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Green Growth and Agriculture in India

1. Introduction

Natural resource use and inputs involving soil, water and fossil fuel is the foundation for agriculture production. Therefore conservation, optimal use and effective management of these natural resources are essential for facilitating resource use efficiency in agriculture in the Indian scenario. At 141.58 million hectares, India's net sown area is 46% of its total geographic area. India's average cropping intensity rests at 140.54% while the net irrigated area is less than half of the net sown area at 63.6 million hectares. The use of NPK (nitrogen-phosphorus-potassium) per hectare was 128.34 kg in 2012-13, lower than that of 2010-11, although post the Green Revolution period, there has been a tremendous increase in fertilizer use (Table1). The total consumption of pesticide has also been increasing over the years and stood at 56.091 thousand tonnes in 2012-13 (MoA 2013a).

Table 1 Consumption of fertilizers in terms of nutrients (N, P and K) in India from 1950 to 2013-14.

Year	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2005-06	2010-11	2013-14
N	58.7	210.0	1487.0	3678.1	7997.2	10920.2	12723.3	16558.2	16750.1
P	6.9	53.1	462.0	1213.6	3221.0	4214.6	5203.7	8049.7	5633.5
K	-	29.0	228.0	623.9	1328.0	1567.5	2413.5	3514.3	2098.9
Total	65.6	292.1	2177.0	5515.6	12546.2	16702.3	20340.5	28122.2	24482.5

Source: MoA, 2014

Agriculture and allied sectors contributed 13.9% to the national gross domestic product (GDP) and 11.9% of India's exports in 2013-14. Although it still employs about 54.6% of the total population, its contribution to the GDP has declined over the years (GoI 2014). Furthermore while the absolute number of agricultural workers has increased (MoA 2013a), there has been a drastic decline in the number of cultivators from 127.3 million in 2001 to 118.7 million in 2011 which indicates the a move from farm towards non-farm employment, (MoA 2013a; GoI 2014). In contrast the numbers of agriculture labor have increased by 37.5 million. (MoA 2013a). Nevertheless the growth rate of agriculture continues to be positive at 4.7% (GoI 2014).

The majority of the landholdings in India are owned by small and marginal farmers (67%) whereas medium farmers and large farmers constitute a mere 4.3% and 0.7% of the total number of land holdings. The average size of land holdings for marginal, small and semi-medium farmers is 0.38 hectares, 1.42 hectares and 2.71 hectares respectively. The medium and large farmers have average land holdings of 5.76 and 17.37 hectares respectively. The national average land holding size is 1.16 hectares (MoA 2013a).

The total area under food grains has increased to 126.2 million ha in 2013-14 whereas production has enhanced to 264.4 million tonnes (GoI, 2014). A detailed description of the decadal trends in area, production and yield of major crops from 1950 to 2013-14 is described in tables 2, 3, 4 and 5.

Table 2 All India decadal trends in area, production and yield for food grains, rice and wheat

	Foodgrains			Rice			Wheat		
Year	Area Million Hectares	Production Million Tonnes	Yield Kg/ Hectare	Area Million Hectares	Production Million Tonnes	Yield Kg/ Hectare	Area Million Hectares	Production Million Tonnes	Yield Kg/ Hectare
1950-51	97.32	50.82	522	30.81	20.58	668	9.75	6.46	663
1960-61	115.58	82.02	710	34.13	34.58	1013	12.93	11.00	851
1970-71	124.32	108.42	872	37.59	42.22	1123	18.24	23.83	1307
1980-81	126.67	129.59	1023	40.15	53.63	1336	22.28	36.31	1630
1990-91	127.84	176.39	1380	42.69	74.29	1740	24.17	55.14	2281
2000-01	121.05	196.81	1626	44.71	84.98	1901	25.73	69.68	2708
2010-11	126.67	244.49	1930	42.86	95.98	2239	28.46	80.80	2839
2013-14	126.04	264.77	2101	43.95	106.54	2424	31.19	95.91	3075

Source: MoA, 2014,

Since 1960 and up until 2013-14 rice and wheat production have increased by over 3 and 8 times respectively. Area under rice has seen an expanded by nearly 10 million hectares whereas that of wheat has improved by roughly 18 million hectares. Yield of rice has risen by 2.4 times while that of wheat has improved by 3.6 times. On the other hand area under coarse cereal cultivation has dropped from 44.96 million hectares to 25.67 million hectares during 1960-61 to 2013-14 although production appeared to have risen by approximately 20 million tonnes. Area under oilseed cultivation has also risen from 13.77 million hectares to 28.53 million hectares and production has increased by close to five-fold in this period. Area under sugarcane cultivation has also approximately doubled and its production has also increased (MoA 2014).

Table 3 All India decadal trends in area, production and yield for coarse cereals, maize and bajra

	Coarse Cereals			Maize			Bajra		
Year	Area MH	Production MT	Yield Kg/ Hectare	Area MH	Production MT	Yield Kg/ Hectare	Area MH	Production MT	Yield Kg/ Hectare
1950-51	37.67	15.38	408	3.16	1.73	547	9.02	2.60	288
1960-61	44.96	23.74	528	4.41	4.08	926	11.47	3.28	286
1970-71	45.95	30.55	665	5.85	7.49	1279	12.91	8.03	622
1980-81	41.78	29.02	695	6.01	6.96	1159	11.66	5.34	458
1990-91	36.32	32.70	900	5.90	8.96	1518	10.48	6.89	658
2000-01	30.26	31.08	1027	6.61	12.04	1822	9.83	6.76	688
2010-11	28.34	43.40	1531	8.55	21.73	2542	9.61	10.37	1079
2013-14	25.67	43.05	1677	9.43	24.35	2583	7.89	9.18	1164

Source: MoA, 2014

Table 4 All India decadal trends in area, production and yield for oilseeds, groundnut, rapeseed and mustard and sugarcane

	Oilseeds			Groundnut			Rapeseed & Mustard			Sugarcane		
Year	Area (MH)	Production (MT)	Yield Kg/ Hectare	Area (MH)	Production (MT)	Yield Kg/ Hectare	Area (MH)	Production (MT)	Yield Kg/ Hectare	Area (MH)	Production (MT)	Yield Kg/ Hectare
1950-51	10.73	5.16	481	4.49	3.48	775	2.07	0.76	368	1.71	57.05	33422
1960-61	13.77	6.98	507	6.46	4.81	745	2.88	1.35	467	2.42	110.00	45549
1970-71	16.64	9.63	579	7.33	6.11	834	3.32	1.98	594	2.62	126.37	48322
1980-81	17.60	9.37	532	6.80	5.01	736	4.11	2.30	560	2.67	154.25	57844
1990-91	24.15	18.61	771	8.31	7.51	904	5.78	5.23	904	3.69	241.05	65395
2000-01	22.77	18.44	810	6.56	6.41	977	4.48	4.19	936	4.32	295.96	68578
2010-11	27.22	32.48	1193	5.86	8.26	1411	6.90	8.18	1185	4.88	342.38	70091
2013-14	28.53	32.88	1153	5.53	9.67	1750	6.70	7.96	1188	5.01	350.02	69838

Source: MoA, 2014

In the two decades between 1990 and 2010 the area under rice cultivation has remained more or less constant at 22% of the total acreage whereas area under wheat crop has increased from 13% to 15%. During the same period area under coarse cereals however decreased from 19.5% to 14.5% as has area under pulses by approximately 1%. In contrast acreage under 'fruits & vegetables' and oilseeds showed an improvement of about 1.8% and 1.4%, respectively (MoA, 2013b). Between triennium ending (TE) 1970-71 and TE 2007-08 the reduced acreage under food gains has been utilized by increased acreage for the cultivation of oilseeds (4.0%), fruits& vegetables (2.8%), and other non-food crops (7.02%) which is indicative of the shift from food grain (mainly coarse cereals) to high value non- food grain crops (Kanan and Sudaram, 2011).

2. Resource use and status

2.1 Energy

Agriculture in India has witnessed increased cropping intensity, expansion of ground water irrigation, greater use of modern chemical inputs, mechanization and diversification to high value crops over the years. These factors have resulted in a surge in energy use in the agriculture sector, the share of which rose from 2% consumption of commercial energy in 1980-81 to 7% by 2008-09. Direct energy use comprises consumption of diesel & petrol for mechanized applications such as tractors, power tillers in addition to electricity and to a lesser extent diesel for water pumping. Indirect energy consumption refers to the energy consumption by way of use of fertilizers and pesticides (Jha, I 2012).

Increase in operation hours of pump sets and use of tractors are the main activities associated with increased energy consumption in the agriculture sector. As the net irrigated area increased from 38.72 million hectares in 1980-81 to over 63 million hectares post 2010 (Gandhi and Namboodhari 2009), the number of diesel pump sets more than doubled from approximately 31.01 lakh in 1982 to over 67.83 lakh in 2011. More significantly the numbers of electricity pump sets in use more than quadrupled during the same period from 35.68 lakh to 167.60 lakh (MoP 2011; TERI 2014). The number of tractors in use has also increased from 76.88 thousand to 6.07 lakhs in between 1985-86 to 2011-12 whereas number of power tillers rose from 3754 respectively and 60 thousand during the same years (TERI 2014). This has led to diesel consumption to increase from 1.01 lakh tonnes in 1980-81 to 112.12 lakh tonnes in 2009-10 which is characterized with a major spurt in use between the period 1990-91 and 2000-01. On the other hand electricity consumption increased significantly between 1980-81 (14489 GWh) and 2000-01 (84729 GWh) thereafter increasing at a slower pace to 2009-10 (120209 GWh) (Jha, et al, 2012). Electricity consumption within the agriculture sector made up approximately 19% of the total electricity consumption in the nation in 2010-11 although in the year 1998-99 its share had crossed 31%. The consumption of fertilizers in (MT of nutrients) also displayed a jump from 5.51 MT in 1980-81 to 28.12 MT in 2020/11 although it decreased slightly to 25.53 MT in 2012-13 (TERI 2014).

There is a government thrust towards farm mechanization as seen in the development of the National Mission of Agriculture Mechanization of 2011. One of the objectives is to provide small and marginal farmers access to farm equipment and implements through custom hiring services which can help improve productivity, save on labour costs and time.

2.2 Water

The agriculture sector in India consumes 89% of the total available water resources in India (Grail Research, 2009). Utilizing surface water by way of canals and tanks or ground water through wells, the agriculture sector is by far the largest consumer of this resource. Given the challenges faced by surface water irrigation and in the view of pumping technologies available to farmers, cheap electricity and agricultural credit, ground water irrigation has witnessed dramatic increase over the years. Net irrigated area under tube wells and other wells increased from 17695 thousand hectare in 1980-81 (45% of the net irrigated area) to 39042 thousand hectare in 2009-10 (62% of the net irrigated area) (Gandhi and Namboodhari, 2009)[1]. In contrast canal irrigation decreased from 39.49% to 26.39% of the net irrigated area between 1980-81 and 2009-10 whereas tank irrigation reduced from 8.22% to 2.5% (Gandhi and Namboodhari, 2009; TERI, 2009),[2].

The stage of ground water development in India is 61% (2009)[3]. Estimates suggest that ground water not only caters to approximately 60-70% of irrigated area, it also provides for 70-80% of the agricultural output (Gandhi and Namboodhari, 2009; Dains and Pawar, 1987). The proliferating tube well culture and increasing depth of water extraction has led to the over-exploitation of ground water resulting in declining water tables as well as deteriorating quality of water.

2.3 Soil

Indian Council of Agricultural Research (ICAR) has classified India into eight major groups of soils viz. laterite, red, alluvial, black, mountain, desert, saline and peaty & marshy soils. Out of the total area, alluvial soils cover 33.5%, red Soils cover 26.8% and black soils cover 16.6% area. These three categories alone cover more than 75% of the total area (Pal 2013). Alluvial soils are mostly found in the states of Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal, Assam, parts of Orissa and delta regions of Southern India (Beniwal 2013). Areas under black soil include Maharashtra, West Madhya Pradesh, parts of Andhra Pradesh, north Karnataka, parts of Tamil Nadu and Rajasthan. Red soil covers Tamil Nadu southern Karnataka, parts of Madhya Pradesh, Maharashtra, West Bengal, eastern Rajasthan and north eastern states. Laterite soils are found in parts of Assam, Karnataka, Tamil Nadu, Andhra Pradesh, Madhya Pradesh and Kerala. Desert soils are found in arid and semi-arid regions of Rajasthan, south Haryana, Punjab, and north Gujarat. Mountain soils are majorly found in Assam, Kashmir, Sikkim and Arunachal Pradesh. Saline soils cover parts of Gujarat, Rajasthan, Punjab, Haryana, Uttar Pradesh and Maharashtra. The peaty and marshy soils are found in Kottayam & Alleppey in Kerala, Coastal Orissa and Sundarbans of West Bengal (Beniwal, 2013). The quality of soil has been deteriorating over the years due to the excessive use of fertilizers, pesticides as well as land degradation (table 5). The NPK

[1] India stat, Statewise Net Area Irrigated by Source Available at http://www.indiastat.com/table/agriculture/2/irrigationbysource19502013/449345/9484/data.aspx;

[2] India stat, Statewise Net Area Irrigated by Source Available at http://www.indiastat.com/table/agriculture/2/irrigationbysource19502013/449345/9484/data.aspx

[3] Dynamic Ground Water Resources of India (as on 31 March 2009), Central Ground Water Board, Ministry of Water Resources, Government of India

consumption has increased from 69.8 thousand ton during 1950s to 27,790 thousand ton in 2011-12[4].

Table 5 States and area affected by soil degradation

	State	Area (million hectare)
Acid Soil	Madhya Pradesh	11.72
	Chattisgarh	10.84
	Orissa	8.67
Saline soil	Gujarat	1.6
	West Bengal	0.44
	Rajasthan	0.19
	Maharashtra	0.18
Alkali soil	Gujarat	0.54
	Maharashtra	0.42
	Tamil Nadu	0.35

Source: NBSS&LUP, ICAR

As per the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), ICAR an area of approximately 120.40 million hectares (DAC, 2012) was affected by land degradation (37% of Geographical Area). This land degradation by various sources includes water and wind erosion 94.87 million ha., water logging 0.91 million ha., soil acidity 17.93 million ha., salinity 2.73 million ha, soil sodicity/alkalinity 17.93 million ha and industrial waste 0.26 million ha (DAC,1012). Acid soils in India cover about 89.94million hectare area (Jehangir, 2013).

General practices harming soil include deforestation, overgrazing by animals, faulty methods of agriculture, erosion caused by rivers, removal of top soil for bricks, pots, tiles etc. and certain practices of shifting cultivation. Such harmful practices usually end up causing loss of cultivable lands, reduction in the soil fertility, increased run off, siltation in rivers and may at times cause a river to change its course and also reduces percolation of ground water.

3. Key issues and challenges related to resource efficiency in agriculture

- Climate change poses a significant challenge. Evidence from the last three five year plans (FYPs) suggests a shift towards drier and warmer conditions along with monsoon disturbances such as lower mean rainfall as well as higher variability in rainfall (GoI 2013a). Besides warming trends, occurrence of extreme weather events is also on the rise in India. Therefore climate change can impact agricultural production by presenting reduced water availability for irrigation and increasing

[4] The Fertilizer Association of India

temporal and spatial variations in water availability, increasing intensity and frequency of floods and droughts, causing soil erosion etc. There is already evidence of decreased wheat and paddy yields due to temperature rise, reduced rainy days and water stress (MoA, 2013a).

- Whereas the agriculture sector utilizes over 83% of the available water resources, estimates suggest that by 2050 water availability for agriculture will reduce to 68% due to demand from other sectors. (MoA, 2013a).
- India has low water use efficiency in irrigation. For surface water irrigation it stands at only 35-40% while for ground water it is 65-75%. Inefficient water use during irrigation, especially surface water irrigation results in water logging and soil salinity (MoA, 2013a). The XII Five Year Plan also states that water use efficiency in agriculture at 38% is one of the lowest in the world in comparison to 45% in Malaysia and Morocco and 50–60% in China, Israel, Japan and Taiwan.
- Area under canal irrigation has stagnated. Lack of investment in canal infrastructure, absence of proper maintenance of canal and distribution systems, incompletion of projects, uneven distribution of water and lack of rational pricing for canal water are major problems. These problems alongside the provision of subsidized or free power to farmers have resulted in expansion of groundwater irrigation.
- Subsidy policies encourage overuse of chemical fertilizers as well as power to draw ground water (GoI, 2013a)
- Provision of free or highly subsidized power to farmers has resulted in tremendous increased energy consumption for ground water irrigation. It is also responsible for over-exploitation of groundwater in the Green Revolution belt (Columbia Water Center 2012). Depletion of water tables in turn results in greater electricity utilization for pumping water from greater depths.
- Since the subsidized nature of the power results in financial loss for electric utilities and state governments, supply of poor quality of power and load shedding is common, impairing pump operating efficiency. Off peak supply also leads to concentrated demand and transformer burnouts due to poor maintenance. In some cases it has been observed that free electricity is captured by a few farmers with large landholdings farmers or is invariably stolen by non-agricultural consumers (Swain and Charnoz, 2012).
- Over-exploitation of ground water resources has led to ground water scarcity and has reduced ground water quality. Out of the over 5000 administrative units assessed by the Central Ground Water Board, 802 units are categorized as over-exploited, 169 as critical and 523 as semi-exploited[5]. According to a study in 2010, 60% of India's ground water resources will be in a critical state in approximately 20 years (World Bank, 2010). An annual ground water decline of 4 cm has been occurring since the last decade causing drying of rivers and wetlands besides contamination of ground water with arsenic fluoride and other toxic elements (GoI, 2013a). Furthermore the states in the north western part of India including Punjab and Haryana which epitomized the nation's green revolution exhibit extreme ground water exploitation.

[5] Dynamic Ground Water Resources of India (as on 31 March 2009), Central Ground Water Board, Ministry of Water Resources, Government of India

Here an average decline of 33 cm per year from 2002 to 2008 has been estimated using satellite measurements (Rodell, et al, 2009).

- Soil erosion and land degradation are the major challenges in India. Soil erosion has also led to the degradation of arable land (MoA, 2013b). The low soil organic carbon pool in the soils of India is somewhat due to the severe problem of soil degradation.
- Almost 1 mm of topsoil is annually lost due to soil (mostly water) erosion at an average rate of 16.4 tonnes/ha/year, which translates to an annual soil loss of 5.3 billion tonnes through erosion (Lenka 2015). While problems of soil alkalinity and salinity have affected an area covering almost 6.727 million hectare (Jehangir 2013). At present more than 90% of land area covering the north eastern states itself is affected by soil acidity.
- Excessive use of pesticide and fertilizer use has led to pollution of surface water bodies (through run-off) and leaching into ground water (ENVIS 2009). Crops just require and utilize 25% to 71% of total nitrogen fertilizers that are applied. The rest of it either stays in the soil or is usually lost from the soil-plant system through leaching, ammonia volatization or denitrification. A substantial quantity of the fertilizer that is applied move into deeper layer of soil as nitrate due to percolation and eventually fuses with the groundwater polluting it (Ramakrishna 2012).
- Imbalance in nutrient use (high level of nitrogen application has skewed the NPK ratio in soils) and decline in organic matter in several parts of the country has led to nutrient deficiencies, decline in carbon content and loss of soil fertility. Decrease in soil carbon also leads to lowered fertilizer use efficiencies (MoA, 2013b). Nitrogen fertilizers are essential for plant growth and are usually used in high quantities. The recommended ratio between N, P and K is 4:2:1 while in 2005-06 the actual ratio in India was 7:3:1(Ramakrishna, 2012).
- In the recent micronutrient analysis done on soil and plant samples collected from all over India indicates that almost 49 % of soils across India are potentially deficient in Zinc, 33% in Boron, 12% in Iron, 11% in Molybdenum, 5% in Manganese and 3% in Copper (Singh, 2008).

4. Institutional Framework

4.1 Policy agencies

The Ministry of Agriculture is responsible for formulation and implementation of national level policy and programs for agricultural growth and optimum use of natural resources involved. Amongst the three departments under it the Department of Agriculture and Cooperation (DAC) is involved with strategic planning, program design and implementation in relation to growth and development specifically of the agriculture sector. The other departments under MoA are "Department of Animal Husbandry, Dairying and Fisheries" and "Department of Agriculture Research and Education (DARE)". The former is involved in livestock production and management as well as dairy and fisheries development whereas the latter is responsible for coordinating and promoting agricultural research[6]. The Ministry of Water Resources is also involved in design and development of irrigation in the country.

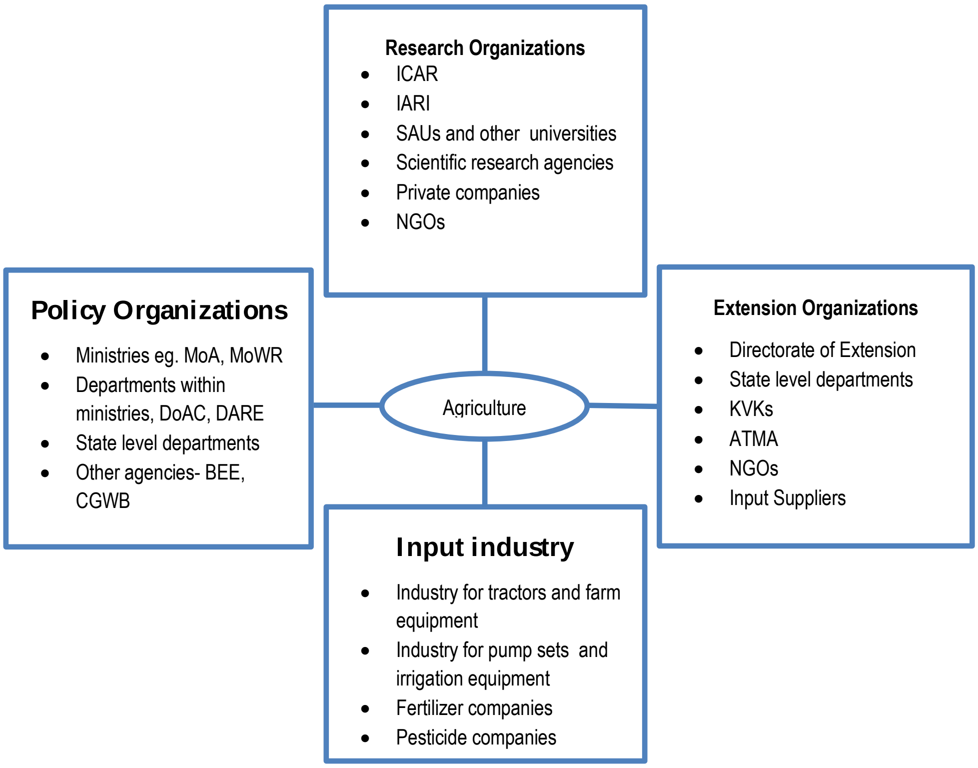

Figure 1 Overview of the key actors in the agriculture domain

4.2 Research and extension

The Indian Council for Agricultural Research, is associated with planning, promoting and coordinating education, research and its application in agriculture and its allied sectors[7],[8]. State agricultural universities (SAUs) also undertake state relevant agriculture research, development and education[9]. Agriculture related research supported by agencies such as DST and DBT is also undertaken in other scientific organizations. Private agency involvement in agriculture research and development (R&D) is significant. Research by private companies spans the spheres of agriculture biotechnology, hybrid and genetically modified seeds, plant breeding, plantation crops, agrochemicals, mechanization and irrigation. Non-governmental organizations also involved in agriculture R&D. [10]

The Directorate of Extension resides in DAC that is responsible for extension management and training, providing farm information in addition to providing assistance to state

6 Entrepreneurship in Agriculture & Allied Sectors, Agricultural sector, organizational framework; http://www.archive.india.gov.in/business.gov.in/agriculture/organisational_framework.php
7 Indian Council for Agricultural Research, Our Mandate, ICAR, http://www.icar.org.in/en/mandate.htm
8 Indian Council for Agricultural Research, About us, ICAR, http://www.icar.org.in/en/aboutus.htm
9 T. Balaguru, National Agricultural Research System in India: History, Vision, Mandate, Organization and Functions, India NARS. Available at http://aiasa.in/aiasa77/sites/default/files/public/publications/NARS-India.pdf
10 T. Balaguru, National Agricultural Research System in India: History, Vision, Mandate, Organization and Functions, India NARS. Available at http://aiasa.in/aiasa77/sites/default/files/public/publications/NARS-India.pdf

extension. Line departments across agriculture, horticulture and animal husbandry at the state level, ICAR's Krishi Vigyan Kendras (KVKs) and State Agricultural Universities are the primary public institutional arrangements for extension alongside the relatively recently established National Mission on Agricultural Extension and Technology (NMAET). In the private domain, non-governmental organisations (NGOs), input suppliers and dealers, agri clinics and business centers, private companies involved in agri-business are now significant entities in extension services. Media based extension service delivery is also an evolving sphere[11].

4.3 Agricultural Input Industries

The agriculture inputs sector caters to supply of seeds, agrochemicals and machinery. The agriculture machinery industry in India consists of small industries, medium and large scale industries besides village craftsmen. Small scale industries manufacture bulk of the necessary agricultural machinery ranging from ploughs, seed drills, harvesters, threshers to plant protection equipment as well as diesel engines and irrigation pump sets. Medium and large scale industries also manufacture irrigation pumps, sprayers and other such equipment alongside tractors, power tillers and land development equipment. Shakti Pumps, CRI Pumps and Oswal Pumps are some of the manufacturers of pump sets in India. Mahindra and Mahindra, Tractor and Farm Equipment Limited and Sonalika International Tractors Limited are some of the leading tractor manufacturers in India. There are about 75 private companies involved in manufacture of micro irrigation (MI) systems. Jain Irrigation Systems and Kisan Irrigation are some examples. Farm machinery training and testing centres have been established by the government of India for training, testing and promotion of quality farm machinery.

Agriculture being one of the major sectors in India has led to the successful development of fertilizer sector in the country. Currently, there are 56 large scale and 72 small and medium scale fertilizer units in the country. The total installed capacity of fertilizer production in 2012 was noted to be 56.19 lakh MT of phosphate and 120.41 lakh MT of nitrogen (DoF 2013). Major players under public sector undertaking include i) National Fertilizer Limited (NFL), one of the major Indian producer of organic fertilizers, chemical fertilizers and industrial chemicals; ii) Rashtriya Chemical & Fertilizers Ltd. (RCF), is the fourth largest Urea manufacturer in India; and iii) The Fertilizer and Chemicals Travancore Limited (FACT). Other than the above mentioned major players, "Projects and Development India Limited (PDIL)", another public sector undertaking, is an engineering as well as project management consultancy providing the various services starting from concept to commissioning for fertilizer and allied chemical (Mathur, 2001). The major player in the cooperative and private sector include Indian Farmers' Fertilizers Cooperative Limited (IFFCO), Krishak Bharati Cooperative limited (KRIBHCO), Coromandel International Limited, Gujarat State Fertilizers and Chemicals, Chambal Fertilizers & Chemical Limited, Deepak Fertilizer & Petrochemical Corporation Limited and Zuari Agro Chemicals Limited.
According to the Directorate of Plant Protection, Qurantine & Storage statistics, the production capacity of pesticides has been noted to be more than 139 thousand metric

[11] Department of Agriculture and Cooperation, Policy Framework for Agricultural Extension, Extension Division, Ministry of Agriculture, GoI.

tonnes annually with over 4000 formulation units and more than 219 technical grade/ manufacturing units. Some of the major players in pesticide manufacture in the country include United Phosphorus Limited (UPL), Rallis India Limited, Gharda Chemicals Limited (GCL), Excel Crop Care Limited, Dhanuka Agritech Limited, Insecticides (India) Limited and Sabero Organics Gujarat limited (MoA 2011).

4.4 Energy domain

Initiatives to rationalize electricity demand and improve energy efficiency in the agriculture sector have been undertaken by the centre and the state governments in India. At the national level an Agriculture Demand Side Management Program was conceived which was characterized by technology upgradation approach. The Bureau of Energy Efficiency (BEE) under the Ministry of Power was established to plan, manage and demonstrate programs for energy efficiency and conservation in India through developing a policy framework and institutionalizing energy efficiency services in India. BEE leads the Agriculture Demand Side Management program that was launched to reduce power consumption in the agriculture sector by replacing inefficient irrigation pump sets with efficient ones thereby improving ground water extraction efficiencies and subsidy burden of states (BEE, 2009). Manufacturers of energy efficient pumps provide the requisite technology. The implementation of the program at state level involves electricity utilities or electricity distribution companies (Discoms) and or an Energy Distribution Company (ESCO) who fund and manage the activities involved in the program. Some part of the work may be outsourced to a program contractor. Financial institutions are usually roped in to facilitate credit to the agency involved in managing and implementing the project. Monitoring and verification agencies may also be appointed to review the program (BEE 2009).

State governments are key players in the energy-water nexus as it pertains to agriculture mainly as a result of the policy that provides free or very highly subsidized power to farmers. At the state level few state governments have tried various measures for energy conservation and enhancing energy efficiency during irrigation but these have had limited scope (most of them being pilot programs) and limited if any success except for an exception or two (for example, Jyotigram scheme). Some of these measures include raising tariffs, installing meters to meter the electricity consumption and charge farmers on that basis. Some state governments have also tried to devise individual schemes to technology up-gradation and enhance pumping efficiencies (Swain and Charnoz 2012).

The industry is involved in the manufacture of agricultural machinery like tractors, pumpsets and micro-irrigation systems. Its description has been provided in the previous section Agriculture Input Industry.

4.5 Water domain

The Ministry of Water Resources frames policy and programs for the development and governance of water resources of the nation. In relation to agriculture development, the ministry is responsible for guiding and monitoring major and medium irrigation projects as well as policy design, planning and guiding minor irrigation projects and command area development program. The ministry is also assigned to plan and regulate ground water resources, providing support to states for ground water development[12]. It also promotes participatory irrigation management in states.

Irrigation is a state subject and therefore the formulation and implementation of minor irrigation schemes are more in the realm of the farming community, NGOs, panchayats and state governments. Furthermore, whereas surface water schemes are publically funded both by central and state government, development and financing of ground water resources has been anchored mainly in the private domain (farmers, industry, NGOs). In contrast the main function of central and state ground water departments has been in the realm of Research & Development (GoI, undated). The Central Ground Water Board however is still responsible for the regulation and control of ground water resource\ development and management which it undertakes through the Central Ground Water Authority[13],[14].

The function of the state level irrigation/water resources departments are dependent on the schemes being undertaken by the state although their work is largely orientated towards construction work rather than management of irrigation systems and extension (MoWR 2011). Some states have also constituted the Command Area Development Authority to undertake implementation of works under the Command Area Development and Water Management Program that seeks to bridge the gap between irrigation potential created and irrigation potential utilized, improving agriculture production and facilitating participation of non-farmers in irrigation management (MoWR 2013).

Participatory ground water management is implemented in India in various states through the establishment of Water User's Associations that are responsible for irrigation management, maintenance of irrigation systems and fee collection[15]. Participatory ground water management initiatives have involved communities, farmers, panchayats and civil society organizations – either independently or with research institutions to plan and sustainably manage ground water resources in their area (GoI 2011).

The ministry also established Water and Land Management Institutes at 14 locations for building capacities of officials involved in irrigation management and also farmers using a multidisciplinary approach to facilitate efficient as well as sustainable use of water and land resources. Other functions of WALMIs include undertaking action research on issues of water & land management related; activities for promoting optimal use of water and land resources, as well as consultancy services (MoWR 2011).

4.6 Soil domain

Soil and Land Use Survey of India (SLUSI) under the Department of Agriculture is an apex institution in the country for conducting Soil Survey since 1958 (MoA, 2015). Soil & Land Use Survey of India facilitates various types of soil surveys and is engaged in the preparation of district-wise maps of land degradation. The mandate of the organization is to

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[12] Ministry of Water Resources , Functions, http:/ / wrmin.nic.in/ forms/ list.aspx?lid=239

[13] Ministry of Water Resources , Central Ground Water Board, http:/ / wrmin.nic.in/ forms/ list.aspx?lid=243

[14] Central Ground Water Board, Central Ground Water Authority, http:/ / cgwb.gov.in/ CGWA/ about_CGWA.html

[15] Ministry of Water Resources, River Development and Ganga Rejuvenation, Status of Participatory Irrigation Management (PIM) in India- Policy Initiatives Taken and Emerging Issues, http:/ / wrmin.nic.in/ forms/ list.aspx?lid=415&Id=4, accessed on 5th November, 2014

provide detailed scientific database on soil and land characteristic to the various State User Departments for planning and implementation of soil and water conservation in the Watershed base Programme for Natural Resources Management.

The National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), a wing of Indian Council of Agricultural Research (ICAR) is responsible for assimilation, verification and dissemination of information on the nature, extent and distribution of soils in the country. Another wing under ICAR , The Central Soil and Water Conservation Research and Training Institute (CSWCRTI) focuses on evolving strategies for controlling land degradation following watershed approach, tackling special problems such as ravines, landslides, mine spoils and torrents, demonstration of technologies for popularization and imparting training besides developing technologies for water harvesting and recycling (MoA, 2015). Facilities like Forest Survey of India (FSI) and National Remote Sensing Agency (NRSA) play a major role in mapping Indian soils, soil erosion as well as soil degradation.

Agencies including Central Arid Zone Research Institute (CAZRI), a wing of ICAR and Central Soil Salinity Research Institute (CSSRI) are involved in research activities related to soil. They also act as repository of information on the state of natural resources, desertification process and its control and management of salt affected soils and waters, in the form of digital database.

As part of soil extension activities Centre for Soil, Plant and Water Analysis under the Indian Agricultural Research Institute (IARI) offers soil, plant, manure and irrigation water analysis services to the farmers and other clients. A regular Advanced Level Training in Soil Testing, Plant Analysis and Water Quality Assessment is also imparted every year for the scientific and technical personnel associated with soil testing. Soil testing service in India began in 1955-56 with the soil testing laboratory at IARI, New Delhi as the hub to coordinate with all the other soil testing laboratories in the country (IARI, 2010).

5. Policy and Interventions

5.1.1 National Agriculture Policy, 2000

The national agriculture policy seeks to enhance agriculture growth in ways that is balanced, demand driven and based on resource efficiency and conservation, aiming also to foster equity, improve livelihoods and strengthen rural infrastructure. Developed with a twenty year period in mind it describes a wide range of objectives highlighting specific initiatives launched to address these objectives. In relation to natural resource management one of the goals is to achieve sustainable agricultural progress through "*technologically sound, economically viable, environmentally non-degrading and socially acceptable use of natural resources*". Another is to achieve balanced and controlled input use by the combined utilization of biomass, organic and in-organic fertilizers together with the promotion of integrated nutrient management (INM) and integrated pest management (IPM).

5.1.2 National Policy for Farmers, 2007

This policy document underscores the need for equal focus on farmers' income and livelihood in the sphere of agriculture policy on par with agriculture growth and productivity. Policy goals and measures outlined under various themes are done so with the view of improving the economic viability of farming. One of the policy goals is to conserve and enhance the natural resources (land, water biodiversity and genetic resources) relevant for ensuring improved productivity and profit generation for farmers. Measures for enabling water conservation and water use efficiency are described. Various steps for bio-resource conservation are also suggested. Conservation farming and organic agriculture and green agriculture techniques are advocated.

5.1.3 National Mission on Sustainable Agriculture, 2010

NMSA was conceived to orient the agriculture sector towards climate resiliency and ecological sustainability. The document identifies appropriate mitigation and adaptation measures for the larger goals of food and livelihood security as well as economic stability in the nation. Conservation of natural resources and strengthening resource efficiency are identified as objectives to be addressed through interventions on water use efficiency; pest management; improved farm practices; nutrient management, appropriate R&D. Linkages to other National Missions on Water, Green India, Enhanced Energy Efficiency, Solar power and Strategic Knowledge on Climate Change are emphasized.

5.1.4 NMSA Operational guidelines, 2014

Addressing the themes of water use efficiency, nutrient management and livelihood diversification, the emphasis of the NMSA operational guidelines is on rainfed area development, water use efficiency, soil health management and capacity building in face of climate change. Under the Rainfed Area Development Mission, sustainable crop management practices, resource conservation technologies, organic inputs generation, water harvesting are to be promoted for conservation of natural resources. Application of water use efficient technologies and effective water management is envisaged under OFWM program. Soil health management, based on soil fertility maps, soil testing is anticipated through various practices including soil specific crop management/INM practices/organic farming. The National Project on Management of Soil Health Fertility and Program on Organic Agriculture have been subsumed under the Soil Health Management theme of NMSA.

5.1.5 Rashtriya Krishi Vikas Yojna (RKVY) Operational guidelines for XII Five Year Plan, 2014

The main objective of RKVY is to incentivize investment, planning and development for agriculture and allied sectors at the state level in ways that that reflect local priorities as well as agro-climatic conditions and natural resources. Assistance is provided for various activities for improving productivity and infrastructure development for natural resource management. Together the activities may include those related to soil health enhancement and management, decentralized production of organic inputs, soil and water conservation, input quality control labs and minor and micro irrigation.

5.1.6 National Horticulture Mission, Operational guidelines, 2014

This mission aimed at the holistic growth and development of the horticulture sector. Amongst the several mission interventions are those that centre on water resources as well as promotion of INM/IPM and organic farming. There is financial assistance for drip irrigation, water harvesting systems, mulching and INM/IPM, organic cultivation and on farm input generation in addition to organic certification.

5.1.7 National Agroforestry Policy, DoAC, GoI

The new policy on agroforestry, 2014 is designed to provide a new impetus to agroforestry in the country, through appropriate policy, regulations and appropriate institutional mechanism also encouraging industry participation. Given the growing interest of Punjab farmers in agroforestry and its adoption in the state due to presence of wood based industries the national policy is of agroforestry assumes significance for Punjab.

The policy aims to establish an Agroforestry Board/ Mission at the helm to develop strategies and undertake various activities. A mechanism to coordinate with state level agriculture and forest departments is envisaged. Implementation of the several recommendations described in the policy will necessitate state engagement. These include addressing restrictive legislations,[16] creating simple regulations, establishing a secure land tenure system and also identifying species for agroforestry that are exempt from the restrictive state legislations. Decentralized institutions may be considered for regulatory roles so long as their capacities are developed for the same. States will also be involved in development of a database for land records and data collection for an MIS for this sector. Promoting research in ICAR institutes as well as SAUs and integrating agroforestry in state extension services and state led farmer training programs is also has also been emphasised.

[16] Regulations related to restrictions on harvest and transit of trees grown on farms

5.1.8 Minimum Support Price Policy and Procurement policy

MSP is a form of subsidy that ensures guaranteed price for farmers for their produce while procurement policy provides assured markets. These policies established also with the view to maintain food security have incentivized farmers cultivate food grains especially wheat and rice in the green revolution cradle, skewering production patterns to these water intensive crops over other food grains- coarse cereals, pulses- and even oilseeds.

5.2 Energy Domain

5.2.1 Tariff Policy

The Tariff Policy, 2006 takes cognizance of the repercussions of electricity subsidies especially provision of free electricity (wastage of energy resources and ground water exploitation) and puts forward suggestions to rationalize electricity pricing citing reasons of energy conservation and sustainable ground water use. In relation to agriculture it proposes the following measures -to levy reasonable user charges and fix tariffs after considering sustainable ground water use and cost of power supply, metered power supply and use of self-closing load limitors in limited cases, limiting higher subsidies to resource poor farmers and in general limiting power subsidies to pre-defined consumption rates.

5.2.2 National Mission on Agriculture Mechanization, Draft Operational Guidelines, 2011

National Mission on Agriculture Mechanization (NMAM) is aimed at fostering the following outcomes - sustaining the evergreen revolution, reducing drudgery; economize utilization of inputs, energy conservation and others. The objectives are to promote farm mechanization through training and demonstration, bring small and marginal farmers access to farm mechanization, enable custom hiring services including that for hi-tech, high value and hi-productive agricultural machinery, provide financial assistance for purchase of farm machinery, and facilitate post-harvest technologies at the lower end of the spectrum as well as enhance farm productivity through appropriate mechanization.

5.2.3 Agriculture DSM Program

The Agriculture Demand Side Management program commenced in the XI Five Year Plan with Bureau of Energy Efficiency at the helm seeking to establish a policy and institutional framework for encouraging market driven interventions in the agriculture pumping sector and promoting PPP based project implementation. The AgDSM Program facilitates up-gradation of in efficient pump sets, replacing them with energy efficient ones through the public private partnership seeking to effect energy conservation, improved ground water extraction efficiencies, and reduced expenditure on subsidies. Pilot programs have been rolled out in 8 states including Punjab and Haryana. In the current Five Year Plan an energy savings of 0.7 BU has been targeted.

5.2.4 Jawaharlal Nehru National Solar Mission and Solar Pumping Programme for Irrigation and Drinking Water under Off Grid and De-centralized Solar Applications

A scheme for solar pumping was initiated in 1992 by Ministry of New and Renewable Energy (MNRE) for commercializing solar pumping systems in India resulting in installation of nearly 14000 pump sets (MNRE 2014). Post the Launch of the Jawaharlal Nehru National Solar Mission (JNNSM) in 2010, this scheme was merged under the mission. As a part of the phase I of the JNNSM, subsidy of 30% is being provided for the installation of solar pumps whereas in phase II a target for deployment of 25000 solar pumps was visualized (MNRE 2012).

Presently, under the 'Solar Pumping Programme for Irrigation and Drinking Water under Off Grid and De-centralized Solar Applications', that commences from 2014-15 for a five year period, MNRE seeks to install solar pump sets in the country in coordination with Ministry of Agriculture, Ministry of Drinking Water and Sanitation and NABARD. The objectives of the scheme are to develop models for deployment of solar pumps in rural areas and scale up this initiative, utilize the program to support development activities and improve energy access to rural communities. The scheme aims to facilitate the installation of 1 lakh solar pump sets in 2014-15, envisioning the deployment of at least 10 lakh such pumps by the end of 2020-21 (MNRE, 2014).

5.3 Water Domain

5.3.1 National Water Policy, 2012

The national water policy 2012 aims at establishing a unified legislative and institutional framework in addition to a plan of action for water for water management. For water use efficiency and demand side management in agriculture it recommends aligning cropping patterns with natural resource endowments, promotion of micro irrigation, automated as well as local level irrigation techniques, appropriate watershed development and suitable pricing of water. Separation of feeders for ground water pumping for agriculture use is suggested as a means for regulating energy use to mitigate excessive ground water withdrawals.

5.3.2 The National Water Mission (NWM), 2011

The National Water Mission (NWM), 2011 has a mandate to promote water use efficiency and efficient irrigation technologies. Implemented by the MoWR, the NWM has promotion of micro-irrigation techniques like the sprinkler and drip irrigation and incentivizing efficient irrigation practices listed as key objectives. Amongst the research programs undertaken water efficiency is transfer of water efficient technologies to the field and pilot projects at state level for improving water use efficiencies.

5.3.3 The Integrated Watershed Management Programme (IWMP), and Common Guidelines for Watershed Development Projects-2008, Revised Edition 2011

The Integrated Watershed Management Programme launched in 2009 seeks to facilitate the conservation, development and sustainable management of natural resources (soil, water and vegetative cover) in rainfed areas for the purpose of enhancing rural development and livelihoods. The Common Guidelines for Watershed Development Projects, 2008 were drafted for implementation of the IWPM[17]. The revised version of the guidelines proposed state based implementation for watershed development with a 3 phase implementation program across the project duration. The guidelines make a multi-tier and cluster based approach essential to the IWMP program. It also recommends establishing an institutional framework covering national, state, district and village levels for managing watershed development and encouraging people's participation at village level. The program aims to prioritize resource conservation and regeneration whilst promoting farming and allied activities for productivity and livelihood enhancements. Works related to agriculture under IWPM include demonstrations for popularizing new varieties, water saving technologies and improved management practices as well as undertaking activities for soil and water conservation, development of water harvesting structures, nursery raising (NRAA, 2011).

5.3.4 Draft Model Bill for the Conservation, Protection and Regulation of Groundwater, 2011

A draft of the Model Bill for the Conservation, Protection and Regulation of Groundwater, 2011 that puts forward a new legal and institutional framework for sustainability use and equity in groundwater has been developed by the Planning Commission. The bill recommends appropriate strategies for energy pricing and energy rationing in "areas where abstraction of groundwater is above the safe yield in groundwater protection zones" It proposes development of Groundwater security Plans under which it suggests incentives for reducing water-intensive crop cultivation and sanctions against the practice, promotion of micro-irrigation and energy efficient pumps, establishment of artificial recharge structures as well as community based sharing of groundwater. It proposes establishing institutional framework for rural areas with constitution of gram panchayat and block panchayat groundwater committee as well as district and state level advisory committees. Water fee for major and medium irrigation projects as well as groundwater usage is proposed.

5.3.5 Micro Irrigation Scheme (MIS); National Mission on Micro Irrigation (NMMI), XI Five year Plan

A central sponsored scheme for implementation of micro irrigation technology in agriculture, the Micro Irrigation Scheme (MIS) was being implemented in the country since 2005-06. In the XI plan the existing MIS was upgraded to the National Mission on Micro Irrigation (NMMI) (MoWR 2011). The objectives of the proposed NMMI are to expand coverage of micro irrigation technology, improve water efficiency and crop productivity and develop and disseminate micro-irrigation technology amongst others. Financial assistance is to be allocated farmers for establishing micro-irrigation systems at farm level. During 2005-

[17] Department of Land Resources, Integrated Watershed Management Program, Ministry of Rural Development, GoI. Available at http://dolr.nic.in/dolr/iwmp_main.asp

2011 approximately 12.40 lakh hectare (46.45%) and 13.96 lakh hectare (53.55%) have been covered under drip and sprinkler irrigation respectively. Under this Mission it is anticipated that 2.85 million hectare to be brought under micro irrigation resulting in savings in use of irrigation water, fertilizer and electricity as well as increase in production and productivity of crops.[18] Policy makers also intend to have a convergence of the initiatives with those ongoing at DAC and other ministries associated with water harvesting, linking them to micro-irrigation systems to facilitate greater water use-efficiency and returns for farmers.[19]

5.3.6 Command Area Development and Water Management Program

The CADWM program, financed by the center but implemented by states has been conceived to enhance irrigation utilization capacities, improving crop productivity and water use efficiency in irrigated areas. As a part of the XII Five year plan this program may include financial assistance for activities related to on farm developmental work including , micro-irrigation and land leveling in addition to other components such as system deficiency correction, reclamation of water logged areas as well as assistance to WUA and others (MoWR 2013).

5.3.7 Participatory Irrigation Management Program

The Ministry of Water Resources has been promoting Participatory Irrigation Management that seeks to involve farmers in the planning and management of irrigation with the purpose of economizing water utilization in irrigation, enhancing systems operations, facilitating equity in water distribution and improving agriculture production in irrigated areas through encouraging collective responsibility for water resource use by farming community. The Ministry has developed a model act for PIM that it intends for state legislatures to enact through new irrigation acts or revision of existing acts. A legal and institutional mechanism that facilitates establishment of WAU as also agencies at various levels was developed which has been enacted and adopted by various states.[20]

5.4 Soil Domain

5.4.1 Soil and Land Use Survey of India (SLUSI)

Initially called The All India Soil & Land Use Survey the central sector scheme later got renamed as Soil & Land Use Survey of India (SLUSI). Some of the mains objectives are to conduct district based Land degradation Mapping (LDM), detailed soil survey of high and very high priority watersheds in order to provide with database for executing soil conservation measures and monitoring & evaluation studies of watershed development projects with the help of remote sensing and GIS.

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[18] Press Information Bureau, 2010, Govt of India, National Mission on Micro Irrigation (NMMI). Available at http://pib.nic.in/newsite/erelcontent.aspx?relid=62431

[19] Press Information Bureau, 2010, Govt of India, National Mission on Micro Irrigation (NMMI). Available at http://pib.nic.in/newsite/erelcontent.aspx?relid=62431

[20] Status of Participatory Irrigation Management (PIM) in India- Policy Initiatives Taken and Emerging Issues. Available at http://wrmin.nic.in/writereaddata/CAD-WUA-20140331.pdf

5.4.2 National Action Program (NAP) to combat desertification

Under The UN Convention to Combat Desertification (UNCCD), Ministry of Environment Forests and Climate Change (MoEFCC) is the National Coordinating Agency for the implementation of the UNCCD in India. A 20 years comprehensive National Action Programme (NAP) to combat desertification in the country has been prepared with the objectives of community based approach to development, awareness raising, activities that improve the quality of life of the local communities, drought management preparedness and mitigation, research & development initiatives and interventions which are locally suited, strengthening self-governance leading to empowerment of local communities. This scheme was started under Macro Management of Agriculture (MMA) in 2000 but got discontinued in 2014 with the closure of MMA.

5.4.3 Reclamation and development of alkali and acid soil

The centrally sponsored scheme for Reclamation of Alkali Soils (RAS) was launched in the Seventh Five Year Plan for reclamation of alkali oils, which contain Exchangeable Sodium Percentage (ESP) more than 15 and pH more than 8.2. It has been implemented through Macro Management of Agriculture (MMA), from 2000 to 2014. Its main objectives include reclamation and development of the lands affected by alkalinity & acidity; improvement of soil fertility by under taking, appropriate on farm development, application of soil amendments and growing suitable crops and horticulture crops; plantation of suitable fuel wood and fodder trees as per local demand and suiting to soil capability; improving capacity of extension personnel and beneficiaries in various aspects of alkali and acid soils reclamation technology and generate employment opportunities & thereby reduce rural urban migration.

5.4.4 Soil conservation in catchments of river valley project and flood prone river

The centrally sponsored programme of Soil Conservation in the Catchments of River Valley Project & Flood Prone River (RVP & FPR) has been implemented through Macro Management of Agriculture (MMA), from 2000 to 2014. Its main objectives include prevention of land degradation by adoption of a multi– disciplinary as well as integrated approach of soil conservation & watershed management in catchment areas; improvement of land capability and moisture regime in the watersheds; promotion of land use to match land capability; prevention of soil loss from the catchments to reduce siltation of multipurpose reservoirs & enhance the in-situ moisture conservation and surface rainwater storages in the catchments to reduce flood peaks & volume of runoff.

5.4.5 The Fertilizers Control Order, 1985

The Fertilizer Control Order, 1985 which is administered by Department of Agriculture Cooperation, Government of India has been issued under the Essential Commodities Act, 1955. The Fertilizer Control Order lays down as to which substances qualify for use as fertilizers in the soil, product-wise specifications, methods for sampling and analysis of fertilizers, procedure for obtaining license/registration as manufacture/dealer in fertilizers and conditions to be fulfilled for trading thereof etc. Under The Fertilizers Control Order, 1985, a large number of fertilizer samples are taken every year from the stocks of fertilizer dealers to maintain quality control. Also to ensure the supply of quality fertilizers to all the farmers, a strict check is kept over the supply of fertilizers.

5.4.6 Environmental Information System (ENVIS) centre[21]

Realizing the importance of environmental information, the Government of India, in December, 1982, established an Environmental Information System (ENVIS) as a plan programme. The focus of ENVIS since inception has been on providing environmental information to decision makers, policy planners, scientists and engineers, research workers, etc. all over the country. Amongst its various tasks the ENVIS centre handles the issues pertaining to land degradation, soil erosion, soil pollution and degradation.

6. Barriers

The following table identifies and explains some of the barriers in relation to resource efficiency in the agriculture sector.

Barrier	Energy efficiency	Water efficiency	Soil Health	Cross cutting issues
Financial	• Cost of energy efficient pumpsets and solar water pumps; • Lack of adequate finance mechanisms/support for bringing about a shift from traditional pumpsets to efficient pumpsets	Finances for improving and maintaining irrigation systems	• Lack of financial support for management of degraded soils	• Provision of MSP on less popular crops • Insufficient investment in infrastructure for agriculture (Specially at village level)
Technological	• Low quality and intermittent power provided to farmers encourages continuous motor use • Standardized products and quality assurance as well as local manufacturers for solar pumpsets • Inefficient pumpsets	• Maintenance & development of existing canal system/ irrigation channels	• Huge capacity gap in terms of inadequate number of soil testing laboratories.	• lack of storage facilities (especially cold storage) • lack of proper connectivity to and from remote villages • need of more low cost technologies which are economical for small and marginal farmers
Knowledge/ info gaps	• Low awareness amongst consumers about solar pumpsets • Market intelligence for incentivizing private participation in solar pumpset sector	• Promotion and spread of knowledge about water saving Micro-Irrigation methods	• Lack of knowledge amongst farmers about ways to overcome soil micronutrient deficiencies	• Lack of know-how of utilization of newer technology • providing correct market information at user end
Policy and regulatory	• Free or subsidized electricity dis-incentives for farmers to conserve electricity • Bringing about a shift from diesel to solar pumps	• Participatory Irrigation Management • Need to strengthen implementation of watershed development programs	• Inadequate mechanisms to monitor and keep in check soil degradation.	• Enhanced participation of civil society and convergence of IWMP with allied sectors • formation and regulation of farmer co-operatives • Need for a stable and long term national policy on storage and • movement of agricultural produce

[21] http://envis.nic.in/about.html

Barrier	Energy efficiency	Water efficiency	Soil Health	Cross cutting issues
Institutions and capacities	• Effective implementation of a national program through institutional mechanisms is needed • Capacities for maintenance of solarpumpsets	• Gaps in human, technical and capacities for operation and management of irrigation systems	• Lack of soil health clinics where farmers could get suitable solutions to problems relating to soil health.	

Source: Anoop Singh, 2009, A Policy for Improving Efficiency of Agriculture, Pump sets in India: Drivers, Barriers and

Indicators, Climate Startegies. Available at http://www.eprg.group.cam.ac.uk/wp-content/uploads/2009/09/isda_indian-power-sector_september-2009-report1.pdf; GIZ, Indo German Energy Programe, Solar Water Pumping for Irrigation, Opportunities in Bihar India, Indo-German Programme

7. Strategies

7.1 Improving energy efficiency

- Technical options for improving energy efficiency in irrigation include facilitating up- gradation of inefficient pump-sets to energy efficient pump-sets through the AgDSM program that seeks to establish viable models for public-private partnership (BEE 2009). This program undertaken in project mode in 8 states may be expanded to other states after addressing inherent challenges. Programmatic interventions that must be promoted include those that facilitate other DSM measures such as installation of footvalves and/or that of capacitors at motors can also promote energy efficiency at the farmers end.

- Replacement of low tension lines with High Voltage Distribution Systems is another option as it results in improved reliability and quality of power reducing losses which in turn may reduce electricity pilferage, incentivize metering of supply and enhance accountability amongst farmers22. This initiative has been tried in select regions and could be expanded. The AgDSM program by BEE also suggests replacement of low tension lines with HVDS prior to up-gradation of pump sets in the chosen region (BEE, 2009).

- However, in order to achieve the success in the scale up of efforts for fostering energy efficiency in ways which can be sustained, the aforementioned strategies must be complemented with other programmatic initiatives that facilitate provision of quality and reliable power to farmers prompting metering/optimal tariff realization and mitigation of energy wastage in irrigation practices. One way to achieve this is via separation of feeders to segregate power supply of farm and non-farm uses and provide rationed but better quality as well as dependable power

[22] High Voltage Distribution System for Agricultural Pumps– A Case Study, read more at <http://www.powermin.gov.in/distribution/apdrpbestprac/NPCL-HVDS.pdf>

supply at an optimal tariff. The Jyotigram scheme implemented in Gujarat that undertook feeder segregation alongside a watershed development program resulted in sustained metering of electricity, reduction in power subsidies, improved ground water levels (GoI 2013b). Adoption of variants of this scheme after understanding socio-economic and institutional contexts in other states may be of use.

- Promotion and effective adoption of solar pumping systems is necessary as it could facilitate a reduction in diesel consumption in irrigation and therefore savings of a non-renewable fossil fuel. It is estimated that a saving of 9.4 billion liter of diesel is possible over the life of solar pumps in the case of their replacing 10 lakh diesel pumps. However spurring the change from diesel pump sets to environmentally friendly solar pump will necessitate steps to correct market, technological and regulatory barriers (GIZ undated) to make this technology attractive to consumers and greater private participation. Adequate steps must be taken towards ensuring adequate subsidies and easing subsidy disbursement and exploring leasing options; establishing effective finance mechanisms (such as loans for end user and private players) and business models for adoption, , creating market assurance and facilitating appropriate regulatory interventions for ease of market promotion and deployment. (GIZ undated; KPMP and SSEL 2014), Developing standardised products that are also tailored to needs of various farmers groups is important as is developing local infrastructure for maintenance and after sales service (GIZ undated). Awareness programs for consumers and mechanisms to develop market intelligence data for private companies is key (GIZ, undated). However given the increased efficiency of solar pumps, there is a possibility of the unintended consequence that its use could lead to greater ground water exploitation. Hence its deployment must be taken up alongside installation of drip irrigation systems at the farm level .[23]
- There is a need to promote fuel efficient tractors as a part of the drive for farm mechanization in India. It is essential to encourage and incentivize industry to focus on R&D related to improving fuel efficiency of tractors and designing tractor implements of standard quality24 (Mandal and Maity 2013). Awareness and training of farmers for use of appropriate power and implements as well as equipment for specific agricultural activities such as harvesting, treshing and grain separation could also help in fuel saving (NAAS 2008). Development of standards for fuel consumption for tractors could be envisaged.

7.2 Improving water efficiency

- Improving water use efficiency in major and medium irrigation (MMI) systems is vital for reducing water wastage and mitigating excessive ground water exploitation. Strengthening the implementation of schemes such as Accelerated Irrigation Benefits Program (AIBP) and CADWM is essential as is linking CADWM with AIBP to reduce the gap between irrigation potential created and utilized. Modernization of

[23] Katherine Tweed, 2014, India Plans to Install 26 million Solar-powered Water Pumps, IEEE Spectrum, http://spectrum.ieee.org/energywise/green-tech/solar/india-plans-for-26-million-solar-water-pumps

[24] Also see Executive Summary, http://www.dsir.gov.in/reports/techreps/tsr042.pdf

the canal system is also imperative. Alignment of cropping pattern with available irrigation potential for optimal water use is also necessary. Furthermore adequate technical, financial and human resources for operation and maintenance of irrigation systems needs to be provided. It is also imperative to undertake the reform of irrigation departments particularly focusing on skill set enhancement of personnel towards irrigation management roles (GoI 2013b).

- There is a clear need for institutional and management reform for satisfactorily addressing the multidimensional issues leading to reduced water use efficiency and deterioration of MMI systems. The XII Five year plan describes various proposed or recent initiatives – National Irrigation Management Fund, Water Resources Information System, centres of excellence for irrigation management, strengthening the capacities of Water and Land Management Institutes - for dealing with these issues (GoI 2013b).

- Streamlining participatory irrigation management especially by enactment of requisite legislation by states, establishment of WUAs, ensuring monitoring and evaluation is necessary. Ensuring coordination, partnership and accountability between department officials and WUAs farmers as well as incentivizing and rationalizing irrigation fee is also crucial. Data collection and research on irrigation management systems must also receive consistent and ample attention (GoI 2013b).

- Promotion of Micro-Irrigation systems amongst farmers and in command areas is vital. Appropriate encouragement, incentives and subsidies for farmers to adopt these systems is necessary. Furthermore awareness and training by extension services to farmers on deployment and use of these systems must be undertaken. There is a need to leverage Public Private Partnerships for establishing MI systems using cluster approach (GoI 2013b).

- There is a clear need to re-envision the minimum support price policy and public procurement policy for various crops for incentivizing farmers to assume cropping patterns in accordance with groundwater status of the geographical area. Implementation of the policy to procurement of rice from the northeastern states and farmer incentives for growing maize and other indigenous commodities would facilitate a decrease in acreage under rice in Punjab and Haryana that is causing serious ground water exploitation and substantial energy expenditure.

7.3 Strategies for enhancing soil health and conservation

- Amongst the various management strategies to overcome soil acidity, soil amelioration with the help of Lime has been recognized to be effective as it reduces Aluminum, Iron and Manganese toxicity and increases the base saturation, Molybdenum and Phosphorus availability of acid soils. Liming the soils also increases Nitrogen mineralization as well as atmospheric Nitrogen fixation in the acid soils. Other strategies to manage soil acidity include selection of crops that are tolerant to the acidity. Use of crops tolerant to soil acidity in areas where liming is not very economical can lead to increased productivity of acid soils.

- One of the various management strategies is that of Leaching wherein the root zone salinity is reduced to desired levels through the removal of excess salts. Other management strategies include choice of crop, proper seed placement, method of water application and method of raising the plant. The use of mulches is another way to tackle the problem of soil salinity. In this method the upward movement of the salts is reduced by mulching due to decreased evaporation and the addition of organic matter improves physical conditions of soil and more water holding capacity keeps salts in diluted form (Jehangir 2013).

- Management strategies for sodic soils include land leveling and shaping, plant population (increase seed rate and reduce the plant distance), age of seedling, green manuring, continuous cropping, management of drainage and irrigation.

- In general soil management practices include addition of organic matter in large quantities for a healthier soil, increase in on-farm biodiversity, prevention of soil erosion with help of soil mulching and use of green manure (Nicholls 2012).

- To overcome the soil micronutrient deficiencies the application of Basal to soil or use of foliar sprays of Zinc, Boron and Molybdenum, and foliar sprays of Iron and Manganese are usually recommended as the most suitable methods for correcting such deficiencies (Singh 2008).

7.4 Cross-cutting strategies

- Conservation agriculture practices (permanent soil cover, like bed planting, laser leveling and direct seeding)(Friedrich and Gustafson undated) as well as techniques such as System of Rice Intensification (Thyagarajan and Gujja 2013) have been observed to reduce the requirement for water for crop production and improve water use efficiency. Organic farming practices have been observed to conserve water (Pimentel, 2006). Furthermore energy efficiency in crop production is also possible due to absence of/ lowered tillage or reduced irrigation needs in conservation agriculture. Lowered use of pesticides and herbicides and absence of chemical fertilizer use also increases energy efficiency in organic farms (Pimentel 2006). The aforementioned practices are also known to improve soil health and agriculture productivity.

- Mainstreaming sustainable agricultural practices is crucial for resource efficiency and greening of agriculture. The NMSA is a starting point for soil health management and organic agriculture. Promotion of SRI has also been adopted as a strategy for sustainable rice production by MoA. The 12th FYP plan also seeks to promote conservation agriculture. Effective implementation of these programs with centre-state coordination and appropriate monitoring and evaluation of is required. However appropriate policy thrust as well as adequate institutional frameworks and arrangements are needed for mainstreaming sustainable agricultural practices and ensuring effective outcomes. The focus of these must be on promotion of participatory knowledge generation, establishment of appropriate partnerships, support for adequate and timely capacity building (Raina *et al* 2005). A focus on developing extension services and identifying market linkages to cater to farmers involved in sustainable agri-production is vital as is expanding community managed sustainable agriculture initiatives and linking agriculture to livelihood opportunities.

- Farmers in rainfed areas, especially small and marginal farmers, operate under resource scarce conditions but hold the key for sustainable agriculture. Strengthening rainfed agriculture and watershed management are vital for ensuring natural resource conservation and sustainability in agriculture. The ineffective implementation of watershed programs at the grassroots levels, low level of participatory processes, lack of appropriate human resources and usefulness of the NRAA have been some of the main challenges of the IWMP program (Shah, 2008). The Mihir Shah Committee was established to revisit the Common Guidelines for Watershed Development Projects and have recommended various interventions/provisions to strengthen the program. These include strategies for capacity and institution building, increased duration and resources for the program, especially to deploy human resources and establishing a Central Nodal Level Agency and redefining role of National Rainfed Area Authority. Other recommendations involve enhanced participation of civil society and convergence of IWMP with allied programs (GoI 2013b).

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