Draft copy

On

National Soil and Land Use Policy- for serving farmers and safeguarding Agriculture

National Soil and Land Use Policy – for Serving Farmers and Safeguarding Agriculture

About the Policy Document:

The National Academy of Agricultural Sciences (NAAS) as per their letter No. NAAS/VI.70 (ii)/18/87 dated July 10, 2018 constituted the Core Group, for preparing a National Soil and Land Use Policy at the behest of the Ministry of Agriculture and farmers Welfare, Govt. of India.

The Core Group had four regional consultation meetings with Agricultural Scientists from NARS, representatives from line departments and progressive farmers at Bengaluru, Kolkata, Bhopal and New Delhi. This report is an outcome of these consultations and the deliberations of this Core Group on this subject.

Out of the geographical area of 329 million hectares, the current level of net sown area in India is about 140±2 million hectares, which was only 119 million hectares in 1950-51. In view of the multiple and competing requirements of the land for developmental needs of other sectors of economic growth, further scope of increasing the area under cultivation in future to meet the growing needs of food grains and other agricultural commodities is limited and negligible.

In the agricultural sector, the number of operational farm holdings increased from 71 million to 138 million from the period 1970-71 to 2010-11, due to fragmentation of farm lands. During 2010-11, the share of marginal (<1 ha) and small (1-2 ha) farm holdings to the total number of holdings was of the order of 85 per cent. The per capita availability of land has decreased from 0.91 ha in 1951 to 0.19 ha in 2001, and is expected to be only 0.15 ha by 2050.

The population of the country which was 361 million in 1950-51 has reached 1358 million (estimated) in 2018, and is expected to stabilize between 1680 and 1700 million by 2050.

It is estimated that the extent of land degradation of various kinds (erosion, physical, chemical, fertility depletion, waste lands etc.) is about 36 per cent (120 m ha) of the geographical area of the country. Combating land degradation and fragmentation of land holdings, protecting the top soil from erosion, building-up and maintaining soil fertility and adoption of best and sustainable farm practices in land, crop and water management are the only crucial pathways for sustainable agriculture, food and nutritional security and evergreen revolution.

A sound National Soil and Land Use Policy and land care practices are basic and fundamental to enduring and sustainable agriculture.

The proposed National Soil and Land Use Policy framework envisages that the crop, land and water management are carried out in the best possible scientific manner without any adverse effects/impacts, so that their inherent use potential is handed over undiminished to the posterity. The ultimate goal is "Greening India", of farm lands, grazing lands, pastures and non-arable urban lands leading to sustainable land use systems and environment security.

To achieve this vision and sustain its goal, recommendations in the areas of policy measures, structural reforms, operational interventions and regulations are made for initiating and strengthening appropriate action programmes by all the stakeholders.

M. Velayutham
Chairman

A. K. Singh
Member

D. M. Hegde
Member

V. Ramamurthy
Member

B. S. Dwivedi
Member Secretary

Acknowledgement

The Chairman and members of the Core Group are grateful to the president of the National Academy of Agricultural Sciences, Dr. Panjab Singh for constituting and assigning the task/role of formulating a " National Soil and Land Use Policy", at the behest of the Ministry of Agriculture and Farmer welfare Govt. of India .

The Core Group benefitted from the contribution and participation by a large number of scientists of NARS, line departments of the states and the central Governments and progressive farmers during the regional consultation meetings held at Bengaluru, Kolkota, Bhopal and New Delhi. We are thankful to all of them for their inputs and active discussion on the above theme during the consultations.

We thank the Director, NBSS&LUP, Dr. S.K.Singh and Heads of the Regional centre, Bengaluru and Kolkata and Dr.K.K.Singh, Director, ICAR-Central Institute of Agricultural Engineering, Bhopal for providing us all the facilities for the Core Group meetings held at the Bengaluru, Kolkata and at Bhopal. Special thanks to Dr. Rajendra Hegde, Head, ICAR-NBSS&LUP Regional Centre, Bengaluru for providing all the facilities for the Core Group meetings held during the period of the preparation of draft policy document.

The help provided by the staff of the Secretariat, NAAS, New Delhi is gratefully acknowledged.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

National Soil and Land Use Policy- for serving farmers and safeguarding Agriculture

1.0 INTRODUCTION

Geographically India is the seventh largest country in the world with 328.73 m ha land area. In 2011, India's population reached 121 crore, about 17 % of the world population while the net sown area was about 140 m ha in 2014-15, about 0.12 ha per capita, and just half of the world average of 0.23 ha (GoI, 2015). This problem of limited availability of land has been compounded by growth in population, urbanisation and diversion of productive agricultural land for non-agriculture purposes. During the last two decades, India's population has increased by about 18.4 crores, while the total agricultural land has decreased by about 3.2 m ha. According to the recent Land Use Statistics of the Ministry of Agriculture, Government of India, a total agricultural land of nearly 3.16 m ha (1.5 lakh ha/ year) was lost to other sectors in the years between Triennium Ending (TE) 1991-92 and TE 2012-13 (GoI, 2015). On the other hand, area under non-agricultural uses has increased by over five m ha (21.3 m ha to 26.4 m ha) during the same period.

With increasing urbanization, industrialization with focus on **Make in India** and need for creation of infrastructure such as roads, railways, irrigation, there is no doubt that these developments will continue to have positive impact on the Indian economy. One of the consequences is that these initiatives require more land and there is a general fear that it might encroach upon agricultural land, particularly the fertile lands in both rural and urban areas. Hence, the conflict between declining availability of agricultural land and population increase, as well as more requirement of land for industrial and infrastructure development has assumed conflict of interest among different sectors of national development. However, the issue has become more complex due to widely varied perceptions about the extent of diversion of agricultural land and the causes and socio-economic consequences of loss of agricultural land. In recent times, it is a common perception that large-scale diversion of agricultural land to non-agricultural uses has occurred and the issue of acquisition of large tracts of fertile lands for such purposes has become a major socio-economic issue.

India has been experiencing rapid urbanization over the last few decades, which accelerated during the last decade (GoI, 2011). In 1981, the proportion of urban population in the country was 23.4 %, which marginally increased and reached 25.7 % in 1991 and 27.8 % in 2001 (4.4% increase). However, between 2001 and 2011, the proportion of urban population increased from 27.8 % to 31.2 % (an increase of 3.4%). In order to give a boost to manufacturing, increase exports and create employment opportunities, government announced Special Economic Zone (SEZ) policy in April 2000 and Special Economic Zones Act. 2005 was passed by the Parliament in 2005. After SEZ Act in 2005, 491 formal approvals have been granted for setting up of SEZs, out of which 352 have been notified and are at various stages of operations. About 56,067 ha land has been acquired for formally approved SEZs in the country as on December 31, 2014 (GoI, 2015a) with focus on the manufacturing sector.

1.1. Land and Soil as Natural Resources

Land as a natural resource is scarce, finite, productive and decisive in determining individual's economic status, social standing, Nation's political strength and key to economic development with social justice. Land is also the focus of conflict between a wide range of land uses including agriculture, mining, forestry, rural and urban civic facilities, industrial development and biosphere protection. Competition among users grows more under increasing population pressure and in countries with a mixed economy. Decision making on land allocation and use options is therefore a current problem of modern societies.

Ever since independence, India's planners and Policy makers have shown concern for efficient use of land, water and other natural resources for accelerated as well as sustainable economic development. The questions of efficiency, equity and environment protection have been flagged in almost all Five Year Plans. However, notwithstanding these concerns, it is often reported that the problems of land degradation, land and water pollution and groundwater depletion have assumed serious proportions in many areas which threaten the sustainability of agriculture, soil health, livelihood system of the people and quality of the environment.

Soil is one of the resources of Earth, on which the human civilization survives. It is a resource of common interest, although mainly private owned, and failure to protect it will undermine sustainability and long term competitiveness of our country in the trade of agricultural raw materials and finished produces and products. Today it is under increasing threat from several anthropogenic activities like intensive agricultural practices, mining, brick making, industrial activities, infrastructure needs, transport and urban development, tourism etc. These activities are damaging the capacity of soil to continue to perform in full in its broad variety of crucial eco-system functions. Moreover, soil degradation has strong impacts on other areas of common interest to the community, such as food and water safety, human health, climate change, and biodiversity protection.

1.2 Population and Food security

India has high population pressure on land and other resources to meet its food and development needs. The natural resource base of land, water and biodiversity is under severe pressure. Food and nutritional security of India is threatened by two issues *viz*., 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-pest and diseases and ultimately resulting in poor health of human beings and permanent loss of good agricultural lands to other sectors. Fast declining factor productivity in major cropping systems and rapidly shrinking resource base pose big challenge to meet the demand of agricultural commodities requirement projected for 2050 (Table 1).

It has been estimated that to meet the diverse demands of the population by 2050 given in table 1, land productivity has to be increased 4 times, water productivity by 3 times and labour productivity by 6 times and all that has to be executed with low carbon emission technology with the smallest of ecological foot prints (Chand, 2012). The shrinking size of farm holdings in India is another major constraint. The land being used for agriculture has to cater not only to provide food and fibre for the human population but also feed and fodder for the 15% of world's livestock population present in India. 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 to name a few.

In India, food production has increased by 400% over the past 65 years, mainly as a result of improving yield outputs due to HYV seeds, adequate fertilizer supplies, improvement of irrigation techniques and extension of irrigable areas, in combination with adapted multi-cropping options and creation of large storage facilities. Per capita food availability has increased from 395 g/day in 1951 to 510 g/day in 1991 and then decreased to 487 g/day in 2016.

India’s population which is 130 million at present, which is expected to stabilize between 1680 and 1700 million by 2050. Currently, India is self-reliant in almost all the major agricultural commodities except oilseeds. The agricultural sector is also the net earner of foreign exchange. By 2050, India needs to step up production of all agricultural commodities by around 30% in food grains and to more than 300% in oilseeds. This increase will be necessitated to meet the needs of increased population and rising living standards. To achieve this higher demand of agricultural commodities, the most suitable strategy seems to be achieved by improvement in productivity, increase in area sown more than once by increasing cropping intensity, preserving potential prime agricultural lands and adoption of best soil and land care management practices. It has been estimated that with present level of productivity, country needs 51 and 57.3 m ha of land for rice in the year 2030 and 2050 and the corresponding area of wheat is projected to be 41 and 50 million hectare. The total area requirement for food grain production in the target year of 2030 and 2050 is estimated to be 151 and 175.6 m ha as per the current scenerio of production. However, by growing of suitable crops in “potential areas” identified for crops and cropping systems based on land evaluation and matching crop and soil suitability and by adoption of best management practices, the country may requires 89 and 103 m ha land area to produce targeted foodgrains for the years 2030 and 2050 respectively. (Mandal *et. al.*, 2001; Naidu *et. al.*, 2017 and Ramamurthy *et al*, 2018)

Table 1. Present production and projected demand for agricultural commodities by 2050

Commodity	Present area (m ha) (2016-17)	Present production (m t) (2016-17)	Projected demand (m t) (2050)
Cereals	98.6	252.7	358.7
Pulses	29.5	22.9	46.3
Food grains	128.1	275.7	405.0
Oilseeds	26.2	32.1	102.1
Sugarcane	4.4	306.7	660.0
Cotton*	10.8	33.1	117
Vegetables	10.3	178.2	342.2
Fruits	6.4	93.0	305.3
Milk	--	163.7	401.4
Meat	--	7.4	13.8
Eggs (billion)	--	87.0	183.9
Fish	--	11.4	22.4

* Seed cotton production

1.3 Vision, Rationale and objectives of National Soil and Land Use policy

1.3.1 Vision Statement: The vision of the National Soil and Land Use Policy (NSLUP) is to ensure food and nutritional security, water security and livelihood security through the adoption of best soil, land, water and crop management practices to achieve the developmental targets and long term use of these resources on a sustainable basis so as to handover the quality of these resources undiminished/improved to the prosterity.

1.3.2. Rationale: The Government of India constituted Commission for Agricultural Costs and Prices (1965), National Commission on Agriculture (1976), National Commission on Cattle (2002) and National Commission on Farmers (2007) to provide meaningful real income levels to farmers, essential agricultural commodities at reasonable prices to the consumers and to suggest ways and means to improve productivity of all sub-sectors of agriculture with inclusive growth of farmers and all regions. In view of the above commission's recommendations, Government of India has formulated a policy framework in the related sectors such as (i) National Water Policy,1987; (ii) National Land Use Policy Outlines, 1988; (iii) National Forest Policy, 1988; (iv) National Livestock Policy Perspective,1996; (v) National Agricultural Policy, 2000; (vi) National Population Policy, 2000; (vii) National Policy for Farmers, 2007; (viii) National Food Security Act, 2013; (ix) National Land Reforms Policy, 2013; (x) National Land Utilization Policy, 2013 (xi) National Nutrition Strategy, 2014, (xii) National Agroforestry Policy, 2014 and accordingly have initiated several mission-mode programmes and special programmes to achieve the stated objectives.

It is urgent and necessary to formulate a "National Soil and Land Use Policy" for the following reasons.

a) To arrest soil and land degradation towards land degradation neutrality
b) For rational allocation of land based on its potentials for different uses
c) For ensuring a viable farm holding size and
d) For ensuring food, nutritional, water and livelihood security

The proposed National Soil and Land Use Policy frame work envisages use of different kinds of lands and soils in different agro-ecosystems based on their potential uses for different purposes like agriculture, inland fisheries, urbanization, infrastructure, ecosystem services, tourism etc. in accordance with the objectives of the Policy in harmony with provisions and implementation of the existing related policies and laws.

1.3.3. Objectives: The objective of the National Soil and Land Use policy is to ensure optimal utilization of the limited land resources in India for achieving sustainable development, addressing social, economic and environmental considerations and to provide framework for states to formulate their respective land utilization policies incorporating state-specific concerns and priorities to achieve both short-term and long-term objectives. Keeping the above in view, the objectives of soil and land use policy cover the following aspects:

- To protect and conserve of natural resources, environment and cultural heritage areas.
- Promote sustainable soil and land use management through improvement of soil health, reclamation of problematic soils and their best utilization.
- To introduce zoning system in order to make demarcation of land and water bodies according to rational criteria for use and management.
- To delineate special agricultural zone/prime agricultural lands/specific commodity zones at state/ region/district level, which should not be diverted to non-agricultural purposes.
- To develop sustainable soil management guidelines to realize the productivity potential of soils put to various types of land uses.
- To prevent soil and water pollution in order to ensure environment friendly land utilization.
- To conserve national forest resources, reduce river erosion and sea erosion in the coastal areas.
- To prevent cutting trees and levelling of hills particularly in hill and mountain ecosystem areas so as to protect fragile environment.
- To propose appropriate legislation for effective implementation of NSLUP recommendations, create awareness of all concerned to the need of conservation and adverse consequences of soil degradation and needs for conservation and control speculative trading of land by the land grabbers.
- To create and improve the capability of national institutions to achieve these aims through awareness, capacity building and large scale on-farm demonstration programmes on improved management of natural resources.

2.0 AGRO-ECOSYSTEMS, LAND, SOIL AND WATER RESOURCES

2.1 Agro-eco systems

The use of land for agriculture and its potential productivity is determined by the agro-ecosystem and its constituent soils and their properties. For ecosystem-based land, soil and water resources and their management for agriculture development, five distinct agro ecosystems which differ from one another in terms of their production potential, are delineated in the country namely (i) Arid agro-ecosystem, (ii) Semi-arid agro-ecosystem, (iii) Sub-humid agro-ecosystem, (iv) Humid-per humid agro-ecosystem and (v) Coastal and island agro-ecosystem.

2.1.1 Arid agro-ecosystem: The hot and cold arid eco-regions occupy an area of about 62 m ha. This ecosystem represents environmental conditions of limited rainfall (10-50 cm) which is less than Potential evapo-tranpiration (PET) almost throughout the year. These soils are commonly referred to as desert soils. The soils are low in organic carbon content, low in nutrient status with generally high pH and calcium carbonate content. The major production constraints are low precipitation and high PET along with adverse physical and chemical properties of the soil and high vulnerability for soil erosion by wind.

2.1.2 Semiarid agro-ecosystem: This ecosystem where rainfed agriculture is practiced covers about 90 m ha. Nearly 67 m ha of rainfed area receives mean annual precipitation in the range of 500-1000 mm. The Length of Growing Period (LGP) ranges from 90 to150 days. This ecosystem is further divided into dry semi-arid with rainfall from 500 to 750 mm with LGP 90 to 120 days and moist semi-arid system with rainfall from 750 to 1000 mm with LGP between 120 to 150 days. Both red and black soils are the two major soil groups occurring in this agro-ecosystem.

2.1.3 Sub-humid agro-ecosystem: The mean annual rainfall in this ecosystem ranges from 1000-1600 mm and LGP ranges from 150 to 240 days. This ecosystem is further divided into dry sub-humid agroecosystem with rainfall from 1000 to 1200 mm with LGP 150 to 180 days and moist sub-humid system with rainfall from 1200-1600 mm with LGP between 180 to 240 days. Alluvial, Tarai, medium deep black, red and yellow soils are dominant in this agro-eco system.

2.1.4 Humid to Per-humid **Agro-ecosystem**: This ecosystem rainfall exceeds PET for most part of the year varying from 1600 to above 2000 mm and LGP ranging from 240 to 330 days. Because of the high rainfall and runoff potential, the catchment areas need to be protected for better control of soil erosion in the downstream. The major soils occurring in the region are brown forest, podzolic soils, loamy to clayey alluvial, red and yellow soils.

2.1.5 Coastal and Island agro-ecosystem: This represents maritime climatic environment covering the vast coastlines in the peninsula with presence of hilly terrain along the coast. The LGP varies from 120 to above 330 days. This ecosystem is very vulnerable for coastal storms, tidal inundation and development of coastal saline soils. However, by prudent policy interventions and regulations, the vast untapped potential of this land mass can provide economic wellbeing for the inhabitants through marine and coastal aquaculture, shelterbelts, mangroves, agro-forestry, integrated farming systems and ecotourism. Alluvium derived soils of the coastal and deltaic plains in eastern coast and red and lateritic soils occur in the west coast.

2.2. Status of Land Resources

The present land use pattern in the country shows that forestry and agriculture are the two major land uses and they occupy 71.8 m ha (21.8 %) and 140 m ha (42.6 %) in the country respectively. Due to the population pressure, which has grown from 36.1 crores in 1951 to 121 crores in 2011, the area under agriculture has increased from 119 m ha in 1950-51 to about 140 m ha in 2014-15 (Table 2). During the same period, the area under forests has increased from 40.5 m ha to 71.8 m ha and area under non-agricultural uses from 9.4 m ha to 26.9 m ha. 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 shows clearly 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, the scope for bringing any additional area under agriculture is very minimal and limited.

This limited land area of our country, which is equal to only 2.4 % of the world's geographical area, supports approximately 17 % of the world's human population and 15 % of the world's livestock population. The population of our country has already crossed one billion mark (1.21 billion as per 2011 census) and is still growing at the rate of about two %. This exponential growth of our population (0.361 billion in 1951 to 1.21 billion in 2011) and dependence of about 60 % of the population for their livelihood on agriculture and allied activities exerts tremendous pressure on the limited land resources of the country.

Table 2. Trends in land use pattern in India ('000 ha)

Year / Land unit	1950-1951	1960-1961	1970-1971	1980-1981	1990-1991	2000-2001	2010-2011	2014-2015
Geographical Area	328726	328726	328726	328726	328726	328726	328726	328726
Forests	40482 (12.3)	54052	63830	67460	67702	69843	71593	71794 (21.8)
Not Available for Cultivation								
Area ,under Non-agricultural, uses	9357 (2.8)	14840	16478	19596	21220	23752	26400	26883 (8.2)
Barren and unculturable Land	38160 (11.6)	35911	28128	19958	19509	17483	17175	16996 (5.1)
Total	**47517**	**50751**	**44606**	**39554**	**40728**	**41235**	**43575**	**43880**
Other Uncultivated Land Excluding Fallow Land								
Permanent Pastures &other Grazing Lands	6675 (2.0)	13966	13261	11989	11406	10528	10305	10258 (3.1)
Land under Misc. Tree Crops & Groves (not incl. In Net Area Sown)	19828 (6.0)	4459	4367	3578	3813	3442	3200	3104 (0.09)
Culturable Waste Land	22943 (7.0)	19212	17500	16744	15000	13520	12647	12469 (3.8)
Total	**49446**	**37637**	**35128**	**32311**	**30219**	**27489**	**26152**	**25832**
Fallow Lands								
Fallow Lands Other than Current Fallows	17445 (5.3)	11180	8728	9720	9663	10513	10323	11092 (3.4)
Current Fallows	10679 (3.2)	11639	10598	14826	13840	15343	14277	15091 (4.6)
Total	**28124**	**22819**	**19326**	**24546**	**23504**	**25856**	**24600**	**26182**
Agricultural Lands								
Net Area Sown	118746 (36.1)	133199	140863	140288	142870	141336	141563	140130 (42.6)
Total Cropped Area	131893 (40.1)	152772	165791	172630	185742	185340	197683	198360 (60.3)
Area Sown More than once	13147 (4.0)	19573	24928	32342	42872	44005	56120	58230 (17.7)
Net irrigated area	20853 (17.6)$	24661	31103	38720	48023	55205	63659	68100 (48.6)$
Gross irrigated area	22563 (17.1)#	27980	38195	49775	63204	76187	88933	95772 (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 increasing human and animal population has reduced the per capita availability of land over the decades. The per capita availability of land has declined from 0.91 ha in 1951 to 0.32 hectare in 2001 and is projected to slide down to 0.23 ha in 2025 and less than 0.19 ha in 2050 (Table 3). 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 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 rising population and resultant fragmentation of farm holdings.

Table 3. Projected land resource and per capita availability

Land resource	**Total maximum (M.ha) 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	-	0.11	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 Agriculture, 2009, NAAS Publication; *2025 and 2050 are projected

2.3. Changes in Land Use Patterns over Time

Significant changes in land use pattern have taken place during seven decades, mainly because of human needs and bio-physical factors. The area under forests and non-agricultural uses increased by 56 and 34.8%, respectively between 1950-51 and 2014-15 and forests account for nearly 21.8 % of the total geographical area. The proportion of area under barren and un-cultivable wasteland, lands under miscellaneous trees, groves etc, cultivable wasteland and permanent fallow lands decreased significantly (44.5%) overtime (Table 4). The net area sown increased from 119 m ha in 1950-51 (36.1 %) to 140 m ha (42.6 %) in 2014-15. This was largely due to extension of cultivation in marginal lands including culturable waste lands and lands under miscellaneous trees, groves etc. During the past several years, nearly 10 m ha of land have been kept permanently fallow.

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 m ha in 1950-51 to 95.8 m ha in 2013-14 coupled with adoption of HYV technology. But the areas under non-agricultural uses are continuously rising. Although the available data do not reveal how much of prime agricultural land has been taken away for non-agriculture purposes, it is often reported that unplanned urbanization around town and cities often lead to conversion of prime agricultural lands for non-agricultural purposes. However, in several states including Andhra Pradesh, Gujarat, Haryana, Karnataka, Maharashtra, Tamil Nadu and West Bengal, there has been a marginal decline in the net area sown. In the states of Gujarat and Odisha, even forest area is reported to have declined (Sharma, 2015).

Table 4. Changes in different categories of land in India, 1950-2014 (000 ha)

Year	**1950-1951**	**2014-2015**	**Change (%) 2014-15 over 1950-51**
Area not available for cultivation	47517	43880	-8.3
Permanent pastures &other grazing lands	6675	10258	53.7
Area under misc. tree crops & groves)	19828	3104	-538.8
Culturable waste land	22943	12469	-84.0
Fallow lands other than current fallows	17445	11092	-57.3
Current fallows	10679	15091	41.3
Net area sown	118746	140130	18.0
Total cropped area	131893	198360	50.4
Area sown more than once	13147	58230	343.0
Net irrigated area	20853	68100	226
Gross irrigated area	22563	95772	324
Cropping intensity (%)	111.1	141.6	27.4

Over the last 65 years, area not available for cultivation declined at the rate of about 8.3%, area under miscellaneous tree, crops and groves by 538.8%, culturable waste lands by 84%, fallow lands other than current fallows by 57.3%, current fallows by 41.3% and arable land by 4.3% (Table 4). The data show that between 1950-51 and 2014-15, the net sown area increased by 18 % (i.e. from 118.75 m ha to 140.1 m ha) which represents an annual average increase about 0.27 %. In case of total arable land, the land area declined from about 189.6 m ha in 1950-51 to about 181.9 m ha in 2014-15, a decline of about 4.3 %. However, total cropped area in the country witnessed an increasing trend during this period. For example, total cropped area increased from 131.9 m ha in 1950-51 to 198.4 m ha in 2014-15. The rate of increase in total cropped area was higher (15.8%) during the 1950-70s compared with other periods mainly due to increase in area under irrigation. The net irrigated area increased by 26% from 1960 to 1970 period and 24% from 1970 to 1990. The gross irrigated area increased from about 22.6 m ha in 1950-51 to 95.8 m ha in 2014-15. The enhanced coverage of irrigation has led to increase in cropping intensity by 27.4 % from 111.1 % in 1950-51 to 141.6 % in 2014-15.

2.4 Land Holdings

Land holding number increased by 48% in five decades from 71 m in 1970-71 to 138 m in 2010-11 (Table 5). Among different land holding sizes, highest number of holdings increased is in marginal category by 61 % followed by small (46%) and semi-medium (23%). Contrary to this, 64% of land holding number decreased in large farmer category and 26% in medium category farmers between 1970-71 and 2010-11. Due to increase in population and fragmentation of land holdings, number of total land holdings increased.

Table 5. Decadal changes in number of operational holdings

Category	**Number of Operational Holdings(In millions)**				
	1970-71	**1980-81**	**1990-91**	**2000-01**	**2010-11**
Marginal (<1 ha)	36.20	50.12	63.39	75.41	92.36
Small (1-2 ha)	13.43	16.07	20.09	22.70	24.71
Semi medium (2-4 ha)	10.68	12.46	13.92	14.02	13.84
Medium (4-10 ha)	7.93	8.07	7.58	6.58	5.86
Large (>10 ha)	2.77	2.17	1.65	1.23	1.00
All size	71.01	88.88	106.64	119.93	137.76

Source: Agricultural Census 2010-11, Dept. Of Agriculture and Cooperation, Ministry of Agriculture, GOI

2.5 Land Degradation

2.5.1. Land degradation due to erosion, physical and chemical degradation: Land degradation is defined as "a process which lowers current and/ potential capability of the land/soils to produce (quantitatively and/or qualitatively) goods and/or provision of services". The degradation of our land resources is taking place at an alarming rate and not all the cultivated lands at present are in prime productivity. The latest estimate of the degraded and wasteland areas of India indicates 36.6% (120 m ha) of the total geographical area of the country. Water erosion is the main problem causing loss of top soil and/or terrain deformation in about 73.3 m ha (representing 25%) of the total geographical area of the country. Wind erosion is dominant in the western region, covering 12.4 m ha (representing 3.8%) of the total area. It causes loss of top soil in 1.9%, terrain deformation in 1.2% and over blowing and shifting of sand dune in 0.5% of the affected area. Water logging and/or areas affected by submergence or flooding cover about 0.88 m ha. The extent of land/soil degradation status in India is given in Table 6.

Table 6. Extent of degraded and wastelands in India

Degradation type	Land area (m ha)	Open forest area (< 40 % canopy) (m ha)
Water erosion (> 10 tonnes/ ha/year)	73.27	9.30
Wind erosion(Aeolian)	12.40	-
Subtotal	**85.67**	**9.30**
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
Sub total	**17.45**	**7.23**
Physical degradation		
Mining and industrial waste	0.19	
Water logging (permanent sea water inundation)	0.88	
Sub total	**1.07**	
Total	**104.19**	**16.53**
Grand total (Arable land and open forest)	**120.72**	

Source: Degraded and Wastelands of India – Status and Spatial Distribution (2010). ICAR & NAAS.

Soil degradation in all its nefarious forms has serious repercussions on crop and biomass productivity. Soil loss tolerance limits (SLTLs) (permissible soil loss) serves as a tool to gauge the potential erosion risk in a given area with regard to long term sustainability (Mandal and

Sharda, 2011). Their analysis has indicated that soil loss tolerance or *T*-value varies from 2.5 to 12.5 t/ha/y depending upon soil quality governing soil resistibility to erosion and depth at a particular location. About 57% area in the country has permissible soil loss of less than 10.0 t/ha/yr, which needs to be treated with appropriate conservation measures. Highest priority needs to be accorded to about 7.5% area where the *T*-value is only 2.5 t/ha/yr due to soil quality constraints. Case study evidences in different watersheds revealed that soil productivity can be maintained at sustainable levels by bringing the erosion rate within tolerance limit.

The gross erosion of the country is estimated as 5.11 ± 0.4 billion t/yr, out of which 34.1 ± 12% of the total eroded soil is deposited in the reservoirs, 22.9 ± 29% is discharged outside the country (mainly to oceans), and the remaining 43.0 ± 41% is displaced within the river basins. The river basins of northern India contribute about 81% of the total sediment yield from landmass while the share of southern river basins is 19% (Sharada and Ojasvi, 2016).

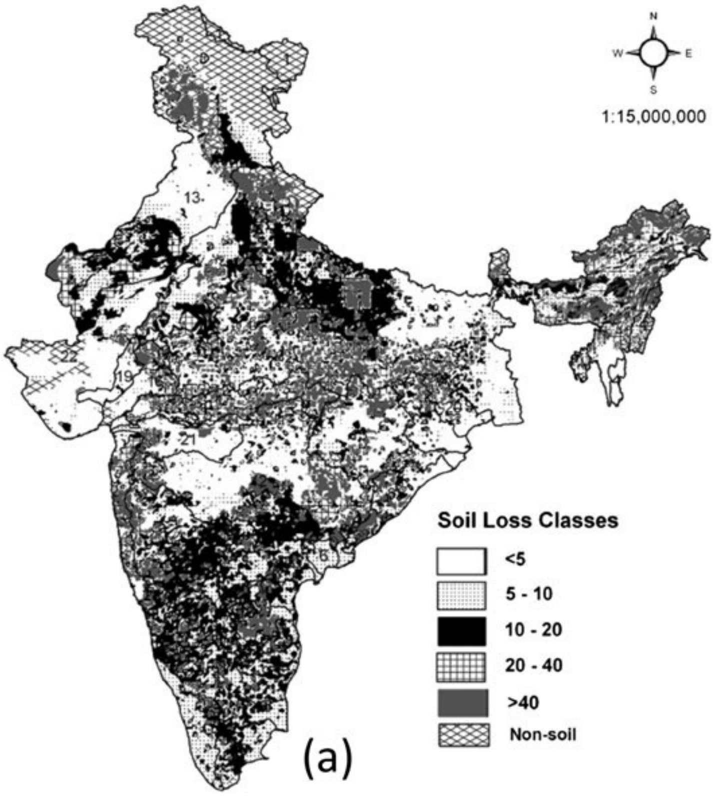

Fig.1. Potential soil erosion map of India (Source: Sharda and Ojasvi, 2016)

The annual economic loss due to degraded land and change in land use in India was valued at Rs 3.17 lakh crores ($46.90 billion) in 2014-15, which was 2.5% of the country's gross domestic product (GDP) in 2014-15 (Ministry of environment and climate change).

The government needs to speed up reclamation as the cost of land degradation will outstrip the cost of reclamation in 2030, according to the 2018 study done by The Energy and Resource Institute (TERI). It is a serious concern, since India aims to be land degradation-neutral in 2030, where any increases in land degradation are balanced by equivalent gains in land reclamation. The cost of land degradation by land type, including agriculture, rangelands and forests is almost 82% and the loss incurred due to land changed from a more to a less productive use is 18% as give in Table 7 by TERI.

Table 7. Economic losses from land degradation and change of land use

Category	**Annual Economic Costs Of Degradation (Rs crore)**	**Loss (As % of GDP)**
Agricultural loss	72331.9	0.58
Loss due to degradation of rangelands	12024.5	0.10
Loss due to forest degradation	175857.4	1.41
Total due to land degradation	260213.8	2.08
Loss due to land use/cover change	57525.2	0.46
Total cost of land degradation and land use change	317739	2.54

Source: The Energy and Resource Institute (TERI); Note: Costs are according to 2014-15 prices

Losses in the agriculture sector caused by land degradation due to water erosion, wind erosion, salinity and loss of vegetation are pegged at Rs 72,000 crore ($10.68 billion). Production losses due to erosion of soil through water are found to be the highest in the agriculture sector.

2.5.2. Soil/Land conservation for arresting water erosion of top soil: Several programmes on soil conservation were initiated by both central and state governments in the past such as**:**

1. Treating catchments of river valley projects
2. Integrated watershed management in catchments of flood prone rivers
3. Control of shifting cultivation
4. Reclamation and development of ravine areas

5. Survey categorization and development of culturable wastelands
6. Drought-prone areas programme
7. Desert development programme
8. Rural landless employment guarantee programme
9. National watershed development programme in rainfed areas (NWDPRA)
10. Soil, water and tree conservation in the Himalayas (Soil watch)
11. Social forestry

Strengthening of the intervention measures for the programmes under the item numbers 4, 5 and 8 are most needed.

Studies at the ICAR-Indian Institute for Soil and Water Conservation Research, Dehradun has shown that by treating 25 % of the catchment area with appropriate soil and water conservation measures, the sediment production rate can be brought down by 50%. Hence the need for people centered watershed development programmes to be taken up on priority in the most vulnerable areas as demarcated in the proness to soil erosion maps of different states brought out by the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) and Indian Institute of Soil and Water Conservation (IISWC).

2.5.3. Land degradation in the north eastern region: The major threats are observed in the destruction of tropical rainforest, dying of wetlands, shrinkage of biodiversity cover, soil erosion and air and water pollution. Though geomorphological erosion on the surface of the earth has been continuously taking place since time immemorial, the soil erosion that is taking place today is an abnormal and undesirable process caused by human activities and neglect of land care. Problem of soil erosion and land degradation in the northeast India is widely visible both in the valleys and in the hills. After the great earth quake that occurred in the region in 1958, the frequency and intensity of siltation and floods have taken a new dimension due to the disturbance and imbalance caused to the river courses and surrounding land mass. There is a vertical and a horizontal increase in river beds and increasing frequency and intensity of floods is the perennial problems of plains of the East and North east. Soil erosion, silt deposition and rising of the river beds level have also been accelerated due to the changes taking place in the hills. Increase in population growth and its ever rising demand for basic necessities for survival as well as for other comforts of life necessitated expansion of *jhum* lands in the hills. Besides settled agriculture in the valleys, industrial growth, road construction, mining, urbanization etc, added to the problem. The decreasing *jhum* cycles, landslides and the hill features have started to take a new and unaesthetic and ecologically unfriendly look.

2.5.4. Land degradation in coastal region: Geomorphic processes of erosion, sediment transport, deposition and sea level changes continuously modify the shoreline. It is also vulnerable to various natural hazards such as cyclones, storms, tsunamis which impact the coast. Coastal habitats, especially wetlands, coral reefs, mangroves, salt marshes, and sea grasses, are rapidly being cleared for urban, industrial, and recreational growth as well as for aquaculture ponds. Wetlands are responsible for maintaining reproductive fisheries not only by way of catch but as feeding, spawning and nursery grounds as well. About 90 % of the world's marine fish catch (measured by weight) is produced in these wetland areas. Thus, degradation of coastal habitats can have long-term consequences for fish populations. Apart from this, they also serve as buffer for the mainland against ocean storms and protect the coast from erosion.

2.5.5. Non-forest public degraded lands: These are not lawfully defined as forests or which have not been legally included in government records. These are registered by different names in the revenue records. Ownership of these lands is vested with the government, such as revenue department, public works department, Railways, etc. These lands may be under the control of the village Panchayat and are meant for common use; no individual can occupy them for private use through encroachment. But, huge area is under this category and needs to be greened.

A National level "Greening India" movement will fit in with new land use policy of converting barren, degraded and non-arable waste lands with planting of herbs, shrubs and trees as required. In this endeavor work force under the MNREGA can be profitably and usefully deployed. The land areas adjacent to vast network of roads and railway lines need to be demarcated and made inclusive under the "Greening of India" programme with PPP mode. Besides there is great scope for involving the rural youth, land less labour.

To give impetus to the "Greening India" Movement, a stream of "National Green Corps (NGC)" by involving students of schools and colleges may be created, similar to NCC/NSS. The students may be incentivized for their participation in this movement.

2.6. Soil Resources

India can be called as a land of Mosaic because of the large variety of soils that the land surface. A girdle of high mountains, snow fields, glaciers and thick forests in the north, seas washing lengthy coasts in the Peninsula, a variety of geological formations, diversified climate, topography and relief have given rise to varied physiographic features. In the country, temperature varies from arctic cold to equatorial hot; rainfall from barely a few centimeters in the arid parts, to per-humid with world's maximum rainfall of several hundred centimeters per annum in some other parts. These conditions provide for a landscape of high plateaus, stumpy relic hills, rolling uplands, shallow open valleys, fertile plains, swampy low lands and dreary barren deserts. Such varied natural environments have resulted in a great variety of soils in India compared to any other country in the world (Bhattacharayya *et.al*., 2013). The major soil groups of India so far recognized are shown in Table 8.

2.6.1. Soil health and its maintenance: Soil health, being a composite index of physical, chemical and biological processes is constantly declining and is often cited as one of the reasons for stagnating or declining crop yields and low input use efficiency. The degradation of soil physical, chemical and biological health along with inadequate and imbalanced nutrient use and neglect of use organic manures is the cause of multi-nutrient deficiencies in many areas over time. Our soils have very low organic matter content. Therefore, without regular application of organic manures and recycling of crop residues, we cannot hope to maintain good soil health to sustain productivity and ensure high responses to NPK fertilizers. With rapid urbanization, the bulky organic wastes are increasing and their disposal and profitable use in agriculture in rural areas is hampered because of transportability and cost constraints. The green manuring practice is seldom followed. This coupled with poor field water management is the major cause of low crop productivity and reduced nutrient and water use efficiency. As such, it poses a great threat to the soil's inherent capacity to sustain productivity for posterity. Maintaining soil health, thus, is indispensable for sustaining the agricultural productivity at the desired level.

Table 8. Soil groups of India and their distribution

S No.	Soil Group	Area ('000 ha)	**Distribution in the States
1	Red loamy	21,327	Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Madhya Pradesh, Odisha, Rajasthan, Telangana
2	Red sandy	33,059	Tamil Nadu, Karnataka, Andhra Pradesh, Telangana, Bihar, West Bengal
3	Laterite	13,007	Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, Odisha, Maharashtra, Goa, Assam, West Bengal, Andaman & Nicobar Islands, Gujarat
4	Red and yellow	40, 365	Madhya Pradesh, Odisha, Bihar
5	Shallow black	3,153	Maharashtra
6	Medium black	43,038	Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh, Telangana, Karnataka, Rajasthan
7	Deep black	11,206	Maharashtra, Andhra Pradesh, Telangana, Karnataka, Madhya Pradesh, Gujarat, Rajasthan
8	Mixed red and black	16,225	Karnataka, Tamil Nadu, Maharashtra, Madhya Pradesh, Andhra Pradesh, Telangana, Bihar
9	Coastal alluvium	5,440	Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, Telangana, Maharashtra, Gujarat, West Bengal, Andaman & Nicobar Islands
10	Coastal sands	453	Odisha, Tamil Nadu, Andhra Pradesh, Telangana, Puducherry
11	Deltaic alluvium	8,704	Tamil Nadu, Andhra Pradesh, Telangana, Odisha, West Bengal
12	Alluvial khadar (recent) bhangar (old)	35, 672	Uttar Pradesh, Punjab, Bihar, West Bengal,Andhra Pradesh, Telangana, Gujarat, Haryana, Jammu & Kashmir, Kerala, Maharashtra, Rajasthan, Delhi
13	Alluvial (highly calcareous)	1,361	Uttar Pradesh, Bihar
14	Calcareous sierozemic	4,508	Punjab, Haryana, Rajasthan
15	Grey brown	10,157	Gujarat, Rajasthan
16	Desert-Regosolic	15,442	Rajasthan, Goa, Haryana
17	Tarai	2,892	Uttar Pradesh, Bihar, West Bengal, Andaman & Nicobar Islands
18	Brown Hill	8,124	Uttar Pradesh, Himachal Pradesh, Jammu & Kashmir, Kerala, Punjab, West Bengal
19	Sub montane (Podzolic)	7,969	Uttar Pradesh, Jammu & Kashmir, Himachal Pradesh
20	Mountain meadow	5,979	Jammu & Kashmir
21	Saline and alkali	1,738	Uttar Pradesh, Haryana, Punjab, Maharashtra, Kerala, Tamil Nadu, Gujarat, Rajasthan
22	Peaty and saline peaty	227	Kerala, West Bengal
23	Skeletal	7,915	Madhya Pradesh
24	Glaciers and eternal snow	2,933	Uttar Pradesh, Jammu & Kashmir

* Adopted from Soils of India by Roy Choudhuri and Govinda Rajan, 1971 and Studies on Soils of India by Govinda Rajan and Gopala Rao, 1978.

Soils of about 59, 36 and 5% area are low, medium, high in available N, respectively. Similarly, soils of about 49, 45 and 6 % area are low, medium and high in available P, respectively; and soils of around 9, 39 and 52% area are low, medium and high in available K, respectively (Chaudhari *et al.*, 2015). Not only the inherent soil fertility is poor and the nutrient input is low but also there is growing evidence of increasing deficiency of phosphorous, potassium and sulphur, aggravated by the disproportionate/imbalanced application of higher doses of N in relation to P and K (Tewatia *et al.*, 2017). The N based fertilizers constitute a major fraction, nearly 70 %, of the total fertilizer material used. There is a growing evidence of increasing responses to S for oilseeds, pulses and legumes and high-yielding cereals. Sulphur and micronutrient status of Indian soils is going down with each passing year. The current gap between annual drain of nutrients from the soil and inputs from external sources is 10 m t, 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. Hence, site-specific sustainable soil nutrient management by following soil test based fertilizer use is necessary for realizing targeted yield (Ramamoorthy,1968).

Our soils are under stress and fatigue. To upgrade the quality and health of our soils, a centralized apex organization mandated with collaborative research for technology generation to address the "Soil health problems" affecting factor productivity and crop productivity in different agro-ecological sub-regions of the country is needed.

2.6.2. Soil and sand quarrying: Beside land degradation due to erosion, physical and chemical degradation, in recent years soil quarrying activities like brick industry and sand from river beds for building construction causes serious damage to agricultural land and river courses. This man made activity causes soil erosion, generates solid wastes, waterlogging and water management problems. All these factors contribute in degradation of the land. Brick industry uses top fertile soil, which is most important for crop production. Most of the brick kilns areas soils are mined up to 3 m. One of the estimates indicate 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 to 90, 000 ha.

Similarly, sand is in high demand in the construction sector. By 2020, 1.4 billion tonnes 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 all around major cities and towns. Sand mining affects agriculture, water infiltration and also leads to environmental problems. These activities have affected local economy drastically, leading to conflicts among rural people and sand mining operators and administrators.

2.6.3. Crop residue burning and inadequate organic manure inputs: According to the Ministry of New and Renewable Energy (2009), ~500 m t of crop residues are generated every year and ~125 m t are burnt. Crop residue generation is greatest in Uttar Pradesh (60 m t) followed by Punjab (51 m t) and Maharashtra (46 m t). Among different crops, cereals generate 352 m t of residues followed by fibre crops (66 m t), oilseeds (29 m t), pulses (13 m t) and sugarcane (12 m t). Rice (34%) and wheat (22%) are the dominant cereals contributing to crop residue generation (NAAS, 2012). Burning of crop residues for cooking, heating or simply disposal is a pervasive problem in India and contributes to soil organic matter (SOM) loss.

2.6.4. Management of salt affected soils: The development of salinity and alkalinity in the soils are mainly due to the introduction of surface irrigation by canal command and associated mismanagement of the system. Topographical situations, poor drainage, use of brackish irrigation waters and surface/subsurface ingress of sea water in the coastal belt are also other causative factors. Salt affected soils occupy around 6.74 m ha (ICAR, 2010). Major concentration is in Punjab, Haryana and Uttar Pradesh. Research work carried out at the Central Soil Salinity Research Institute (CSSRI), Karnal and its large scale adoption through government. supported programmes have ameliorated large areas of salt affected soils of north Indian states. These techniques involve soil application of gypsum /pyrites, conjoint use of surface and ground water of both good quality and brackish water, and suitable choice of crops during the reclamation and post-reclamation periods.

2.6.5. Management of acid soils: The acid soils are formed due to intense weathering, influenced by heavy precipitation (above 1500mm rainfall) and hot and humid climate. They occupy about 30% of the cultivated area of the India. The adverse physical properties met with in acid soils can be managed by appropriate tillage practices and straw mulching on seed lines in row crops. The most common constraints due to chemical properties in these soils are (i) low pH, (ii)low CEC, (iii) nutrient imbalance, (iv) low level of base saturation percentage, (v) high Al, Fe and Mn saturation percentage leading to toxicity, (vi) high P fixing capacity and (vii) clay fraction consisting of rather surface-inactive minerals.

The soil acidity and the associated nutrient availability problems to crops can be reclaimed by use of lime as an integral part of liming activity in the crop production process, using limestone, stromatolitic limestone and dolomite. The north-eastern states have considerable deposits of limestone.

Several industrial wastes such as steel mills slag, blast furnace slag, lime sludge from paper mills, pressmud from sugar mills using carbonate process, cement kiln waste and precipitated $CaCO_3$ from fertilizer factories need to be promoted as amendments for correcting soil acidity. The problem of phosphate fixation and low P fertilizer use efficiency in these soils can be managed by direct use of low grade rock phosphate, use of partially acidulated rock phosphate, mixed use of water soluble P and citrate insoluble P in rock phosphate and combined use of physical mixture of triple super phosphate (TSP) and rock phosphate.

The application of modest dose of limestone and its subsidized promotion is a must component in the integrated nutrient management system (INMS) of acid soils. The practice of liming of acid soils is negligible in contrast to the vastness of the area. Incentives for transport and application of lime in the management of acid soils need to be provided for correction of soil acidity and increasing the productivity of these lands.

2.6.6. Management of calcareous soils: Calcareous soils occur not only in arid and semi-arid but also in humid and perhumid climatic regions of India. Calcareous soils are predominant in the states of Gujarat, Maharashtra, Bihar, Rajasthan, Madhya Pradesh, Uttar Pradesh., Karnataka, Andhra Pradesh, Telangana and Tamil Nadu. Excess lime in calcareous soils is the main constraint for the efficient management of soil fertility and crop growth. The availability of nutrients is limited, posing a serious threat to successful crop production. Low solubility of nutrients and high degree of nutrient fixation may cause nutritional disorders including lime induced iron chlorosis of crops in these soils. Therefore, farmers tend to add extra amount of fertilizers which may result in an imbalanced nutrition. Thus, balanced nutrition is essential for sustaining fertility and productivity of calcareous soils and must form part of special attention in the adoption of package of practices under the National "Soil Health Mission".

It is crucial to recognize that soil health revolution is basic and fundamental to ever green revolution. Hence, the crop production package of farm practices must dovetail adoption of site-specific sustainable soil management practices as advocated by the global Soil partnership guidelines of the FAO.

2.7. Water Resources

India has the very formidable and challenging task of feeding 17.5 % of the world's human population from a meagre 4 % of the global water resources available for its use. In addition to the second largest human population, the country has to also provide feed and fodder to 15% of the world's livestock population from the same quantum of land and water resources.

Water is required by different sectors like agriculture, industry, power, domestic purpose etc. Among the different sectors, irrigation requires maximum amount, it ranges 78% in 2010 and expected to use around 68 % of water for irrigation in 2050 (Table 9).

Table 9. 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); BCM=Billion cubic meter

Water is a finite resource the availability of which is declining with each passing day. If the international yardstick of 1700 cu. m per capita availability per annum of water is taken as a criterion, then the whole country became "Water Stressed" in the year 2007 with per capita water availability declining to 1656 cu. m from 5200 cu. m in 1951 (Table 10). The reported per capita availability of water was 1544 cu m in 2011. It is estimated that the per capita availability of water is likely to reach a level of around 1100 cu. m in 2050 but in reality we may reach this threshold much earlier considering the wasteful ways of water usage at homes and farms. It may be noted that per capita availability of <1000 cu. m indicates "Water Scarcity". If the per capita availability is scrutinized basin-wise, a significant number of basins in the country were either in the "water scarcity zone" or worse even in 2010.

Table 10. Per capita availability of water

Year	Population	Per capita availability (m^3/year)	Remarks
1951	361	5178	
1955	395	4732	
1991	846	2210	
2001	1027	1820	
2011	1211	1544	water stressed#
2015	1326*	1441[$]	water stressed#
2021	1345[a]	1421[$]	water stressed#
2031	1463[a]	1306[$]	water stressed#
2041	1560[a]	1225[$]	water stressed#
2051	1628[a]	1174[$]	water stressed#

Source: Government of India, 2009 (NCIWRD Report, 1999). *projected from 2011 census [a]Population figures for 2021 to 2051 are taken from projected population by Planning Commission. $The per capita availability from 2015 onwards has been calculated from 2017 WRA estimate

2.7.1. Rain water Resource: The normal annual rainfall precipitation in the country is estimated to be 400 million hectare-metres (Mha-m) of water received in just 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 a mere 6 % of the total water available through rain and from flows from outside the country (20 Mha-m). Out of the 215 Mha-m infiltrating into the soil, only 13 Mha-m is utilized for groundwater irrigation and other uses. This again constitutes a mere 6 % of the annual precipitation infiltrating into the soil, indicating the substantial potential for rainwater harvesting.

Table 11. Distribution of area by annual rainfall in India

Rainfall classification	Rainfall (mm)	Approx. area (%)
Low/Dry	<750	30.0
Medium	750 to 1150	42.0
High	1150 to 2000	20.0
Very high/Assured	>2000	8.0
Total		100

Source: IMD, Pune

One of the reasons for the poor utilization of rainwater in India is the high concentration of rainfall over a few months and its uneven distribution. About 74 % of the rainfall is received during the south-west monsoon period of 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 a situation of long dry periods when cropping is difficult if water is not retained or made available in some other way. Only 8 % of the country receives very high/assured rainfall of above 2000 mm, and another 20 % receives high rainfall of 1150 to 2000 mm (Table 9). The rest of the country, that is, 72 %, is in the low, dry, or medium rainfall range of less than 1150 mm, with 30 % area particularly dry at below 750 mm. Thus, in vast areas, groundwater usage is must for crop production and for sustainable use of ground water adequate rainwater recharge is pre-requisite.

2.7.2. Surface water sources: India has developed one of the largest irrigation infrastructures in the world which today stands at more than 68 m ha of net irrigated area (48% of Net sown area (NSA)). It is second only to China. It is no doubt that irrigation development played a very crucial role in ensuring food security to the huge population. However, the productivity of the irrigated production system (occupying 48% NSA area) at around 3 t/ha is considerably lower than the existing potential. A study completed in late 2011 revealed that the gap between the irrigation potential created and utilized in these projects is substantial and growing (Singh, 2014). It is not only the demand – supply mismatch in the major and medium irrigation projects but also the fact that the gap between the irrigation potential created and utilized has been widening continuously and today it stands at more than 25 m ha. Top most priority should be given to bridge this gap considering the fact that the Government of India invests a huge amount on this sector. Major reasons are low water discharge, insufficient water distribution mechanism, unequal water distribution across farmers located at different points, loss of water during distribution, incorrect recording of irrigated area and diversion of cultivable land to other purposes within the command area. The conclusions of a study carried out on 28 major/medium irrigation projects in the country have indicated that the overall water use efficiency was 38% with the conveyance efficiency pegged at 69% and on farm application efficiency at 52% (Singh, 2014). The overall efficiency of surface irrigation systems (around 38 %) implies that at least 60 % of the water supplied is being lost at various stages in the system.

2.7.3. Ground Water Resources: Development of ground water resources which was a low key affair in the earlier stages, is now contributing to more than 60% of the irrigation demand and playing a critical role in ensuring food security in the country. However, it's over exploitation has now become a very serious cause of concern and the potential of judicious exploitation of ground water resources is now confined only to some states in the eastern part of the country. Out of the 6607 assessed blocks, 4530 are safe while the rest are in the semi-critical (697), critical (217) and a large number of over exploited (1071) blocks. By 2025, an estimated 60% of India's groundwater blocks will be in a critical/semi critical/ over-exploited conditions (Fig 2). Almost 54% of the groundwater blocks in Gujarat, Haryana, Maharashtra, Punjab, Rajasthan, and Tamil Nadu are likely to fall in these categories if the present rate of decline trend continues. In view of the seriousness of the problem, the Government is, therefore, putting a lot of emphasis on artificial recharge of ground water.

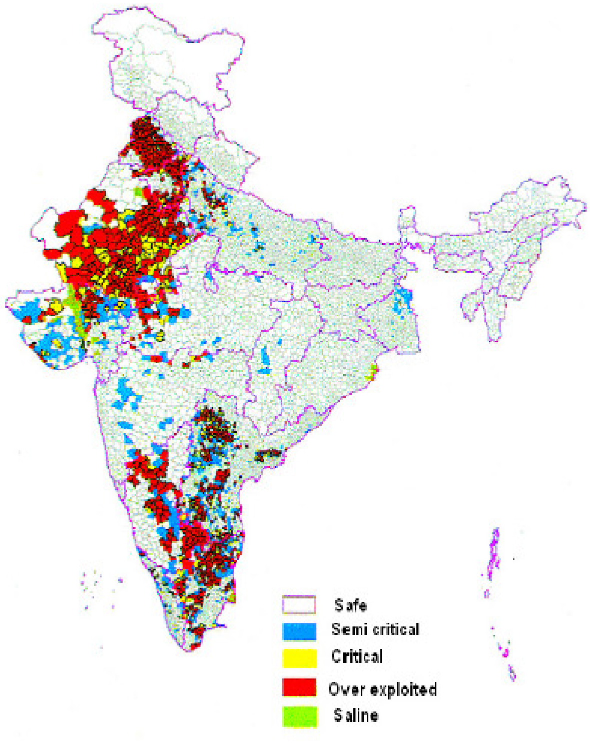

Fig 2. Ground water resource scenario in India

India has the highest ground water abstraction. In fact, India is abstracting more water than USA and China put together. The overall ground water development in the country is 62 % only but the variability within the states is very high. In states like Delhi, Haryana, Punjab, Rajasthan etc, the ground water development is more than 100%. But in states of eastern India and North east, the ground water development is at a low level. Considering this fact, GoI has rightly decided to focus on Eastern India under the programme aptly titled "Bringing Green Revolution to Eastern India" (BGREI).

2.7.4. Waste water, its recycling and utilization: With the projected scenarios of water availability compounded by global warming, increasing urbanization (circa 55% of India's estimated 1.6 billion would be urban by 2050) and industrialization, huge volumes of waste waters will be generated. These waste waters would be of varying qualities depending upon the source, 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% of industrial water and 26% of domestic water is treated in India. Waste waters are being used indiscriminately, particularly in peri-urban agriculture. Considering the size and vast population of the country and various sectoral demands, India is a growing market for "waste water treatment" and its reuse. It includes both sewage treatment and effluent treatment. Currently, 75 % of the rural population and 85 % of the urban population have access to public water supply. However, municipal agencies in many Indian towns and cities are unable to increase their water supply capacities to match population growth, especially in the urban areas. The challenge, thus, is to avoid threatening of our substantial wastewater dependent livelihoods on one hand and on the other hand protect degradation of our valuable natural resources by strict enforcement of regulatory measures for safe disposal of solid and liquid wastes by public-private investment support for low-cost, low-tech, user-friendly methods.

2.7.5. Rainfed agriculture: India has a very sizeable area under rainfed agriculture (nearly 75 m ha) which caters largely to pulses, oilseeds, nutra cereals, cotton and even rice (~45%) but their productivity of them is very low (~1 t/ha). The average annual rainfall in India is 117 cm which is higher than the global average of 110 cm but there is a wide spatial and temporal variation in its distribution and intensity. The ratio of the minimum, average and maximum is of the order of 1:10:100 with the maximum being around 11000 mm in Cherrapunji (Meghalaya) to 100 mm in the Thar Desert. The number of rainy days can vary from 4 days to over 300 days a year and the intensity can vary anywhere from <1 cm/hr up to 15 cm/hr. It has also been estimated that almost

80 % of the rain occurs in only 100 hrs in a year. Soil and nutrients loss due to run off is of the order of 5.34 billion tonnes and 6 million tonnes, respectively, resulting in production losses in excess of Rs. 115 billion (Singh, 2014).

A comprehensive assessment of district level water harvesting potential had revealed that the potential to realize the rainfed agriculture lies in the harvest of small part of available surplus runoff and reutilize it for supplemental irrigation at critical crop growth stages. The study identified about 28.5 m ha of potential rainfed area covering large number of districts in central and eastern India that can generate sufficient runoff (114 BCM) for harvesting and reutilization. It is possible to raise the rainfed crop production by a total of 28-36 m t from an area of 20-25 m ha during normal monsoon years which accounts for about 12% increase over the present productiion level. With adoption of improved technologies, the benefits could be still higher. Extensive area coverage rather than intensive irrigation, needs to be followed in regions with higher than 750 mm/annum rainfall, since there is larger possibility of alleviating the in-season drought spells and ensuring a second crop with limited water application. This component may be made an integral part of the ongoing and new development schemes in the identified rural districts.

2.7.6. Irrigated Agriculture: At present, irrigation consumes about 84 % of total available water. The irrigated area in India was just 22.6 m ha in 1950-51(Patel and Rajput, 2015). With efforts directed toward national food security, irrigation expansion was given due focus and the ultimate irrigation potential of India has been estimated at 140 m ha. Currently the irrigated area in india is around 60 percent. According to Samra and Sharma (2009), India met its irrigation & medium sources (58.5 m ha), minor sources (81.5 m ha) and inter-basin river water transfer (35 m ha). The minor sources comprised 64.1 m ha as ground water and the rest as surface water. Canal irrigation had an important place in agriculture until the 1970s but by the late 1990s, groundwater irrigation became the top source of irrigation in India (Sekhri, 2011). Since 1960, there has been 500 percent increase in groundwater irrigated area (World Bank, 2010). With irrigation predicted to remain the dominant user of water, “per drop more crop” is an imperative. The efficiency of water use must improve to expand area under irrigation while also conserving water. In India, there has been an increase in dependence on groundwater over the last five decades.

One of the main responses to these emerging challenges is to focus on improving water productivity (output per unit of water used/applied for irrigation by crop) in agriculture, as even small improvements could have large implications for local and national water budgets and allocation policies. Sharma *et.al*. (2018) observed that at the present level of water stress existing in the country there is need to re-calibrate the cropping patterns in line with their irrigation water productivity, and not remain obsessed with only their land productivity. Else, country will be moving towards unsustainable agriculture from water availability point of view, raising risks for the farmers, and promoting extreme inequity in the use of scarce water resources.

2.8 Use of ICTs in soil and land use management: The stupendous progress in information technology coupled with the rapid advancements made in Digital GPS, Geographical Information Systems (GIS), simulation tools, sensors, precision farming and remote sensing have opened up new vistas for land and water resources development and management. 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 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 centre as piloted and demonstrated in the M. S. Swaminathan Research Foundation (MSSRF) model.

2.9. Crops and Cropping Systems

2.9.1. Area under different crops: Significant land use changes have been observed in the last seven decades (Table 12). Rice area increased by 43% from 30.8 m ha in 1950-51 to 43.9 m ha in 2016-17. Similarly, area under wheat increased from 9.75 m. ha in 1950-51 to 30.78 m.ha in 2016-17 (216%) and maize from 3.16 to 9.63 m ha (205%), whereas, area under sorghum decreased from 15.6 to 5.6 m ha (36 %), pearl millet from 9 to 7.4 m ha (82 %) and coarse cereals from 37.7 to 25 m ha (66 %). Whereas, area under pulses increased by 54% from 19 m ha in 1950-51 to 29.4 m. ha in 2016-17 and pigeon pea is the major contributor for area increase (144%). Area under total food grain production increased from 97.3 to 129.2 m ha (33%) only. Area under oilseed crops increased by 144% from 10.73 m ha in 1950-51 to 26.2 m ha in 2016-

17 and major contributor is soybean (283%) and rapeseed and mustard (193%). Though, area under groundnut increased substantially (85%) up to 1990-91, later area has been decreased and net area increased from1950 to 2016 by only 19%. Commercial crops like cotton area increased from 5.9 to 10.8 m ha by 84% and sugarcane from 1.7 to 4.4 m ha by 159%. Shift in cropping area over last seven decades indicate that land use was influenced by market prices and food habits.

Table 12. Area under different crops (m ha)-temporal change

Crops / **Year**	**1950-51**	**1970-71**	**1990-91**	**2000-01**	**2010-11**	**2016-17**
Rice	30.81	37.59	42.69	44.71	42.86	43.99
Wheat	9.75	18.24	24.17	25.73	29.07	30.78
Sorghum	15.57	17.37	14.36	9.86	7.38	5.62
Maize	3.16	5.67	5.90	6.61	8.55	9.63
Pearl millet	9.02	12.91	10.48	9.83	9.61	7.45
Other coarse cereals	9.92	10.0	5.58	3.96	2.80	2.31
Total cereals	78.23	101.78	103.18	100.7	100.27	99.78
Chick pea	7.57	7.84	7.52	6.42	9.19	9.62
Pigeon pea	2.18	2.66	3.59	3.63	4.37	5.33
Total Pulses	19.09	22.54	24.66	20.35	26.40	29.44
Total food grains	97.32	124.32	127.84	121.05	126.67	129.22
Oilseeds	10.73	16.64	24.15	22.77	27.22	26.17
Groundnut	4.49	7.33	8.31	6.56	5.86	5.33
Rapeseed and mustard	2.07	3.32	5.78	4.48	6.90	6.07
Soybean	-	0.03	2.56	6.42	9.60	11.5
Cotton	5.88	7.61	7.44	8.53	11.24	10.82
Sugarcane	1.71	2.62	3.69	4.32	4.88	4.43

Source: Directorate of Economics and Statistics, GOI

2.9.2. Productivity of principal crops: Total food grains productivity increased by 256 %, whereas wheat productivity by 339%, rice productivity by 200%, sorghum productivity by 114% and maize productivity by 214% in 2016-17 as compared to 1951-60 (Table 13). In the same period, pulse productivity improved 54% and oilseeds by 138%. Among the pulses and oilseed crops, mustard registered higher productivity improvement of 233%.

2.9.3. Extent of different crops to total cropped area: Contribution of rice area to the total cropped area remains constant from 1950-51 to 2014-15 and it was around 22 to 23%. Whereas, contribution of wheat area increased from 7.6 to 16.2% during the same period. However, area contribution to total cropped area by sorghum and pearl millet reduced significantly.

Contribution of cereals to total cropped area reduced by 10% between 1950-51 and 2014-15. Similar trend was observed in total pulses and food grains too. However, increased area contribution of oilseeds, sugarcane, condiments and spices, fruits, vegetables and fiber crops to total cropped area was observed (Table 14).

Table 13. Productivity (kg/ha) of principal crops

Commodity	1951-60	1971-80	1991-2000	2001-2010	2016-2017
Food grains	606	892	1525	1731	2159
Wheat	728	1375	2496	2727	3200
Rice	830	1156	1852	2053	2494
Sorghum	446	597	831	837	954
Maize	759	1056	1636	2007	2413
Pulses	475	482	591	603	734
Pigeon pea	743	703	687	691	913
Chick pea	575	635	773	816	974
Oilseeds	485	543	832	936	1153
Groundnut	742	800	990	1084	1398
Mustard	391	511	881	953	1304
Soybean	-	771	1001	1006	1219
Cotton	95	145	237	325	512
Sugar cane	33736	50670	68123	66305	69001

2.9.4. 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.

If one examines the past trends in cropping systems, it will be quite clear that expansion in area has occurred in favour of those of 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 favour or high growth rates in yields were combined with high prices resulting in sharp increases in their total profitability. Pricing policy can alter the relative profitability of competing crops and hence induce change in cropping systems adopted by the farmers.

Table 14. Extent (%) of different crops to total cropped area in India (1950-51 to 2014-15)

Crop	1950-51	1970-71	1990-91	2014-2015
Rice	23.5	22.5	23.0	22.3
Wheat	7.6	11.0	12.9	16.2
Sorghum	11.8	10.2	7.6	3.1
Pearl millet	7.4	8.1	5.8	4.0
Maize	2.5	3.5	3.2	4.4
Total cereals	**61.1**	**61.4**	**55.5**	**51.3**
Chickpea	5.9	4.7	4.0	3.9
Pigeon pea	1.7	1.6	1.9	1.7
Total Pulses	**15.6**	**13.9**	**13.4**	**10.9**
Total food grains	**76.7**	**75.3**	**68.9**	**62.3**
Groundnut	3.3	4.6	4.5	2.6
Rapeseed & mustard	0.8	0.9	2.8	2.7
Soybean	-	0.02	1.4	5.8
Total oilseeds	**8.3**	**8.9**	**13.5**	**14.3**
Sugarcane	1.3	1.6	2.1	2.8
Condiments & spices	0.9	1.1	1.3	1.7
Total fruits	0.6	0.9	1.4	3.1
Total vegetables	1.2	1.3	2.2	4.7
Cotton	4.3	4.7	4.1	6.4
Total fibres	5.1	5.5	4.7	6.8
Tobacco	0.3	0.3	0.2	0.2
Other crops	5.6	5.1	5.7	6.9
Total cropped area (m ha)	**131.9**	**165.8**	**185.7**	**198.4**

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 incomes. 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 including e-NAAM, procurement interventions and improvements in marketing sector by strengthening storage structures and connectivity.

The approach for realizing high productivity of crops demands, matching of the crop requirements with climatic and soil-site features. Based on this principal, Mandal *et.al.* (2001) used climate quality index (CQI), and soil quality index (SQI) and derived land quality index (LQI) for the areas grown under sorghum in India. Ramamurthy *et.al.* (2018) have devised and demonstrated a methodology by using national level data base for Agro-Ecological regions, physiography, soil-site factors, crop requirements and the relative yield index and spread index as inputs for demarcating 'efficient crop zones' and potentially suitable areas for different crops, with an illustration for sunflower. Restricting the crops, cropping sequences and the application of related production technologies (soil conservation measures, balanced fertilization and best available irrigation management) to the respective potential area/zone (Ramamurthy *et. al.,* 2018) is one of the best land evaluation approaches for sustainable Agriculture. This approach and strategy will promote land use planning based cropping systems, 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 for identifying potential crop specific areas at village/ cluster of villages and also soil and water conservation plans for ensuring successful execution of watershed development programmes. Selecting crops and the production technologies in the potential area domains also ensures enhanced water and nutrient use efficiency and has the potentiality to link with market demands of the farm produce.

Integrated Farming System (IFS) modules/typologies dovetailing the proven efficient cropping systems in the form of a National grid covering all the AESRs of India needs to be initiated. These models will be operationalized both at the research stations and as on-farm demonstrations in a consortium mode by the all the research and extension units of NARES within a given AESR. These models will create the awareness and promote bridging the yield gaps, appropriate crop-livestock integration and increasing the share of export of agricultural and animal husbandry products. This will also showcase the harnessing of supplementary and complementary relationships among different farm enterprises to achieve greater productivity, profitability and sustainability. The monitoring of these bench mark sites with suitable indicators will provide an evaluation of system productivity, profitability and soil health over time. The results of these demonstrations and farmer's feedback will fine tune further research efforts and promote large scale replication of these models by the farmers.

2.10. Energy input in Agriculture

The global climate change and shift in food consumption towards high-value commodities are putting immense pressure on the Indian agriculture to produce more and efficiently for improving food and nutritional security while reducing the environmental footprints. In view of this, there are increasing trends towards commercialization and diversification of agriculture by integration of livestock, horticulture, fisheries and poultry sectors. These developments have significant implications for energy-use in agriculture due to increased demand for modern inputs and farm mechanization. Modern inputs and mechanization require more commercial energy and this holds true for the management of perishable commodities also. This implies a significant change in energy-use pattern in the Indian agriculture. This coupled with rising requirement of commercial energy in the non-agricultural sectors is escalating the demand for more energy. With rising trend in oil prices countries are looking for alternative sources of energy and energy-efficient technologies.

The structure 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 electricity and diesel 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 % energy. In a span of three and a half decades, 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 % and that of agricultural workers and draught animals has come down to 6 % and 8 %, respectively.

The cost of production and the share of energy costs vary widely by crops and regions. The productivity of crops depends upon the energy inputs consumed during various farm operations. The sources of energy that go into the production of crops include material inputs such as seeds, fertilizers, manures, pesticides and mechanical energy along with human and bullock labour hours used in the crop production process. Considerable variations in the form and extent of energy use and its efficiency exist in the production of major crops.

Estimate show that the all India average farm power availability at present is 1.35Kw/ha. At this average power availability level the food grain productivity corresponds to 1.7t/ha. However, under double cropping conditions, on an average the farm power requirement is estimated as 2.5 Kw/ha.

Clusters of smart Bio-villages have to adopt integrated management of land , water and energy. In these clusters, already available energy efficient farm equipments and practices should be promoted through custom hiring and service centres facilities, so as to reduce cost of cultivation per unit area and increase profitability.

Stand alone power units and power distribution systems using solar, wind, biomass, biogas and producer gas with incentives and bank loans to entrepreneurs to set up these units in intensive agricultural areas and special agricultural zones for agro-processing and rural domestic consumption. This will reduce the dependence on energy supply from uncertain non renewable and costly fossil fuel based sources. We should encourage to energizes all the irrigation pump sets with solar PV water pumping system.

2.11. Augmenting supply of renewable energy resources

It is estimated that 642 m t of crop residues are generated per year in the country, of which about 102 m t is burnt causing environmental pollution problem. R & D efforts need to be strengthen for development of low cost pyrolysis kilns for generation bio-char, high carbon product for land application to improve the land and soil quality.

Linking of the Mission on providing toilet facilities in rural areas with bio-gas programme would generate additional power estimated at 8750MkWh.

As per National Bio-fuels policy, the 2G technology for conversion of surplus ligno-cellulosic biomass to ethanol has high potential in the country.

2.12. Climate change

The impact of climate change on agriculture could result in problems with food security and may threaten the livelihood activities upon which much of the population depends. Climate change can affect crop yields (both positively and negatively), as well as the types of crops that can be grown in certain areas, by impacting on timely culturable activities, use of agricultural inputs such as water for irrigation, amounts of solar radiation that affect plant growth, as well as the prevalence of pests.

Climate change will also have an economic impact on agriculture, including changes in farm profitability, prices, supply, demand, trade and regional comparative risks and advantages. The magnitude and geographical distribution of such climate induced changes may affect our ability to expand the food production area as required to feed the burgeoning population projected for 2050.

The extent of inter- and intra-annual variability in climate happens to be large, and the crops respond differentially to these changes. Understanding of this differential behavior can aid in working out the impact of climate change. The vast genetic diversity in crops provides a platform to identify suitable thermal and drought tolerant cultivars for sustained productivity in the changed climate. Refinement of suitable agronomic management practices can be a potential solution to optimize agricultural production in the changed climate. To have an overall assessment of soil health by the climate change, the possible alterations in soil physical, chemical and biological characters need to be looked into by including land use and land cover change driving forces. Intensive cultivation in our country has already started showing signs of yield stagnation in some parts of north-west India, raising the alarm of sustaining the yields by adoption of suitable agronomic management options. This concern has now to be viewed along with the climate change and its variability. Increased frequency of droughts and floods in this region, as a result of climate change scenarios, caution us to identify suitable management options to face the situation. This needs continuous assessment of the magnitude of the impact of climate change and the benefits of adoption of adaptation/mitigation measures evolved and recommended by the NICRA programme studies carried out by the ICAR for the different districts of the country. Socio-economic aspects of climate change are relatively weak, and future scenarios are to be modeled for various agro-ecological regions for subsequently linking with other relational layers to work out the impact.

Agriculture is the Nation's life line and the primary industry. It supports 50% of the population of the country for its livelihood opportunities. Every year the Ministry of Agriculture and Farmers Welfare prepares advance agricultural plans, in consultation with the states during pre-*kharif* and pre-*rabi* seasons on various field programmes and targets of production. However, the country is differentially endowed with the distribution of the natural resources spatially in different agro-climatic regions, in particular in relation to rainfall, cropping seasons and soils. Hence, the planning and monitoring of the disaggregated agricultural production programmes has to be centrally organised in a consultative and participatory mode, with the convergence of both top down and bottom up processes of programmes for planning and execution. In a multi-party federalized system of Governance, as in India, the sum total of the impact and benefits of the efforts and financial allocation for the agriculture sector will be more than additive, if Agriculture is brought in the concurrent list of the constitution, rather than being a State subject as of now.

Problems of farmers' distress in different areas due to different causes, mostly natural, cannot be left to be tackled by the affected areas (states) alone. Moreover, the country is moving towards e- NAAM and a single Indian national common agricultural market and Indian Trade Agency (ITO) in the lines of European Common Market (ECM) and WTO. This change will result also in maximising the comparative advantages of the growth and contribution of different regions to the National Food and Nutritional security.

3.0. NATIONAL SOIL AND LAND USE POLICY FRAME WORK

Vision Statement: The vision of the National Soil and Land Use Policy is to ensure food and nutritional security, water security and livelihood security through the adoption of best soil, land, water and crop management practices to achieve the developmental targets and long term use of these resources on a sustainable basis so as to handover the quality of these resources undiminished/improved to the prosperity.

The proposed National Soil and Land Use Policy framework envisages that the science and technology- led development of the natural resources of the nation *viz*., soil, land, water, agro-biodiversity be managed in the best possible scientific manner without any adverse effects/impacts, so that their inherent use potential is handed over undiminished to the posterity.

The frame work also reinforces the "Principles and Guidelines for Action" enunciated in the revised "World Soil Charter" adopted by the FAO in June, 2015.

The ultimate goal is “**Greening India**”, of farm lands, grazing lands, pastures and non-arable urban lands leading to sustainable land use systems and environmental security.

The framework also envisages promotion of advocacy, stewardship, safeguarding and adoption of optimal land use allocation, matching its potential and intended purpose based on informed opinion derived from SWOT analysis of each kind of landscape, land and its soil.

Thus, the National Soil and Land Use Policy framework calls for an enabling environment, logistic support and incentives to the farming community to profitably engage themselves with “**Integrated land use systems**” as co-operatively organized and professionally guided agri-business enterprises and estate clusters of "Smart Bio-villages” for realizing the scale of power, for a sustainable and enduring agriculture of today and tomorrow. These efforts by all the stakeholders will ensure food, nutrition, water and environment security of the nation for all times.

To achieve this vision and sustain its goal, the following recommendations in the areas of policy measures, structural reforms, operational interventions and regulations are made for initiating and strengthening appropriate action programmes by all the stakeholders.

Recommendations

3.1 **Prime agricultural lands** with high carrying capacity, perennial orchards/plantations, parks and similar green spaces within urban limits may be demarcated and regulated against diversion. Only under exceptional circumstances, these lands may be allotted for non-agricultural purposes provided concerned agencies compensate by treating and developing fully an equivalent area of degraded/wasteland elsewhere. Further, incentivizing policies for setting up industries in marginal lands will be helpful to achieve the above objective.

3.2 Clear demarcation of biosphere reserves, production forests, community lands, urban green belt and potential agricultural lands/special agricultural zones must be made using geo-spatial techniques. The land use survey organization should use **district or even taluka level geo-spatial data to suggest most appropriate land use and allocation.** This will help in identifying "potential crop zones/special agricultural zones" and accordingly plan desired cropping patterns at the state/national level. This will also facilitate land use planning-based production and market system for sustainable agriculture.

3.3 Soil management plays an important role in increasing the crop productivity in acid soils of the country which form about 30% of the cultivated area of the country. Use of soil amendments need to be incentivized and made available to the farmers in those areas by suitable logistics, transportation and availability, for ameliorating the soil acidity and enhancing the crop productivity.

3.4 Enhancing agricultural productivity has been the major land saving strategy. However, there is still a large **exploitable yield gap** in most of the crops and greater effort on **bridging this gap with effective transfer of technology** on soil-water-crop management are very critical to achieve the **production targets,** both at farmers' level and at National level, in the wake of shrinking land and water resources. This will result in sparing substantial low productive and marginal areas presently cultivated to other non-agricultural purposes.

3.5 In view of nearly one-third of the land area being under degraded and wasteland categories, there is a need for a correct and periodic assessment of the nature, magnitude and extent of soil and land degradation through rapid inventory **using appropriate tools and techniques** with particular reference to cultivated lands for their effective rehabilitation and updated every three years.

3.6 To enhance feed, fodder production and pasture development, an efficient and integrated land use management system which includes **optimum utilization of degraded and wastelands and common property resources** through proven social forestry, silvi-pasture/ agri-silvi-pastoral/bio-fuel system need to be encouraged. This demands devising suitable regulatory measures by the *Gram Sabhas*, other civic bodies and Country &

Town Planning organizations for the development of these lands and their protection from encroachment. "**Greening India**" programme also needs to be extended to land areas adjacent to vast networks of roads and railway lines. To give impetus to the "Greening India" Movement, a stream of "National Green Corps (NGC)" by involving students of schools and colleges may be created, similar to NCC/NSS. The students may be incentivized for their participation in this movement.

3.7 Establishing **modern high output soil testing laboratories**, use of ICTs for effective monitoring, and quality control mechanism will enhance the utility and larger reach of **soil health card programme**. **A dedicated service cadre** for soil testing, balanced fertilizer use and soil health monitoring may be created in the State Departments of Agriculture. This would ensure adoption of soil test based recommendations of fertilizers and soil amendments, production and distribution of specified fertilizers (customized fertilizers, novel products for fertigation and soil and foliar application) for ensuring greater nutrient use efficiency as well as to upgrade and maintain soil fertility.

3.8 To enhance the importance and utility of soil health cards, apart from soil chemical and nutrient status parameters, features of the land such as irrigated/rainfed system, soil depth, texture, irrigation water quality and stoniness and gravelly nature may also be included in soil health card and such a composite card may be better designed as "**Soil Health Management Pass Book**" for every farmer. This pass book may also contain the information on **Best Management Practices** (BMPs) for the recommended crops. The soil health management pass books data may also be used for preparation of digitized, geo-referenced soil fertility maps by the National Agricultural Research System (NARS) for promoting balanced fertilization.

3.9 Since there are a diverse set of soil related constraints affecting crop production in agriculture in different agro-eco-regions, the Indian Institute of Soil Science may be renamed as **Indian Soil Health Research Institute** (ISHRI) and appropriately re-organized for taking up collaborative research with State Agricultural Universities and Other Research Agencies for tackling the Soil Health Problems and monitoring Soil Health in different agro-eco-regions.

3.10 Soil health status may be monitored by capturing the emerging changes in soil properties due to anthropogenic activities and climate change on a time scale (preferably every 3 years) in the **bench- mark sites** representing different soils, cropping/farming situations in different agro-ecological regions to predict future changes and take-up corrective measures for higher productivity and sustainability. The ISHRI may co-ordinate this activity as one of its mandates. **Periodic submission of soil health status report to the Parliament be made mandatory**.

3.11 A '**National Mission on Soil Carbon Improvement**' should be launched in order to improve organic carbon status of soils, and for adaptation/mitigation of climate change. In view of India's climate pledge (COP 21, Paris, 2015), GHGs emission intensity has to be reduced by 33-35% of 2005 level by 2030. This demands creation of additional carbon sink of 2.5-3 billion tonnes of CO_2 equivalent by 2030. Hence, particular emphasis and drive be given to programmes related to efficient recycling of crop residues and sewage, conservation agriculture, agro-forestry and community-based composting in rural areas.

3.12 It is necessary to incentivize the adoption of BMPs, which will lead to improvement in soil quality and reduced land degradation footprint to achieve the target of **land degradation neutrality** by 2030. For the larger adoption of these BMPs, farmers must be incentivized (like land tax remission etc.) for the **Ecosystem Services** provided by healthy soil and Greener landscape.

3.13 Voluntary Soil and Land Care groups may be promoted through Social Media and KVKs to create awareness and local level action programmes by Government and local institutions for promoting a healthy soil and Greener landscape.

3.14 A **National Grid** of Region specific Integrated Farming System (FS) Models (Typologies) may be established at representative research stations by the NARS, covering all Agro-eco-sub regions of India. Concurrently "**Smart Bio-village FS Models**" may also be institutionalized by the National Agricultural Research and Extension System (NAR & ES) at representative villages in the States as operational Research and Extension Education (Farmers' Field School) Models.

They will be the epicenters for rapid spread of such "**agri-business enterprises compact**", which will spatially connect the rural hinterlands with adjacent towns and Smart Cities as a growth trajectory continuum, as envisaged in the PURA Model of development advocated by the Late President Dr. APJ Abdul Kalam.

Such paradigm shift of inclusive and dovetailed Rural and Urban landscape planning will contain the undue horizontal and vertical growth of towns and cities beyond their carrying capacity and sustainability limits on one hand and contain the emergence of "Urban Heat Lands" and rural out-migration to cities on other.

3.15 **Organic Farming** along the entire value chain may be strengthened and promoted in poorly-endowed regions like rainfed and hilly tracts, tribal and north-eastern regions with low productivity and low/negligible usage of agro-chemicals, for chosen crops and commodities where the country has comparative market advantage.

3.16 **Protected Cultivation** of high-value crops like vegetables, flowers and selected fruits need to be promoted with suitable incentives for steady year-round supply. This will help in efficient use of inputs with high productivity, and releasing some land presently occupied by these crops for other purposes.

3.17 **Peri-urban Agriculture** is evolving as a new sector. Scientific policies and practices for promoting peri-urban agriculture are crucial for environmental safety. Recycling and reuse of treated sewage and effluent water for irrigation and mechanized composting of urban wastes as source of plant nutrients may be promoted as integral components of peri-urban agriculture. In this regard, compliance of **pollution and health standard protocols** must be ensured for their utilization. Peri-urban agriculture must also encompass hydroponics, aquaponics and terrace & vertical farming.

3.18 As the fragile **coastal eco-system** is affected by cyclonic storms and sea erosion, policy interventions are required in the form of restricting indiscriminate expansion of coastal aquaculture. The coastal lands must be protected against sea water ingression by regulating ground water usage, cyclonic storms and sea erosion by erecting embankments and creation of **bio-shields**. Therefore, it is necessary to enforce the provisions of "**Coastal Regulation Zone**".

3.19 In the **North Eastern Hill Regions**, it is essential to ensure minimal landform/landscape disturbance to reduce/arrest land degradation. In areas where *jhum* cultivation is prevalent, alternate modes of land ownership and integrated models of land use as evolved and demonstrated by ICAR Research Complex for NEH Region may be encouraged with suitable incentives for their adoption to ensure livelihood security and sustainability of the fragile eco-system.

3.20 Special package involving multi-sectoral interventions may be implemented for minimizing degradation and **rejuvenation of ravine, waterlogged, coastal saline, riverine *diara* lands and Mining areas.**

3.21 **The present practice of using soil from cultivated lands for brick making should be discouraged/ banned.** The brick industry must be made responsible for accelerated rejuvenation of lands degraded by their activities. Simultaneously, suitable incentives be given for full utilization of fly ash for brick making besides greater emphasis on use of cement blocks and other viable alternatives in construction sector.

3.22 In view of the fact that India is already in the **water stressed category** and the current level of surface water use efficiency is around 38 %, it is necessary to promote through policy interventions and incentives the efficient use of irrigation water by adoption of micro-irrigation, improved land configuration, laser land levelling and **rational pricing of water and electricity for ensuring sustainable use of water for agriculture**. Further, these incentives will encourage adoption of fertigation, harvesting of rain water and excess runoff in farm ponds, artificial recharge of groundwater and capacity building in land and water management. All these efforts shall lead to enhancing the level of **Composite Water Management Index** of a given watershed/basin/state in the backdrop of stressed and scarce per capita availability scenario.

3.23 Creation of Farm Ponds for harvesting rain and potential run-off water may form integral part of water shed management in the Rainfed Agriculture landscape. Inland water bodies need to be protected and optimally utilized for aquaculture.

3.24 With increasing emphasis on energy efficiency and labour productivity, **gender friendly small farm mechanization**, improving farmer's skills in use of modern tools and techniques, developing relevant **agri-voltaic systems** and use of **ICTs** by establishing "ICT enabled Resource Knowledge Centres" in effective transfer of latest technologies will go a long way in improving overall management of farms, leading to enhanced profitability and efficient use of natural resources. Since more than 52% of work force are still in agriculture, they and in particular the rural youth may be trained in the KVKs and Polytechnics under the Agricultural Skill Council Programmes of the Government.

3.25 Considering the skewed ownership of cultivated lands and fragmentation of holdings, it is necessary to strengthen implementation of laws relating to land reforms, with particular reference to **tenancy, land pooling, leasing, co-operative farming as Farmers' Producer Companies and joint stock companies, contract farming and land acquisition**.

3.26 It is proposed that a **Land Development Department** be created under the Ministry of Agriculture and Farmers Welfare both at the Centre and States. Existing Department of Land Resources, presently under the Ministry of Rural Development may be merged with this new Department.

This Department will be the apex body for all **Land Care Policies and Programmes**. All the activities related to land *viz*., digital land records, conservation, reclamation, rejuvenation of Fallow lands and their development should be planned, implemented and monitored by this Department in collaboration with R&D organizations and the State Governments. The **National and State Land Use Boards** may be revived and strengthened with representations from all the concerned stakeholders including farmers. These boards may be serviced by this Land Development Department at the National and

State levels. Water and Land Management Training Centres may be established at the State Levels and Union Territories in technical coordination with SAUs and KVKs.

3.27 The contribution of Agricultural GDP to National GDP slided from 53.1% in 1950-51 to 13.7% as of now. Agriculture being the primary industry has 45% share in employment and 52% of the work force are engaged in Agriculture.

It is time that Agriculture is brought under the **Concurrent List** for effective implementation of policies and programmes on soil, water and land use for achieving the production targets of various agricultural commodities required in future for meeting the internal demands and enhanced export prospects.

References

1. Ayyappan, S (2018) Agricultural Research & Development: Vision for 2050. In: Souvenir of Institution of Agricultural Technologists Golden Jubilee Celebrations. 18-23.
2. Bharat R. Sharma, Ashok Gulati, Gayathri Mohan, Stuti Manchanda, Indro Ray, and Upali Amarasinghe (2018) water productivity mapping of major Indian crops.
3. Bhattacharyya, T, D. K. Pal, C. Mandal , P. Chandran , S. K. Ray , Dipak Sarkar , K. Velmourougane, A. Srivastava , G. S. Sidhu , R. S. Singh , A. K. Sahoo , D. Dutta , K. M. Nair , R. Srivastava , P. Tiwary , A. P. Nagar and S. S. Nimkhedkar (2013) Soils of India: historical perspective, classification and recent advances. Current Sci., 104 (10): 1308-1323.
4. Chand, R. (2012) Agricultural R&D for next generation-ICAR vision 2050. AU Vice-Chancellor and ICAR Director Meet.
5. Chand, Ramesh. (2017) Doubling Farmers' Income: Rationale, Strategy, Prospects and Action Plan, NITI Policy Paper No. 1/2017, NITI Aayog , Government of India, New Delhi, 34 p..
6. Chaudhari, S.K., Biswas, P.P., Abrol, I.P. and Acharya, C.L. (2015) Soil and nutrient management policies. In*: State of Indian Agriculture–Soil* (Eds.) H. Pathak, S.K. Sanyal and P.N. Takkar. *National Academy of Agricultural Sciences*, New Delhi, India, pp. 332-342.
7. CRIDA (1999) 50 Years of Dryland Agricultural Research In India. HP Singh, YS. Ramakrishna, KL Sharma And B. Venkateswarlu (Eds.) Central Research Institutute for Dryland Agriculture. Hyderabad.
8. Dwivedi, B.S and Dwivedi, V (2007) Monitoring soil health for higher productivity. *Indian Journal of Fertilisers* 3 (4), 11-23.
9. Dwivedi, B. S (2015) Revisiting soil testing and fertilizer use research. The 41st Dr. R.V. Tamhane Memorial Lecture. *Journal of the Indian Society of Soil Science* 62 (Supplement), S40-S55.
10. Dwivedi, B.S and Meena, M.C (2015) Soil testing service- retrospect and prospects. *Indian Journal of Fertilisers* 11 (10), 110-122.
11. Gangawar, B and Singh, Anil Kumar (2011) Efficient alternative cropping systems. PDFSR, Modipuram, India. p-339.
12. FAO (2015) Revised World Soil Charter. p 7.
13. FAO (2017) Voluntary Guidelines for Sustainable Soil Management. p 15.
14. Gangawar, B and Singh, A.K. (2011) Efficient alternative cropping systems. p-339.
15. Ganesh Murthy, A.N. (2014) Towards a National Soil Policy for Food and Nutritional security. Indian Journal of Fertilizers 10 (12), 62-67

16. GoI (2011) "*Census of India 2011, Population Totals Paper 1 of 2011, India Series 1*", Registrar General and Census Commissioner, Govt. of India, New Delhi.

17. GoI (2015) "Land Use Statistics at a Glance 2003-04 to 2012-13", Directorate of Economics & Statistics, Department of Agriculture & Cooperation, Ministry of Agriculture, Govt. of India, New Delhi, May 2015.

18. GoI (2015a) "*Annual Report 2014-15*", Department of Commerce, Ministry of Commerce and Industry, Government of India, New Delhi, pp. 133-134.

19. Hegde, D. M., Tiwari, S. P. and Rai, M. (2003) Crop diversification in Indian Agriculture. *Agricultural Situation in India*. LX (5): 225-272.

20. Hedge, D.M (2018) Addressing the emerging challenges in Indian Agriculture. In: Souvenir of Institution of Agricultural Technologists Golden Jubilee Celebrations. 31-44.

20. http://www.bhoomigeoportal-nbsslup.in/

22. https://landcareaustralia.org.au/

23. https://grdc.com.au/

24. ICAR (2010), "*Degraded and Wastelands of India – Status and Spatial Distribution*", Indian Council of Agricultural Research, New Delhi.

25. ICAR (2010) Hand Book of Agriculture

26. ICAR (2015) Vision Document- 2050.

27. ICAR (1999) 50 years of NRM Research (Ed., G.B.Singh and B.R Sharma).

28. ICAR- Vision documents, 2050 of related institutes.

29. Indian Society of Soil Science (ISSS) (1991) Soil-related constraints in crop production. Bull. No.15. p-175.

30. ISSS (1998) Soil organic matter and organic residue management for sustainable productivity. Bull. No. 19. p-164.

31. ISSS (2004) Organic farming. Bull. No. 22. p-107.

32. ISSS (2007) Nutrient Management in Acid soils. Bull. No. 25. p-87.

33. ISSS (2009) Soil and water management for Agricultural transformation in Easter India. Bull. No. 26. p-120.

34. ISSS (2011) Salt affected soils. Bull. No. 28. p-117.

35. ISSS (2012) Soil Science in the Service of Nation (eds. N. N. Goswami et al.), Indian Society of Soil Science, New Delhi.

36. Mamta Mehra, Singh, C. K., Abrol, I. P and Oniam.B. (2017) A GIS based methodological framework to characterize the Resource Management Domain (RMD):A case study of Mewat District,Haryana.Land use policy,60:90-100.

37. Mandal, D and V. N. Sharda. (2011) Assessment of permissible soil lossin India employing a quantitative bio-physical model. *Current Sci.*, 100 (3): 383-390.

38. NAAS (2009) State of Indian Agriculture

39. NAAS. (2012) *Management of Crop Residues in the Context of Conservation Agriculture*; Policy Paper No. 58; National Academy of Agricultural Sciences: New Delhi, India, p. 12.

40. NAAS. (2012) *Management of Crop Residues in the Context of Conservation Agriculture*; Policy Paper No. 58; National Academy of Agricultural Sciences: New Delhi, India, p. 12.

41. NAAS (2015) State of Indian Agriculture -Soils

42. NAAS (2015) State of Indian Agriculture -Water

43. NAAS (2015) State of Indian Agriculture -Energy

44. NAAS (2018) Soil Health: New Policy Initiatives for Farmers Welfare. Policy Brief No. 3, National Academy of Agricultural Sciences, New Delhi. 19 p.

45. NBSS& LUP, Reports on soil survey and soil maps (1:250,000) of different states and UTs

46. NBSS& LUP (2002) Soil map of India (1:1 million) and report.

47. NBSS & LUP and CSWR & TI, Proneness to soil erosion maps (1:250,000) of different states.

48. L.G.K.Naidu, V.Ramamurthy, O.Challa, R.Hegde and P.Krishnan. (2006) Manual Soil-site suitability criteria for major crops. NBSS Publ. No.129, NBSS&LUP, Nagpur, 118p.

49. Naidu, L.G.K., Ramamurthy,V., Challa, O. and M. Velayutham, (2017) Land Evaluation for Sustainable Agriculture. Brillion Publishing, New Delhi, p-356.

50. NBSS&LUP Staff (2002) Soils of India,NBSS&LUP pubn.94.p.130+11sheets

51. NCIWRD (1999) Report of the National Commission for Integrated Water Resources Development, Ministry of Water Resources, Vol. I, 542 p.

52. NITI Aayog (2018) Composite water Management Index (CWMI): A National tool for water measurement, 180p.

53. NITI Aayog Publications on Doubling of farm income (all the volumes).

54. M.S.Swaminathan Research Foundation- Annual Reports, Chapters on information, communication and education and food security.

55. M.S.Swaminathan Research Foundation (2018) Farming system for nutrition- policy recommendations. p-23.

56. Pal, D.K., T Bhattacharyya and M. Velayutham (2001) Genesis and Classification of Calcareous Soils of India. In: Proceedings of National symposium on Balanced Nutrition of Groundnut and Other Field Crops Grown in Calcareous Soils of India. p19-32.

57. Panjab Singh (2019) Agricultural Science Congress, Presidential address-Indian Agricultural - Past, Present and Future, NAAS, New Delhi.

58. Paroda, R.S. (2017) Strategy paper on Strategy for Doubling Farmers' Income. Trust for Advancement of Agricultural Sciences, New Delhi, p- 27.

59. Patel, N. and Rajput, T.B.S. (2015) Water management in Indian Agriculture: Issues and Strategies. *Indian Journal of Fertilizers.* 11 (4): 86-97.

60. Peter, K.V (Ed).2018.Zero Hunger India-Policies and perspectives.p.670.Brillion Publishing Co, New Delhi.

61. Ramamoorthy,B., Narasimham,R.L and Dinesh,R.S. (1967) Frtilizer application for specific yield targets of Sonar-64 wheat. Indian Fmg., 17:43-45.

62. Ramamoorthy,B. and Velayutham,M.(2011).The "Law of optimum" and soil test based fertilizer use for Targeted yield of crops and Soil fertility management for sustainable Agriculture.1st Dr.B.ramamoorthy Memorial lecture, *Madras Agric.J.*98,(10-12), 295-307.

63. Ramamurthy, V and Dipak Sarkar (2009) Participatory Land-Use Planning improved employment opportunity. ICAR News, 4-5.

64. Ramamurthy, V. (2018) Participatory Land Use Planning to Enhance Rural Livelihoods in Eastern Maharashtra Plateau of Central India. *Int.J.Curr.Microbiol.App.Sci*. 7(04): 867-880.

65. Ramamurthy, V., S. Chattaraj, S. K. Singh and R. P. Yadav. (2018) Identification of Potential areas for crops. *Current Sci.*, 115 (5): 955-961.

66. Raychaudhary, S.P.(1969) land and Soil. National Book Trust.

67. Raman, K.V., (2003) Multiple livelihood opportunities - towards sustainable human development. In: Bhoovigyan Vikas Foundation Publn. "Reshaping our earth view" p. 70-101.

68. Samra, J.S. and Sharma, P.D. (2009) Food Security- Indian Scenario. *Proceedings IPI-*OUAT-IPNI International Symposium on potassium role and benefits in improving nutrient management for food production, quality and reduced environmental damages, Bhubaneswar, India, November 5-7. 1: 15-43.

69. Sarkar, A.K. (2013) Acid soils their chemistry and management. New India Publishing Agency, New Delhi.

70. Sekhri, S. 2009. Missing water: agricultural stress and adaptation strategies in response to groundwater depletion in India. http://www.virginia.edu/economics/RePEc/vir/virpap/ papers/ virpap406.pdf.

71. Sharda, V. N. and P. R. Ojasv. (2016). A revised soil erosion budget for India: role of reservoir sedimentation and land-use protection measures. *Earth Surf. Process. Landforms*, 41, 2007–2023.

72. Shukla, A.K., Behera, S.K., Pakhre, A., & Chaudhari, S.K. 2018. Micronutrients in soils, plants, animals and humans. Indian J. of Fertilizers, 14(3): 30-54.

73. Singh, A. K. (2014). Sustainable Management of Water Resources: Issues and Strategies. In: Efficient Water Management for Sustainable Agriculture (ed: Rattan, R.K. and D. R. Biswas), *ISSS Bulletin No. 29*, 1-86.

74. Singh, R.B. (2011).Towards an Evergreen Revolution: The Road Map.NAAS,New Delhi, p.66.

75. Singh, R.B. (2013) Climate smart Agriculture.Towards an Evergreen Economy.Presidential Address,NAAS, p.32.

76. Singh, R.B. (2015) Zero Hunger India:The Challenge:p.73-114.In Zero Hunger India-policies and perspectives, 2018, (ED) K.V.Peter. Brillion publishing Co New Delhi.

77. Singh, S, Y.P. Singh, R.B. Sinha, A.K. Singh, S.K. Dubey and G.P. Verma (2018) Socio-economic impact of reclamation of Chambal ravines through anicuts and afforestation. *Indian Journal of Soil Conservation*, 46 (2): 225-232.

78. Sree Ramulu, U.S. (1994) Utilization of sewage and sludge for increasing crop production. 12th Prof. J.N. Mukherjee-ISSS foundation lecture. *J. Indian Soc. Sci*., 42 (4):525-532.

79. Sree Ramulu, U.S. (2018) Smart villages of tomorrow. Sri Shakti Promotional Litho Press, Coimbatore. p-274.

80. Swaminathan, M.S. (2005) Serving farmers and saving farming. 3rd report of the National Commision on Farmers. p 4-5.

81. Swaminathan, M.S. (2006) Jai Kisan: Revised draft National Policy for framers. P.49.

82. Swaminathan, M.S. (2017) Looking forward to ever green revolution. *Smart Agripost*, January issue, 11-13.

83. Swindale, L.D. (1991). Research for the implementation of a land use policy in India. J.Indian soc.soil sci.39:14-31.

84. Tandon, H.L.S (2014) Soil testing for balanced fertilization.FD&CO, New Delhi. p-170.

85. Tewatia, R.K., Rattan, R.K., Bhende, Shital and Kumar, Lalit (2017). Nutrient use and balance in India with special reference to phosphorus and potassium. *Indian Journal of Fertilizer*, 13(4): 20-31.

86. Velayutham, M., Mandal, D.K., Mandal, C. and Sehgal, J. (1999) Agro-Ecological Subregions of India for Planning and Development. NBSS and LUP, Publ. No.35, 372p.

87. Velayutham, M. (2012) National Soil Information system (NASIS) and Landresource mapping for perspective land use planning and pragmatic farm level planning .4th Dr.S.V.Govindarajan Memorial lecture. *Madras Agric.J*., 99(4-6),147-154.

88. Velayutham, M, Santhi, R, Subba Rao, A, Muralidharudu, Y and Dey, P. (2015) The “Law of Optimum” and its application for targeted yield of crops in India-A Mini review. e-ifc (International fertilizer correspondent), *Intl. Potash Institute*, 44:12-20.

89. Velayutham, M., Ramamurthy, V. and M. V. Venugopalan, (2002) Agricultural Land Use Planning- from theoretical perspectives to participatory action plan in the Indian context. *The Land.* 6(4): 45-60.

90. Velayutham, M. and T. Bhattacharya (2000) “Soil Resource Management”, in Yadav, J.S.P. and G.B. Singh (Ed.) *Natural Resource Management for Agricultural Production in India* — International Conference on Managing Natural Resources for Sustainable Agricultural Production in the 21st Century. February 14–18, 2000. New Delhi: Indian Society of Soil Science. pp. 1–135.

91. Velayutham, M (2017) Soil nutrients and crop response-curve types in farmers fields: key to balanced fertilizer use and sustainable soil fertility management. ifc(IPI),49:29-35.

92. Velayutham, M. (2017). The Law of Optimum - A unified concept in Plant Nutrition : bridging The Law of Minimum and The Law of The Maximum. 6th Dr. B. Ramamoorthy Memorial Lecture, 5th Dec. 2017.

93. World Bank. (2010) Sustainable Groundwater Irrigation: Approaches to reconciling demand with resources. Strategic Overview Series Report No. 4. Washington, DC.
