levels [12].

2.4 Biological pressure

Maintenance of soil biodiversity is essential for food production, nutrient cycling, regulation of water flow, soil and sediment movement, detoxification of xenobiotics and other pollutants etc. Erosion, salinization, land sealing and pesticides and heavy metal contamination threaten soil biodiversity by destroying the habitat of the soil biota. Management practices that reduce organic matter in soils, or bypass biologically-mediated nutrient cycling also tend to reduce the size and complexity of soil communities.

3.0 NEED FOR CONVERGENCE OF TECHNOLOGIES TO OFF-SET NEGATIVE IMPACTS ON SOIL

In developing countries facing ever-increasing population pressure (like India), agricultural land is viewed primarily as a medium of plant growth and hence, existing soil management technologies have been evolved with the objective of increasing and sustaining high agricultural productivity. However in the context of growing concerns on food quality, groundwater quality, green house gases (GHG) emissions, climate change, soil biodiversity etc., there is a pressing need for reorientation/integration of different soil management technologies so that all the basic functions of soils are improved and sustained by combating above chemical, physical and biological pressures.

4.0 INTEGRATED SOIL MANAGEMENT

Integrated soil management (ISM) involves a combined strategy of effective nutrient, crop, water, soil and land management for sustainable agricultural production and other forms of land use. ISM can be tailored to the characteristics of site and soil and importantly, to environmental, economic and social constraints faced by farmers. ISM technologies should enhance soil structure, improve nutrient and water use efficiency, conserve valuable soil and water resources, and, wherever possible, increase cropping intensity [12].

4.1 Objectives of ISM

(i) Improving soil structure

(ii) Improving nutrient and water use efficiency

(iii) Conservation of soil and water

(iv) Protection from pollutant build-up and remediation of polluted soil

(v) Increasing cropping intensity

(vi) Improving soil biological condition

5.0 SOIL MANAGEMENT PRINCIPLES

5.1 Arresting soil degradation

In India, about 120.72 million ha of land (more than 36% of total geographical area) is affected by various forms of degradation (Table 2) [15]. Wind erosion has been responsible for destroying the valuable top soil in many areas. Halting the march of desert in Rajasthan and adjoining areas of Punjab is one of the vital and outstanding problems facing the country today. An extreme example of sand movement from the coast is to be seen in the Saurashtra region of Gujarat where the once-flourishing ports are now covered with advancing sand-dunes. In relation to agricultural activities, crops, cropping systems, tillage techniques significantly influence removal of top soil through erosion. Deforestation, increased frequency of Jhum cultivation in north-east states, and destruction of pasture land are causing havoc on soil resources due to accelerated soil erosion. It has been reported that about 170 tonnes/ha/yr of top soil is removed in the 2nd year of Jhum cultivation. As much as 2.3 million ha is already under ravines scattered all over India. The ravines apart from ruining the soil resources for ever are a constant threat to the adjoining fertile cultivated lands. The erosion largely caused by water has shaped the Earth (first appeared) and over several thousand years human being pitted themselves against erosion, trying to defend their lands against the assaults of rain and run-off. In order to protect the top soil, it is of prime importance that there should be minimum migration of soil out of a given field/catchment area. Universal Soil Loss Equation models (USLE, RUSLE, MUSLE and other erosion models) can be used to assess 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. While making resource conservation, tolerance limit of soil to be taken into consideration. Basic principles behind reclaiming degraded lands lie on enhancing soil structure, conserve soil, and enhancing biological activity.

5.2 Water harvesting, conservation and management

Water is a limiting factor in different events for crop production and at the same time, high velocity flow caused by intense rainfall results in removal of considerable fertile top soil. Though, India gets an average of 75 cm annual rainfall, its distribution in space and time makes Indian agriculture a gamble in monsoons. India has a large area under arid region (31.7 million ha receiving less than 450 mm annual rainfall) and semi-arid region. Despite huge investments on irrigation in the past and projections for the future, the country cannot irrigate more than half of its

Table 2. Degraded land areas of India

	Type of degradation	Area under arable land (million ha)	Area under open forest with < 40% canopy (million ha)
1.	Water erosion (> 10 t/ha)	73.27	9.30
2.	Wind erosion (Aeolian)	12.40	-
3.	Physical degradation		
	Mining and industrial wastes	0.19	-
	Permanent surface inundation	0.88	-
4.	Chemical degradation		
	Exclusively salt-affected soils	5.44	-
	Salt-affected and water eroded soils	1.20	0.10
	Exclusively acidic soils (pH < 5.5)	5.09	-
	Acidic (pH < 5.5) and water eroded soils	5.72	7.13
	Total degraded area	104.19	16.53

Source: [15]

cultivated area and the remaining half will continue to be under rainfed agriculture. Negative effects of major irrigation projects on environment due to soil degradation, waterlogging and salinization have often been highlighted. Thus ISM should also give an emphasis on rain water management focusing on maximum retention in the soil profile, groundwater recharge, water harvesting by controlling run-off water alongwith appropriate drainage facility etc. Inclusion of water harvesting alongwith specific amendment materials in the ISM has the great potential of reclaiming problem soils.

5.3 Soil organic matter management

Soil organic carbon (SOC) helps to improve and sustain soil fertility and conserve soil and water quality, and organic carbon compounds play a variety of roles in the nutrient, water, and biological cycles. For the global environment, agricultural systems provide both sources and sinks of greenhouse gases (GHGs), which include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Soil management strategies have a great potential to contribute to carbon sequestration, since the carbon sink capacity of the world's agricultural and degraded soil is 50–66% of the historic carbon loss of 42–72 Pg (1 Pg = 10^{15} g). India needs to devise a strategy for 'C credit trading' in sequestered SOC under the Kyoto Protocol. Soil testing, synchronized fertilization techniques, no-tillage/conservation tillage practices, and optimum water control for flooding paddy fields and promoting aerobic rice, among other things, can reduce GHG emissions. Off-site management of crop/farm residues and other organic wastes has been viewed as a tool for INM and enhancing SOC and thus may be considered as an important component of ISM.

An estimate indicates generation of 679 million tonnes crop residues (~33% available), 375 million tonnes livestock dung (~50% available), 16.5 million tonnes human excreta (~80% available); 70 million tonnes municipal solid wastes (only about 10% recycled presently). More than 2 lakh units of agro-industrial units operating in the country are also generating considerable organic wastes. If crop residues are converted into enriched compost with available animal dung using improved technology, enriched compost generated would be about 121 million tonnes per year. Further, the country has the potential of producing about 10 million tonnes of compost each year from municipal solid wastes which can be used as amendment in an area of about 5 million ha.

5.4 Balanced multi-nutrient fertilization

Application of fertilizers has played a major role in bringing self-sufficiency in food production in the country. Intensive cropping systems remove about 554 to 932 kg of nutrients (N, P, K) per ha per year. However, a large gap of 4 million tonne NPK per annum has been estimated between their removal by crops and external application in Indian Agriculture. Although overall nutrient use ($N:P_2O_5:K_2O$) of 4:2:1 is considered ideal for Indian soils, the present use ratio of 6.8:2.8:1 is far wide. Soils in large area of the country have been found deficient in secondary and micronutrients, particularly S (41%), Zn (49%), and B (33%), although their application through external sources is limited. In order to eliminate/minimize nutrients imbalances, regular soil testing coupled with site-specific nutrient management has to be incorporated into the ISM policy.

5.5 Enhancing input use efficiency

Due to inadequate knowledge about soil and crop requirement, costly inputs like fertilizers, chemicals, water and other inputs go waste, resulting in monetary loss and adverse effect on environment. The current status of nutrient use efficiency is quite low in case of P (15-20%), N (30-50%), S (8-12%), Zn (2-5%), Fe (1-2%) and Cu (1-2%). Efficient fertilizer nutrient management and precision farming can improve the use efficiency of applied fertilizers. Time and again, it has been emphasized the needs for the use of slow release fertilizers and bio-fortification of nutrients.

5.6 Manipulation of soil biota

Several steps in the nutrient cycling processes are mediated by soil microorganisms and are responsible for either enhancing or depleting nutrient availability to plants. Thus manipulation of soil biota and their activities for enhancing nutrient use efficiency can constitute a part of ISM in several situations. Efficient strains of beneficial microbes from soils must be explored, manipulated and exploited for inoculation on massive scale.

5.7 Amelioration of problematic soils

Considerable area of the country faces different kinds of chemical degradation processes like water-logging, acidification, salinisation, alkalinization etc. Salt affected lands in India occupy about 6.73 million ha out of which 3.5 million ha are in canal commands, commonly referred to as man-made or wet deserts. Several technological options available for amelioration of problem soils must be inter-woven.

5.8 Integrated pest management

As weeds take away considerable plant nutrients from soil and affect crop productivity and crop quality, weed management forms an essential component of ISM. Moreover, conventional weed management through herbicide application has always been viewed skeptically as it adversely affects on soil microbial community. Sustainable agriculture requires integrated management of weeds, pests and diseases of crops with minimum chemical inputs. The weeds on community lands may be profitably replaced by grasses, legumes and fodder crops.

5.9 Remediation of contaminated soils

Toxic heavy metals, inorganic compounds and persistent organic pollutants released into the soil leaves considerable impact on soil structure, blocking of pores, chemical environment in the rhizosphere, soil biota, food quality with consequent reduction in crop productivity and animal and human health. Threat from soil contamination by hazardous chemicals must be kept under check so as not to increase in the coming years due to pressure from developmental activities in the country. Several technologies have been developed to decontaminate the soils fully or at least to a level that may not pose threat to environment. Thorough diagnosis and detailed risk assessment are performed for the contaminated site. Based on risk review, ISM options can be selected for minimizing threat to soil quality and to man and animals depending on it.

6.0 MAJOR AGROECOLOGICAL REGIONS OF INDIA

Entire geographical area of the country has been classified into 20 agro-ecological zones (AEZ) on the basis of 'bioclimate', 'length of crop growing period' and 'soil/landscape' for formulating effective land use plan for various regions (Table 3) [adapted from 16].

Table 3. Major soil types under different Agro-Ecological Zones (AEZ) of the country

AEZ No.	Location	Climate type	Soil type
1.	Western Himalayas	Cold arid eco-region	Shallow, loamy skeletal soils
2.	Western Plain, Kachchh and part of Kathiawar Peninsula	Hot arid eco-region	Desert and saline soils
3.	Deccan plateau	Hot arid eco-subregion	Red and black soils
4.	Northern Plain (and Central Highlands) including Aravallis	Hot semi-arid eco-region	Alluvium derived soils
5.	Central (Malwa) Highlands, Gujarat plains and Kathiawar Peninsula	Hot semi-arid eco-region	Medium and deep clayey black soils
6.	Deccan Plateau	Hot semi-arid eco-region	Shallow and medium (dominant) black soils
7.	Deccan Plateau (Telangana) and Eastern Ghats	Hot semi-arid eco-region	Red and black soils
8.	Eastern Ghats and Tamil Nadu Uplands and Deccan (Karnataka) Plateau	Hot semi-arid eco-region	Red loamy soils
9.	Northern Plain	Hot sub-humid (dry) eco-region	Alluvium derived soils
10.	Central Highlands (Malwa and Bundelkhand)	Hot sub-humid (dry) eco-region	Red and black soils
11.	Chattisgarh / Mahanadi Basin	Hot sub-humid (dry) eco-region	Red and yellow soils
12.	Eastern Plateau (Chhotanagpur) and Eastern Ghats	Hot sub-humid eco-region	Red and lateritic soils
13.	Eastern Plain	Hot sub-humid (moist) eco-region	Alluvium derived soils
14.	Western Himalayas	Warm sub-humid (to humid with inclusion of perhumid) eco-region	Brown forest and podzolic soils

Contd...

AEZ No.	Location	Climate type	Soil type
15.	Assam and Bengal Plain	Hot sub-humid (moist) to humid (inclusion of perhumid) eco-region	Alluvium derived soils
16.	Eastern Himalayas	Warm per-humid eco-region	Brown and red hill soils
17.	North-eastern Hills (Purvachal)	Warm per-humid eco-region	Red and lateritic soils
18.	Eastern Coastal Plain	Hot sub-humid to semi-arid eco-region	Coastal alluvium derived soils
19.	Western Ghats and Coastal Plain	Hot humid-perhumid eco-region	Red, lateritic and alluvium derived soils
20.	Islands of Andaman-Nicobar and Lakshadweep	Hot humid to per-humid island eco-region	Red loamy and sandy soils

Source: Adapted from [16]

Besides soil types, ISM is also strongly influenced by availability of water for irrigation (which is in turn dependent on climate) and physiography of land. Therefore, keeping in view major soil types, climatic conditions and physiography of land area, constraints and technological options have been described for contrasting agroecological situations/areas which cover major geographical area of the country (Figure 2 and Table 4).

7.0 RESEARCH AND POLICY NEEDS FOR IMPROVEMENT, SUSTENANCE AND PROTECTION OF SOIL RESOURCES

7.1 Research needs

(a) Basic research on water, carbon and nitrogen footprints and their role in soil-crop management with special reference to climate change and climate vulnerability.

(b) Developing efficient techniques of water and nutrient management for their economic use in different agro-ecosystems.

(c) Efficient technologies for utilization of diverse biomass from different sources (agricultural, agro-industrial, municipal etc.) for improving soil productivity under integrated nutrient management and organic farming.

(d) Role of resource conservation agriculture in abiotic and biotic stress management with special reference to climate change.

Fig. 2. Agro-Ecological Regions of India

Source: [16]

Note: Numbers in the different color-shaded area in the map represent area under respective AEZ No.

Table 4. Constraints and technological options for major soil and agroecological situations of India

Constraints	Technological options
1. Integrated soil and water management in Vertisols and associated soils in central India (AEZ/ESR*: 10, 6, 5.1, 5.2)	
◆ Soil swells and shrinks, formation of large cracks, increased surface area for evaporation ◆ Narrow soil moisture range for tillage ◆ Low terminal infiltration rate – waterlogging ◆ Development of salinity and alkalinity associated with low rainfall ◆ Moderate to severe soil erosion ◆ Low to medium organic matter and available nutrients (N, P and Zn)	◆ Conservation of soil moisture - mulching ◆ Site-specific cropping system matching with availability of soil water ◆ Adoption of soil conservation measures according to slope of land ◆ Raised and sunken bed in waterlogged areas ◆ Site Specific Nutrient Management and balanced nutrition ◆ Enhancing soil organic matter status – reduced tillage & crop residue recycling
2. Integrated soil and water management in north-west Himalayan region (AEZ: 14)	
◆ Severe soil erosion (>40 t/ha/yr in 43% area and > 10 t/ha/yr in 64% area) ◆ Limited water availability - assured irrigation hardly in 10% area ◆ Shallow soil depth ◆ Steep slope and undulating topography ◆ High acidity, deficient in P ◆ Small and fragmented holdings	◆ Lime application in acid soils ◆ Soil test based nutrient application ◆ Participatory integrated watershed management ◆ Rain water harvesting to improve productivity of rainfed lands ◆ Crop diversification ◆ Reducing soil erosion - agronomical and engineering measures ◆ Integrated farming system comprising of poultry, fishery, piggery and crop production

Contd...

Contd...

Constraints	Technological options
3. Integrated management of salt affected soils (AEZ/ESR: 4.1, 4.3, 9.1)	
Salinity related constraints ◆ Toxicity of Na, Cl and B ◆ Reduced availability of water to plants ◆ Accelerated soil erosion due to poor vegetation cover	**Management of waterlogged saline soils** ◆ Sub-surface drainage ◆ Disposal of drainage effluent ◆ Analytical & numerical models ◆ Package of practices for saline soils
Sodicity related constraints ◆ Poor soil physical properties ◆ Low infiltration resulting in water stagnation ◆ Accelerated soil erosion due to deflocculated clay particles	**Alkali soils reclamation** ◆ Making 30 cm high bunds to ensure rainwater storage and uniform distribution of irrigation water ◆ Uniform gypsum application in upper 10 cm depth ◆ Ponding of water for a minimum of one week before transplanting of rice ◆ Crop improvement for salt stress situations ◆ Multiple use of water for multi-enterprize agriculture
4. Integrated soil and water management in Indo-Gangetic alluvial plains (AEZ/ESR: 13, 9.2, 15)	
◆ Stagnant or negative growth rates of crop productivity ◆ Multi-nutrient deficiencies ◆ Decline in factor productivity ◆ Greater NO_3-N leaching beyond root zone ◆ Receding groundwater table ◆ Sub-surface soil compaction, leading to poor crop establishment of wheat	◆ Enhancement and maintenance of soil organic matter ◆ Integrated and site-specific plant nutrient supply for sustaining soil fertility and restricting emerging multi-nutrient deficiencies ◆ Crop residue management ◆ Inclusion of legumes in cropping system and green manuring ◆ Correcting multiple micronutrient deficiencies

Contd...

Contd...

Constraints	Technological options
5. Integrated soil and water management in North-Eastern India (AEZ/ESR: 16, 17)	
◆ Land degradation ◆ Shifting cultivation on hill slopes ◆ Soil erosion and run-off losses ◆ Soil acidification ◆ Soil Compaction and Crusting ◆ Iron toxicity, ◆ Low S and Zn availability ◆ Leaching of nutrients (NO_3^-, SO_4^{2-}) ◆ Rainfed agriculture (lack of irrigation facilities) ◆ Moisture stress (during rabi season)	◆ Liming to correct soil acidity ◆ Bio resource recycling ◆ Conservation of rainwater and diversified use of conserved rainwater ◆ Soil conservation measures ◆ Discouraging shifting cultivation ◆ Crop diversification based on slope of land ◆ Correction of multiple nutrient deficiencies
6. Integrated soil-water management for coastal regions (AEZ/ESR: 18, 19, 5.3)	
◆ Excess accumulation of soluble salts in soil ◆ Pre-dominance of acid sulphate soils ◆ Intrusion of seawater into coastal aquifers ◆ High depth to underground water table rich in salts ◆ Periodic inundation of soil surface by the tidal water vis-à-vis climatic disaster and their influence on soil properties ◆ Heavy soil texture and poor infiltrability of soil ◆ Eutrophication, hypoxia and nutrient imbalance ◆ Erosion and sedimentation of soil	◆ Budgeting of water resources and optimizing crop water productivity ◆ Checking intrusion of seawater into agricultural land ◆ Rainwater harvesting, conservation and utilization ◆ Growing salt tolerant crops and varieties ◆ Improved water management in acid sulphate soils and coastal alluvial soils ◆ Efficient organic resource utilization ◆ Diversified farming

Contd...

Contd...

Constraints	Technological options
7. Integrated soil-water management for arid region (AEZ/ESR: 2)	
◆ Sandy soil with low water holding capacity ◆ High evapotranspiration ◆ Poor soil fertility ◆ Severe wind erosion ◆ Salinization ◆ High biotic pressure – over grazing ◆ Over exploitation of land and water resources	◆ Wind break-vegetative barrier, compaction ◆ Stabilization of sand dunes ◆ Gully control structures ◆ Soil moisture conservation - Stubble & grass mulching ◆ Micro-catchment for tree establishment ◆ Stream flow water harvesting ◆ Conservative irrigation practices- drip, sprinkler ◆ Crop diversification
8. Integrated management of red, laterite and lateritic soils in plateau region (AEZ/ESR: 3, 7, 8, 11, 12)	
◆ Soil acidity ◆ Poor soil fertility, especially Ca, Mg ◆ Poor SOM status ◆ Low CEC ◆ Soil becomes very hard upon drying ◆ Limited root penetrability ◆ Severe soil erosion	◆ Lime application in acid soils ◆ Organic manure application ◆ Green manuring, introduction of legume in cropping systems ◆ Appropriate soil conservation measures based on slope of land ◆ Improved management of P and K for sustainable production

Source: [compiled from the discussion and presentations made at the Brainstorming Session]

Note: Number in the left hand side of decimal indicates Agro-ecological zone (AEZ) number and number in the right hand side of decimal indicates Ecological sub-region (ESR).

(e) Identifying and characterizing the functions of microbes both as individuals and as consortia in soil and water in regulating different soil functions and their interaction with plants.

(f) Soil quality assessment, developing soil quality index and periodic monitoring through identification of minimum data set under different agroecosystems.

(g) Understanding the underlying causes for declining factor productivity of fertilizer nutrients, particularly in intensively cultivated Indo-Gangetic alluvial plain and developing remedial measures.

(h) Research on soil-plant-animal/human continuum in different agroclimatic zones with reference to heavy metals and other pollutants to assess the extent of pollution and for safeguarding the animal and human health.

(i) Developing models for predicting the impact on soil quality under different climate change scenarios.

(j) Development of improved and economical technologies for reclamation of waterlogged sodic soils.

7.2 Policy needs

a. A web portal for National NRM Systems

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.

b. National roadmap for assessment of soil quality

A national roadmap for revamping the existing soil testing laboratories, including mobile laboratories for efficient, rapid and reliable soil quality assessment and linked to soil test based site-specific recommendations to the farmers may be formulated.

c. Establishment of a national database centre for monitoring the soil quality

A national database centre with real-time dynamic access preferably at the Indian Institute of Soil Science, Bhopal, may be created to enable access to soil health data by the stakeholders. This centre may be linked to all research institutions and various soil testing laboratories. Requisite search engines and robust online platform for data acquisition, storage and retrieval may be in-built within this architecture.

d. National Network on carbon credit and carbon sequestration

Soil organic matter content is essential in the maintenance of soil health and quality. Under the Kyoto Protocol, C sequestered in soil qualifies for the inclusion in C accounting process (Article 3.4) with subsequent benefit of C credit. Inclusion of soil C sequestration for accounting purpose requires authentic database for independent assessment and verification. Thus there is need to generate verifiable soil baseline data for SOC under agroforestry, grass land 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 crop residues, various forms of composts, urban wastes etc. may be created.

e. Need for effective land use policy

An effective land use policy needs to be evolved by each State Government to facilitate earmarking of areas not suitable for farming because of their limitations of ecologically fragile nature, and therefore can alternatively be used for agroforestry/ forestry/ range lands. Delineation of prime agriculture land is a must, so that the best agricultural land should not be diverted for non-agricultural purposes for which inter-ministerial dialogue at central level is needed to devise an effective land use policy regarding the use of fertile lands.

f. Adoption of measures to protect fertile soil from chemical, biological and physical pressures

National-level soil protection policy may be formulated to regulate the entry of pollutants to soil from gas-dust releases from power plants, metal smelting, the burning of raw materials for cement; heavy metals from fertilizers, pesticides and industrial effluents; salts and heavy metals from contaminated surface water and groundwater. The policy framework regulations must be binding to all enterprises and government agencies engaged in profession and services affecting soil environment.

g. Remediation of degraded, problematic and polluted soils

Physically and chemically degraded soils pose risks to all strata of organisms including humans, livestock and crops and hence, must not be left untreated. Financial considerations in particular make it difficult to carry out remediation of eroded soils, soils affected with salinity, sodicity, acidity, and contaminated soils. A Land Reclamation Board may be set-up to facilitate monitoring of programmes related to reclamation of above soils by mobilizing necessary resources and agencies. The Board may also initiate proactive measures from preventing risks from pollution.

h. Promoting balanced nutrition of crops

Fertilizer policy needs to be oriented towards ensuring balanced nutrition to major crops through nutrient based subsidy, micro-nutrient fortified major fertilizers and soil test based site-specific nutrient management. The Government may also provide subsidy to soil amendments including mineral and byproduct sources for reclaiming sodic and acidic soils.

i. Creation of awareness among all strata of public about the crucial role of soil in the ecosystem and its vulnerability

Schools, institutions and organizations that provide training and education for people may be strengthened with requisite learning resources for creation of awareness about soil health and quality. A nodal institution at national level may be identified and assigned responsibility for developing a framework and resource materials towards this objective.

REFERENCES

1. Bhattacharyya, T., Sarkar, D., Sehgal, J.L., Velaytham, M., Gajbhiye, K.S. and Nagar, A.P. 2009. Nimkhedkar, S.S. Soil Taxonomic Database of India and States (1:250,000 scale), NBSS & LUP Pub. No. 143, 266 p.

2. NBSS&LUP. 2002. *Soils of India*. NBSS Pub. 94 (2002). National Bureau of Soil Survey and Land Use Planning, Nagpur, India, pp. 130 + 11 sheets maps.

3. Manna, M.C., Swarup, A., Wanjari, R.H., Ravankar, H.N., Mishra, B., Saha, M.N., Singh, Y.V., Sahi, D.K. and Sarap, P.A. 2005. Long-term effect of fertilizer and manure application on soil organic carbon storage, soil quality and yield sustainability under sub-humid and semi-arid tropical India. *Field Crops Research*, **93**: 264-280.

4. Littleboy, M., Cogle, A.L., Smith, G.D., Rao, K.P.C. and Yule, D.F. 1996. Soil management and production of alfisols in the semi-arid tropics. IV. Simulation of decline in productivity caused by soil erosion. *Australian Journal of Soil Research*, **34**: 127-138.

5. Bhandari, A.L., Ladha, J.K., Pathak, H., Padre, A.T., Dawe, D. and Gupta, R.K. 2002. Yield and Soil Nutrient Changes in a Long-Term Rice-Wheat Rotation in India. *Soil Science Society of America Journal*, **66**: 162-170.

6. Fragoso, C., Brown, G.G., Patrón, J.C., Blanchart, E., Lavelle, P., Pashanasi, B., Senapati, B., Kumar, T. 1997. Agricultural intensification, soil biodiversity and agroecosystem function in the tropics: the role of earthworms. *Applied Soil Ecology*, **6**: 17-35.

7. Panwar, N.R., Saha, J.K., Adhikari, T., Kundu, S., Biswas, A.K., Rathore, A., Ramana, S., Srivastava, S. and Subba Rao, A. 2010. Soil and water pollution in India: Some case studies. *IISS Technical Bulletin*, Indian Institute of Soil Science, Bhopal. p. 40.

8. Biswas, A.K., Maji, B., Srivastava, S. and Subba Rao, A. 2010. Indian fertilizer scene and environmental quality. In *Proceedings of the National Seminar on Fertilizers and Environment* (Eds. HS Sen and Kunal Ghosh), 23 June 2010. University of Calcutta, Kolkata. pp. 9-12.

9. Saha J.K. 2005. Changes in Salinity and Sodicity of Soils with continuous application of contaminated water near Industrial area. *Journal of Indian Society of Soil Science*, **53**: 612-617.

10. Aulakh, M.S. and Benbi, D.K. 2008. Enhancing fertilizer use efficiency. In *Proceedings of FAI Annual Seminar 2008*, 4-6 December, 2008. The Fertilizer Association of India, New Delhi, India. pp. SII-4 (1-23).

11. Subba Rao, A. and Reddy, K.S. 2009. Implications of soil fertility to meet future demand: Indian scenario. In *Proceedings of the IPI-OUAT-IPNI International Symposium on Potassium Role and Benefits in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damages, Vol. 1* (Eds. MS Brar and SS Mukhopadhyay), 5-7 November 2009. IPI, Horgen, Switzerland and IPNI, Norcross, USA. pp. 109-135.

12. Lal, R. 2000. Soil management in the developing countries. *Soil Science* **165**: 57-72.

13. Naseby, D.C. and Lynch, J.M. 1997. Rhizosphere soil enzymes as indicators of perturbations caused by enzyme substrate addition and inoculation of a genetically modified strain of *Pseudomonas fluorescens* on wheat seed. *Soil Biology and Biochemistry*, **29**: 1353-1362.

14. Yamamoto-Tamura, K., Ohno, M., Fuji, T., Kataoka, S., Numata, S., Nakajima, M., Hasebe and Akutsu, K. 2011. Assessment of the effects of genetically modified *Pseudomonas* spp. expressing chitinase on the soil microbial community in the cucumber rhizosphere. *Japan Agricultural Research Quarterly*, **45**: 377-383.

15. Degraded and wastelands of India: Status and spatial distribution. 2010. National Academy of Agricultural Sciences, ICAR, New Delhi.

16. Sehgal, J., Mandal, D.K., Mandal, C., Vadivelu, S. 1992. Agro-Ecological Regions of India (2nd Edition), Tech. Bull. Publ.. 24. NBSS&LUP, Nagpur, India. 130 p.

LIST OF PARTICIPANTS

1. Dr C.L. Acharya, Ex-Director, IISS, House No.28, Nagarkot Colony, Thakurdwara, P.O. Maranda, Palampur, H.P.
2. Dr Anwar Alam, Secretary National Academy of Agricultural Sciences, New Delhi.
3. Dr K.K. Bandyopadhyay, Principal Scientist, Division of Agricultural Physics, Indian Agricultural Research Institute (IARI), Pusa, New Delhi.
4. Dr D.K. Benbi, ICAR National Professor, Deptt. of Soils, Punjab Agricultural University, Ludhiana, Punjab.
5. Dr P.K. Chhonkar, A-3, Shaman Apartments, Plot 9, Sector 23, Dwarka, New Delhi.
6. Dr S.K. Chaudhari, Head (Soil & Crop Mgt), Central Soil Salinity Research Institute (CSSRI), Kachawa Road, Karnal.
7. Dr J.C. Dagar, ADG (Agronomy), ICAR, KAB-II, Pusa, New Delhi.
8. Dr B.S. Dwivedi, Head, Divn. of Soil Sci. & Agril. Chem., IARI, New Delhi.
9. Dr P.K. Ghosh, Head, Crop Production Division, Indian Institute of Pulses Research (IIPR), Kalyanpur, Kanpur, U.P.
10. Dr G.P. Juyal, Head, Hydrology & Engineering Division, Central Soil & Water Conservation Research & Training Institute, 218, Kaulagarh Road, Dehradun, Uttarakhand.
11. Dr Himanshu Pathak, Sr. Scientist, Divn. of Environmental Sciences, IARI, New Delhi.
12. Dr Rajendra Prasad, C-309, Vardhman Appartments, Mayur Vihar Extension, Phase I, New Delhi.
13. Dr A. Subba Rao, Director, Indian Institute of Soil Science (IISS), Bhopal, M.P.
14. Dr Ch. Srinivasa Rao, Principal Scientist, Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, A.P.
15. Dr D.L.N. Rao, Network Coordinator (BF), Indian Institute of Soil Science, Nabi Bagh, Berasia Road, Bhopal, M.P.
16. Dr E.V.S. Prakasha Rao, Central Institute of Medicinal & Aromatic Plants, Research Centre, Allalasandra, GKVK Post, Bangalore, Karnataka.

17. Dr M.M. Roy, Director, Central Arid Zone Research Institute, Jodhpur, Rajasthan.
18. Dr J.K. Saha, Principal Scientist, Indian Institute of Soil Science, Nabi Bagh, Berasia Road, Bhopal, M.P.
19. Dr H.S. Sen, 2/74, Naktala, Kolkata.
20. Dr P.K. Sharma, Dean, College of Agriculture, CSK Himachal Pradesh Krishi Viswavidyalaya, Palampur, H.P.
21. Dr A.K. Singh, DDG (NRM), ICAR, KAB-II, Pusa, New Delhi.
22. Dr V.K. Singh, ICAR National Fellow, Project Directorate of Farming System Research (PDFSR), Modipuram, Meerut, U.P.
23. Dr S.P. Wani, Principal Scientist (Watersheds) and Project Coordinator (IWMP), ICRISAT, Patancheru, A.P.

NAAS Documents on Policy Issues*

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
6.	Reorienting Land Grant System of Agricultural Education in India	- 1999
7.	Diversification of Agriculture for Human Nutrition	- 2001
8.	Sustainable Fisheries and Aquaculture for Nutritional Security	- 2001
9.	Strategies for Agricultural Research in the North-East	- 2001
10.	Globalization of Agriculture: R & D in India	- 2001
11.	Empowerment of Women in Agriculture	- 2001
12.	Sanitary and Phytosanitary Agreement of the World Trade Organization Advantage India	- 2001
13.	Hi-Tech Horticulture in India	- 2001
14.	Conservation and Management of Genetic Resources of Livestock	- 2001
15.	Prioritization of Agricultural Research	- 2001
16.	Agriculture-Industry Interface: Value Added Farm Products	- 2002
17.	Scientists' Views on Good Governance of An Agricultural Research Organization	- 2002
18.	Agricultural Policy: Redesigning R & D to Achieve It's Objectives	- 2002
19.	Intellectual Property Rights in Agriculture	- 2003
20.	Dichotomy Between Grain Surplus and Widespread Endemic Hunger	- 2003
21.	Priorities of Research and Human Resource Development in Fisheries Biotechnology	- 2003
22.	Seaweed Cultivation and Utilization	- 2003
23.	Export Potential of Dairy Products	- 2003
24.	Biosafety of Transgenic Rice	- 2003
25.	Stakeholders' Perceptions On Employment Oriented Agricultural Education	- 2004
26.	Peri-Urban Vegetable Cultivation in the NCR Delhi	- 2004
27.	Disaster Management in Agriculture	- 2004
28.	Impact of Inter River Basin Linkages on Fisheries	- 2004
29.	Transgenic Crops and Biosafety Issues Related to Their Commercialization in India	- 2004
30.	Organic Farming: Approaches and Possibilities in the Context of Indian Agriculture	- 2005
31.	Redefining Agricultural Education and Extension System in Changed Scenario	- 2005
32.	Emerging Issues in Water Management The Question of Ownership	- 2005
33.	Policy Options for Efficient Nitrogen Use	- 2005
34.	Guidelines for Improving the Quality of Indian Journals & Professional Societies in Agriculture and Allied Sciences	- 2006
35.	Low and Declining Crop Response to Fertilizers	- 2006
36.	Belowground Biodiversity in Relation to Cropping Systems	- 2006
37.	Employment Opportunities in Farm and Non-Farm Sectors Through Technological Interventions with Emphasis on Primary Value Addition	- 2006
38.	WTO and Indian Agriculture: Implications for Policy and R&D	- 2006
39.	Innovations in Rural Institutions: Driver for Agricultural Prosperity	- 2007
40.	High Value Agriculture in India: Prospects and Policies	- 2008
41.	Sustainable Energy for Rural India	- 2008
42.	Crop Response and Nutrient Ratio	- 2009
43.	Antibiotics in Manure and Soil A Grave Threat to Human and Animal Health	- 2010
44.	Plant Quarantine including Internal Quarantine Strategies in View of Onslaught of Diseases and Insect Pests	- 2010
45.	Agrochemicals Management: Issues and Strategies	- 2010
46.	Veterinary Vaccines and Diagnostics	- 2010
47.	Protected Agriculture in North-West Himalayas	- 2010
48.	Exploring Untapped Potential of Acid Soils of India	- 2010
49.	Agricultural Waste Management	- 2010
50.	Drought Preparedness and Mitigation	- 2011
51.	Carrying Capacity of Indian Agriculture	- 2011
52.	Biosafety Assurance for GM food Crops in India	- 2011
53.	Ecolabelling and Certification in Capture Fisheries and Aquaculture	- 2012
54.	Integration of Millets in Fortified Foods	- 2012
55.	Fighting Child Malnutrition	- 2012

***For details visit web site: http://www.naasindia.org**