Management of soil and water resources
For
Sustainable Agricultural Production

Editor

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ATPA

Agrotech Publishing Agency

Udaipur

CONTENT

P R E F A C E

Increase in agricultural productivity through sustainable management of natural resources is the thrust area of Indian Agriculture. The per capita arable land is declining rapidly due to demographic pressure, degradation of soil, non-availability of water in large areas, urbanization, industrialization and conversion of prime agricultural land for non-agricultural purposes. This is coupled with injudicious and imbalanced use of plant nutrients, over-exploitation of ground water resources and inability to conserve soil and water, have resulted in a wide gap between potential and actual yields of major crops in India. Disasters, such as flood, drought, tsunami etc. are also creeping into the agriculture based livelihood systems causing irreparable damage of life as well as the natural resource base.

The country is expected to have the largest human population (about 1.5 billion) in the world by 2030. With 140 m ha net cultivated area and widespread soil related constraints (about 40% degraded area) meeting the food security target of the population could be a problem in the long run.

Land and water are the two major components of environment and one cannot afford to misuse them. Their management has to be planned and implemented in an economically viable and ecologically sustainable manner. Eastern India with states of Bihar, Jharkhand, west Bengal, Odisha, eastern and Central UP, Assam and Chhatisgarh have a high potential of agricultural development and need to be developed as major food producing states. Retrospection on the reasons of under-development compared to other regions of the country will help in taking up suitable corrective steps.

The purpose to bring about this publication was to critically assess the status of the natural resource base of the region and suggest how to build up and improve social capabilities and bring about desired transformations for a better future.

Authors of this book have made invaluable contributions by synthesizing and collating the information of different eastern and north eastern states and highlighting the need of implementing situation specific technology led agricultural innovations to achieve the desired goal of a second green revolution through farmers. Their efforts are gratefully acknowledged. I am especially thankful to my esteemed colleague Dr.Dilip Kr. Kundu, Principal Scientist, CRIJAF (ICAR) for contributing the lead paper on the subject. It is always advisable to use resources, such as soil and water as per their potential in a particular area, using rationally the improved scientific technologies keeping in view the farmers needs and preferences.

It is hoped that this book succeeds in generating and sustaining interest in this challenging but achievable field of natural resource management.

Place------------------------------------
Dr.A.K.Sarkar
Date-------------------------------------
Editor

About the Book

Natural resources management is the key to raise small farm productivity. Sustainability, productivity, income, equity, and livelihood concerns of rural households depend largely on our ability to understand the ground realities, promote land and water conservation measures along with efforts for intensification and diversification of agricultural systems with active participation of farmers. Eastern India, for example, had the highest crop productivity in the country during 1950-51.But,over the years, the situation has worsened, and now the average crop yields, cropping intensity, nutrient use per unit of cropped land and farm profits have declined considerably. This has resulted in great distress among farmers. Small & fragmented land holdings, rainfed cropping, regular occurrence of natural calamities, such as drought, flood, weather aberrations, poor soil health maintenance and faulty water management practices have contributed immensely towards the deceleration of total factor productivity. An effort has been made in the present publication to critically assess and analyse the situation and suggest a “way forward” to revive the situation and move towards a Second Green revolution for a better life and prosperity of our countrymen.

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INTRODUCTION

There is a consensus among planners, administrators and people that a second “Green revolution “is essential to boost the Indian economy and it is possible through the farmers of eastern India. It is also recognised that primarily by managing and improving the soil and water resources, a gradual but distinct transformation can be brought about, which ultimately will lead to the desired goal. Therefore, in the present Book, emphasis has been laid to assess the status of soil and water resources of different eastern states and the area needing attention to derive the best from the present and plan for the future.

Eastern India has a geographical area of 73.60mha, which is 22%of the TGA of India. Out of this, 33.60mha is the net cultivated area, which produces about 58mtonnes of food grainsannually. This production level of less than 2t/ha can be enhance to more than 4t/ha in a decade or so by adopting appropriate corrective measures. The region has alluvial and red soils, which are fertile. Climate of the region is tropical with abundant rainfall(1500mm annually).There are three river basins:Mahanadi,Brahmani-Baitarani and Subarnarekha.Annual utilizable surface water in the three basins is about 8.8Mha-m.The region has good groundwater potential. Total utilizable ground water resource is about 19.5 Mha-m.This ‘Low productivity high potential’ region has majority of resource poor farmers with small land holdings(about 85% of farmers are small & marginal).This region is rich in natural resources with perennial rivers, but has much lower crop productivity compared to many northern, southern and eastern states. Associated with this, fertiliser use for crop production is also fairly low and also imbalanced, which is responsible for low production levels.Globally,it is established that fertiliser use accounts for 40 to 60 % of current food supplies.

Major soil and water related constraints for agricultural growth are soil erosion and degradation,soil acidity,poor status of soil organic matter, soil nutrient deficiencies, inadequate and unreliable irrigation systems, improper utilization of ground water resources and soil and water pollution.

Climatic extremes pose a major challenge for agricultural development in the region. Almost every year, while some part would experience drought and scanty rainfall; another part faces the menace of flood, cycloneetc.These conditions result in crop damage;cropfailure,poor crop productivity, waterlogging and distress among thepeople.Farmers thus are compelled to bear huge losses,due to weather extremes and the risks involved.

The aim of natural resource management should be to reduce and moderate flood, manage drought and control erosion and displacement of soil. Purpose should be to harvest rainwater/ground water for productive purposes, create an atmosphere for enhanced farming activities,lowermigration,create employment opportunities for rural youth through skilful association of crop rotations, market led demand driven agriculture, processing , value addition technologies and conservation of resources available with the farmers.

The renewable fresh water is under relentless pressure. Water stress has increased over the years due to growing population, urbanization, industrialization and agricultural intensification. We are going to see rapid changes in water use in the next few decades, compared to the present, which is 85%for agriculture, 10% for industry and 5% for domestic purposes. Agriculture in most cases shows the lowest return of water in economic terms. The strategy for managing water (Satpathy, 2009) should be twofold: i.to conserve rainwater in the watershed itself for productive use, and ii.to ensure maximum return from the harvested water through its multiple use. It is interesting to note that India has the highest area under irrigation in the world (59 mha), but the average crop yields from irrigated areas is exceedingly low (< 3t/ha).

Integrated and participatory watershed development programme should be the emphasis for resolving soil and water centric issues. The approach towards a successful watershed based farming system approach must integrate the following:i. Land use based on capability ii.adoption of conservation technologies iii.managing soil related constraints for agricultural production iv.rain water storage and re-use v.managing excess water in lowlands vi. Maintaining soil health vii.Checking soil erosion vii.Creating resilience to climatic aberrations viii.Training and empowerment of farmers ix.Meetinginfrastructure, market, storage, transport, and communication needs of the farmers.

Soil resources of eastern India are dominated by Inceptisols (34mha), Alfisols (20mha), andEntisols (14.5mha).Alfisols are common in the hill and plateau region, while in the alluvial and coastal regions, Entisol and Inceptisolsdominate.Managing and optimizing the use of soil resources for sustainable crop production in farmers' fields is a great challenge, which has to be accepted by the scientific community. From the point of view of crops, soil health refers to its ability to sustain productivity on a long term perspective. There is an urgent need for monitoring the soil health indicators and take corrective measures as per need for realising good yields and derive benefits from nutrient use. Indicators of good soil health could be i. Available nutrient status of soil ii.cation exchange capacity of soil iii.organic matter content of soil iv.Soil texture v.soil erosion status vi. Soil related constraints, which affect crop production, such as soil acidity, salinity, alkalinity, water loggingetc. vii. physical and biological environment of soil etc. In practical terms, available nutrients (major, secondary and micronutrients) in soil and its interaction with water determine to a large extent, the use efficiency of both water and nutrients by growing crops. Taking the case of eastern India, the major soil health constraints are: i. Soil erosion in the hills and plateau region ii.Soil acidity (pH <5.5) in north-east, parts of Odisha, WestBengal, Jharkhand & Chhattisgarh iii.coastal soil salinity in parts of Odisha, and West Bengal iv.low organic matter status of upland soils v.widespread deficiency of plant nutrients (P,N,Zn,B,S etc.) in cultivated soils. Soil contamination/pollution is also posing threats to successful agriculture in the region.Theseare: i.excess of Arsenic in soil and groundwater and its adverse impact on human and animal health in the states of West Bengal,Jharkhand&Assam etc., andii.Flouride as well as Iron toxicity in the states of Odisha&Bihar.

Central and State governments are implementing a number of programmes for raising the agricultural productivity in the eastern region. Theseare:RKVY,NFSM,BGREI, NPMSHF etc. In most cases,the approach is not multi-dimensional (concurrent attention to conservation,sustainable use,and equitable sharing of benefits),leading to inefficient and ineffective use of financial and technical resources meant for development .The BGREI (bringing green revolution to eastern India) programme of the Government of India is the latest in this regard, which is intended to address the constraints limiting the productivity of “Rice based cropping systems “so that agricultural productivity is reasonably enhanced and stabilized in these areas. This programme has been designed to improve the infrastructure at individual farmers level coupled with a mix of innovative crop production and protection technologies and appropriate extension support by way of convergence of inputs and services from various programmes and institutions. A critical analysis reveals that all these programmes intends to improve the condition of farmers. But, there is lack of convergence among these programmes. Approach seems to be top-down and not bottom-up.Site-specific needs of farmers are not accounted for.Further, it is not integrated. We talk of farm family, livelihood security, food and nutritional security, sustainability ,environmental protection, climate resilience, waterproductivity,nutrient use efficiency and relate them to farm productivity.These programmes do not take into consideration, the farmer specific needs or “farmers first” as we call it.Second green revolution has to be an integrated concept (as in the case of Green revolution of 1960s). We have to bring about intensification as well as diversification at the level of farmers, train them, strengthen the input supply system, provide them facilities for storage &transport, encourage them for secondary agriculture, and equip them with latest technologies to bring about change.

Keeping an eye on future, it is argued that the drought induced food and water scarcity will become more acute. Technologies on conservation of resources are rarely given much importance in the efforts for technology transfer to farmers of the region. This needs to be addressed to provide solution to farmers on issues like soil and water conservation and management. Farmers prefer low cost, locally available and simple in operation technologies. ITKs of farmers need to be validated and upgraded for reaping the expected benefits. Two approaches needed for scientific technology transfer on natural resource management could be: i.creating a database on soil available nutrients, input supply situation, soil moisture status and cropping system, and ii. development of a Decision Support System (DSS) for real time decision making for farm level activities,such as acid soil management, use of amendments, irrigation water management,nutrient deficiencies in soil,nutrient sources available etc.This with technological backstopping of the Krishi Vigyan Kendras, Agricultural Technology Management Agencies, and Block Agricultural Officers can help in realising our goal.

Dr. M. S. Swaminathan, the architect of the Green Revolution and the first food Laureate of the World Food Prize, in his Acharya N.G.Ranga Memorial Lecture on 9th June,2001 has emphasized the need to bridge the yield gap between potential and actual yields in different farming systems by initiating a systematic effort in each agro climatic zone to identify and remove the constraints responsible for the prevailing yield gaps. He says, the smaller the farm, the greater the need for a marketable surplus to ensure cash income. Some of the measures, he suggests to conserve landare: i. arresting land degradation and the loss of the biological potential of the soil, ii.promoting land and water use on the basis of agro-ecological, meteorological ,and marketing factors, iii.restoring degraded and wasteland through agro-forestry and other appropriate methods of restoring ecology,iv.Launching community centredwaterharvesting,conservation and use programmes to ensure efficient harvest of rainwater and sustainable use of groundwater,and,v.introducing public policies to prevent the diversion of prime farm land for non-farm uses and unsustainable exploitation of groundwater. These observations are of immense practical relevance in present-day agriculture in our march towards sustainable advances in agricultural productivity.

To sum up,“Soil and Water resources management for improving agricultural productivity” provides an insight on the present status of resources available to the farming community of the eastern states, their efficiency/inefficiency in agricultural intensification to boost the farm profits.Suggestions have been provided as to how improvements can be brought about in the region for food security,sustainable food production,poverty alleviation associated with desirable management of natural resources.One has to infuse energy with integration of efforts,quality manpower and knowledge management at different levels to derive the advantage. To make this happen,it is necessary to empower farmers,innovatefarmer friendly technologies for agricultural intensification and to follow a mission mode integrated problem solving approach in technology transfer.

Management of Water Resources for Improving Agriculture in Eastern India

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Introduction

With 4000 billion cubic meters (BCM) of annual rainfall in India, average runoff generated is only 1869 BCM. Due to various constraints about 1122 BCM of water can be put to beneficial use of which 690 BCM is through surface water and 432 BCM by groundwater (CWC, 2010). Declining per capita availability of water, increasing inter-sectoral competition, changing food habits through high-value agricultural crops, adverse climatic variability and existing negative externalities such as declining groundwater table in many pockets of the country, waterlogging and salinity due to excess surface irrigation necessitate reorientation of water management through institutional restructuring, technological interventions and policy changes.

Eastern region, a water resources rich region, is considered to be agriculturally backward because of widespread poverty, low crop productivity and poor irrigation development. Due to poor storage capacity, large area is prone to flood in *kharif* season and drought in *rabi* season. Groundwater development is less than 30% as compared to more than 100% in many pockets of the country. Poor groundwater development coupled with inefficient surface water irrigation compels farmers to depend on rainfall for irrigation and makes agriculture uncertain and risky. There is urgent need to examine water management issues and develop location specific technologies to ensure food security and raise standard of living of the habitants.

Status of water resources in eastern India

The eastern region of India constitutes about 22% of the total geographical area and about 34% of the total population of the country. The climate of the region is tropical hot and humid to sub-humid with high rainfall. The annual rainfall in this region varies from 1091 to 2477 mm with an average of 1526 mm, which is sufficient for growing any crop. Assam gets mean annual rainfall of 2477 mm which is the highest in the region, followed by West Bengal (1750 mm), Odisha (1451 mm), Chhattishgarh (1430 mm), Jharkhand (1277 mm), Bihar (1204 mm) and eastern UP (1091 mm) [Kumar 2012]. Bulk of the rain (about 80%) occurs during the monsoon season. It has erratic temporal and spatial distribution with considerable year-to-year variation. High intensity and heavy rains cause frequent floods in plains and coastal deltaic area of this region. The coastal areas are also vulnerable to seawater intrusion and cyclones.

Table 1. Status of water resources in the eastern region of India (Source: Central Water Commission, 2010)

Particulars	Water availability (BCM per year)		
	Eastern region*	India	Share (%)
Utilizable surface water#	68.9	690.32	10
Available surface water#	31.53	315.98	10
Annual replenishable groundwater resources	130	433	30
Net annual groundwater availability	120	399	30
Annual groundwater draft	36	231	16
Irrigation	31	213	15
Domestic and industrial uses	4	18	22
Groundwater availability for future irrigation	82	161	51
Stage of groundwater development (%)	27	58	-
Total utilizable water (surface+ground) resources	199	1123	18
Ultimate irrigation potential, UIP (000 ha)	33657	139894	24
Irrigation potential created, IPC, up to 10th FYP (000 ha)	21826 (64.84% of UIP)	123336 (88.16% of UIP)	18
Irrigation potential utilized up to 10th FYP (000 ha)	14301 (65.52% of IPC)	91124 (73.88% of IPC)	16
% of net irrigated area in net sown area	35.46	42.15	-

*comprising of West Bengal, Odisha, Bihar, Chhattishgarh, Jharkhand, Assam

#Chopra and Goldar (2000)

Data in Table 1 reveal that the eastern region constitutes about 18% of our country's utilizable water resources (10% of surface and 30% of ground water). An ultimate irrigation potential of 33.65 M ha has been assessed in eastern region as compared to 139.89 M ha for the whole country. Up to the end of 10th Five Year Plan (FYP), 21.8 M ha of irrigation potential has been created in the region. However, utilization of the created irrigation potential (65.52%) is less than the country's average of 73.88%. Further, 64.85% of the ultimate irrigation potential has been developed up to the end of 10th FYP in the eastern region as against about 88% for the whole country. The share of net irrigated area in net sown area in the region is also less (35.46%) than the country average (42.15%). Poor irrigation development in the eastern region is the outcome of poor storage and infrastructure facilities leading to inadequate and unreliable surface irrigation system, meager utilization of groundwater resource and inadequate implementation of soil and water conservation measures in hilly tracts, etc. As most of the cultivated areas in the eastern region do not have provision for assured irrigation, even a short spell of drought adversely affects the stability of agricultural production thereby leading to low productivity. Its overall effect is that the agricultural development is much below its potential, the employment in agricultural sector is limited, and a large proportion of the population still lives below the poverty line. Groundwater development in the eastern region is only 27% as compared to 58% for the whole country while 51% of the total available groundwater for future irrigation (161 BCM) lies in the eastern region. Thus there is ample scope for further exploitation of groundwater resources in the region.

(a) Surface water resources

Total available surface water in different river basins of the country is 188 M ha-m per year. Water resource potential of major river basins of eastern region is presented in Table 2. Three major river basins in the eastern region excluding Assam are Mahanadi, Brahmani-Baitarani and Subarnarekha. The annual surface water available in these three basins is 11.2 M ha-m and the total annual monsoon runoff is 11.7 M ha-m. Annual utilizable surface water in the three basins is estimated at 8.8 M ha-m. It has been observed that due to (i) non-availability of suitable storage sites in hills and plains and (ii) extreme variability in precipitation, which disallows storage of flash and peak flows, all the stream flows cannot be stored in the reservoirs. The live storage capacity under completed projects in the country is 20.65 M ha-m, out of which the share of eastern region is 2.92 M ha-m. The annual per capita water availability in Mahanadi, Brahmani-Baitarani and Subarnarekha basins is 2067, 2388 and 1982 m^3, respectively. Groundwater potential of Ganga, Brahmaputra, Barak and other basins has been estimated at 171725, 27857 and 1795 M m^3, respectively. In Subarnarekha, Brahmani-Baitarani and Mahanadi basins, groundwater potential is estimated at 2185, 5879 and 21293 M m^3, respectively.

Table 2.Water resources potential of major river basins of eastern India

Sl. No.	River basins	Catchment area (km^2)	Water resource potential (Mm^3)		Groundwater potential (Mm^3)
			Average	75% dependable	
1	Ganga-Brahmaputra-Meghna				
	(a) Ganga	>861452	525023	436312	171725
	(b) Brahmaputra-	>194413	537240	491736	27857
	(c) Barak and other	>41723	48357	-	1795
2	Subarnarekha	29196	12368	9855	2185
3	Brahmani-Baitarani	51822	28477	20051	5879
4	Mahanadi	141589	66879	53786	21293

Source: Anonymous (1993)

(b) Ground water resources

The region also has a large groundwater potential. Total utilizable groundwater resource for irrigation is estimated at 19.5 M ha-m year^{-1}. However, average utilization of this resource is only 29%. It varies from 6% in Chhattisgarh and 9% in Assam to 46% in Bihar and 47% in eastern UP. Thus, there is an ample scope for further exploitation of groundwater resource. However, utmost caution is needed in coastal belts to avoid seawater intrusion. In several areas endowed with thick but relatively less pervious clay layer at the land surface (*e.g.* Midnapore district of West Bengal), over-exploitation of groundwater has caused substantial fall in water table. The actual groundwater exploitation level is less than 20% in 25 districts of Odisha, 6 districts in Bihar, all the districts of Chhattisgarh and Assam, 6 districts of West Bengal and 12 districts of Jharkhand (Table 3).

Irrigation status in eastern India

Net irrigated area in eastern India is 14.89 Mha, out of which the net irrigated area of 4.2 Mha is in eastern UP, 2.51 Mha in Bihar, 2.69 Mha in Odisha, 3.91 Mha in West Bengal, 1.26 Mha in Chhattisgarh, 0.20 Mha in Jharkhand and 0.17 Mha in Assam. As most of the cultivated area in the eastern region does not have provision for assured irrigation, even a short spell of drought adversely affects the stability of agricultural production, thereby resulting in low productivity. This has led to agricultural development much below its potential, limited employment in agricultural sector, and a large proportion of the population below poverty line with high incidences of malnutrition. On an average 60% of the created irrigation potential is utilized for irrigation. In Assam and Jharkhand states, utilizable irrigation potential is below 50% level.

Table 3. Irrigation status in eastern India

State	Irrigation status					Ground water	Ground water
	Irrigation	Net	% Utili-	Irrigated	Source wise irrigated		

	potential created (Mha-m)	irrigate d area (Mha)	zation	area in rabi (Mha)	area, % of total irrigated area			resource (Mha-m)	developme nt (%)
					Canal	Well	Others		
West Bengal	4.94	3.91	79.08	1.91	23.5	57.6	18.9	2.31	38
Bihar	4.55	2.51	55.20	1.03	28.4	54.0	17.6	2.70	46
Jharkhand	0.43	0.20	46.30	-	48.9	51.1	-	0.65	33
Odisha	3.62	2.69	74.25	-	64.8	14.8	20.4	2.10	23
Chhattisgarh	1.82	1.26	69.20	0.89	65.2	13.1	21.7	1.61	6
Assam	0.51	0.17	33.33	0.12	87.1	1.2	11.7	2.47	9
Eastern UP	5.88	4.20	71.67	1.68	27.7	68.4	3.9	8.11	47
Eastern India	21.75	14.89	59.78	-	49.4	37.2	13.4	19.95	29
All India	81.10	72.90	89.90	-	30.4	57.9	11.7	36.03	42

Source: Ministry of Water Resources (2000-2001) and Irrigation Departments, Govt. of Chhattisgarh, Assam, Bihar, West Bengal, Odisha, Jharkhand and Uttar Pradesh

Reasons for low groundwater development in eastern India

Singh *et al.* (2009) identified following reasons for low groundwater development in the eastern region of India:

1. In Jharkhand, Odisha and Chhattisgarh states, considerably large areas are under rock zones, which have low water discharge rates
2. Power supply scenario of the region is very poor. In rural areas, power supply situation is still worse than the urban areas
3. Infrastructure facilities developed to utilize vast groundwater potential are inadequate
4. Lack of sound groundwater utilization policies with different state governments
5. In some of the pockets, groundwater is contaminated by arsenic, iron and fluoride.
6. Marginal and fragmented land holdings of the farmers associated with low risk bearing capacity

A substantial scope exists to enhance groundwater utilization in the region for both *kharif* and *rabi* crops for providing supplemental irrigation. This development may be made in phases. The productivity of groundwater can be increased by delivering the well water to fish ponds before utilizing for irrigation. Open-well or tube-well systems should be designed in such a way that their annual yield is equal to recharge. Groundwater for irrigation is more beneficial for low-duty high-value crops because of high energy requirement for lifting of water. Suitable measures should be adopted to recharge the aquifer faster for those regions, which are categorized as white from groundwater exploitation point of view. Such areas are Balasore district of Odisha, North and South 24 Parganas districts of West Bengal, and Gaya district of Bihar. From the point of view of occurrence of exploitable groundwater, the entire region can be divided into five zones:

Zone of groundwater reservoir with ample scope of exploitation. It comprises of alluvium of entire Gangetic plain in the states of eastern UP, Bihar and West Bengal.

1. *Zone of groundwater with hard and consolidated rocks.* It comprises of entire Jharkhand, Chhattisgarh, southern part of West Bengal, western and central parts of Odisha.
2. *Zone of poor groundwater availability.* It comprises of hilly regions of southern Odisha.
3. *Zone of artesian groundwater reservoir.* It comprises of *tarai* regions of Bihar and West Bengal mostly at the foothills of the Himalayas.
4. *Zone of coastal groundwater resources.* It consists of coastal pockets of Odisha and West Bengal.

Groundwater quality in eastern India

Specific problems in groundwater quality identified in some pockets and affected districts in different states of eastern region are presented in Table 4. Groundwater quality is not a problem in eastern UP and Jharkhand states in the region. Excess concentration of iron is observed in 4, 5, 3 and 11 districts in West Bengal, Odisha, Chhattisgarh and Bihar, respectively. Iron problem is also witnessed along the northern bank of Brahmputra in Assam. Salinity problem can be witnessed in coastal areas of Odisha and West Bengal; Durg, Dantewada and Raipur districts of Chhattisgarh; and Begusarai district of Bihar. Arsenic contamination beyond critical level has been reported in Malda, South 24-Parganas, Nadia, Hooghly, Murshidabad, Bardhaman and Howrah districts of West Bengal; Rajnandgaon district of Chhattisgarh; and Bhojpur and Patna districts of Bihar. Problem of excess concentration of fluoride in groundwater is reported in Birbhum district of West Bengal; Bolangir district of Odisha; and Giridih, Jammui and Dhanbad districts of Bihar. Adverse effects of different contaminants are visible not only on the crops grown in the region but also on human beings and animals.

Kundu and Singh (2004, 2006), Kundu *et al.* (2005, 2009a, 2009b) and Panda *et al.* (2009) determined quality of groundwater in inland as well as coastal blocks of Odisha and assessed their suitability for use in irrigation.

Analyses of groundwater quality in Assam (Sarkar *et al.* 2006) showed that high iron content is a problem for its large scale use for irrigation. Occurrence of iron toxicity and high-iron induced P and K deficiency in lowland rice limit crop productivity in irrigated areas. Iron precipitated from ground water used for irrigation often clog soil pores and impede drainage and aeration capacity of the soils, especially heavy-textured soils. To overcome the problem of iron toxicity, following soil and water management practices are suggested: (i) aeration of paddy soil with weeder, (ii) storage and aeration of ground water in a tank for precipitating iron before its use for irrigation, (iii) use of modest dose of lime (Sikka *et al.* 2009).

Table 4: Groundwater quality problems and affected districts in different states of eastern region

Contaminants	Affected states and districts (in part)
West Bengal	
Salinity (EC>3000 µS/cm at 25° C)	Howrah, Midnapore, South 24 Parganas,
Fluoride (>1.5 mg/l)	Bankura, Bardhaman, Birbhum, Dakhindinajpur, Malda, Nadia, Purulia, Uttardinajpur
Chloride (>1000 mg/l)	South 24 Parganas, Howrah
Iron (>1.0 mg/l)	Bankura, Bardhaman, Birbhum, Dakhindinajpur, E. Midnapur, Howrah, Hugli, Jalpaiguri, Kolkata, Murshidabad, North 24 Parganas, Nadia, South 24 Parganas, Uttardinajpur, West Midnapur
Nitrate (>45 mg/l)	Bankura, Bardhaman
Arsenic(>0.05 mg/l)	Bardhaman, Hooghly, Howrah, Malda, Murshidabad, Nadia, North 24 Parganas, South 24 Parganas
Odisha	
Salinity (EC>3000 µS/cm at 25° C)	Cuttack, Balasore, Puri
Iron (>1.0 mg/l)	Balasore, Bargarh, Bhadrak, Cuttack, Deogarh, J.Singhpur, Jajpur, Jharsuguda, Kalahandi, Kandmahal, Keonjhar, Khurda, Koraput, Mayurbhanj, Nayagarh, Puri, Rayagada, Sambalpur, Sundergarh, Suvarnapur
Fluoride (>1.5 mg/l)	Bolangir, Angul, Balasore, Bargarh, Bhadrak, Boudh, Cuttack, Deogarh, Dhenkanal, Jajpur, Keonjhar, Suvarnapur
Nitrate (>45 mg/l)	Angul, Balasore, Bargarh, Bhadrak, Bolangir, Boudh, Cuttack, Deogarh, Dhenkanal, Gajapati, Ganjam, J.Singhpur, Jajpur, Jharsuguda, Kalahandi, Kendrapara, Keonjhar, Khurda, Koraput, Malkangiri, Mayurbhanj, Nawapada, Nayagarh, Phulbani, Puri, Sambalpur, Sundergarh, Suvarnapur
Jharkhand	
Fluoride (>1.5 mg/l)	Bokaro, Giridih, Godda, Gumla, Palamu, Ranchi
Iron(>1.0 mg/l)	Chatra, Deoghar, East Singhbhum, Giridih, Ranchi, West Singhbhum
Nitrate (>45 mg/l)	Chatra, Garhwa, Godda, Gumla, Lohardega, Pakur, Palamu,

	Paschimi Singhbhum, Purbi Singhbhum, Ranchi, Sahibganj
Chhattisgarh	
Nitrate (>45 mg/l)	Bastar, Bilaspur, Dantewada, Dhamtari, Jashpur, Kanker, Kawardha, Korba, Mahasamund, Raigarh, Raipur, Rajnandgaon
Iron (>1.0 mg/l)	Bastar, Dantewada, Kanker, Koriya,
Fluoride (>1.5 mg/l)	Bastar, Bilaspur, Dantewada, Janjgir-Champa, Jashpur, Kanker, Korba, Koriya, Mahasamund, Raipur, Rajnandgaon, Surguja
Arsenic(>0.05 mg/l)	Rajnandgaon
Bihar	
Fluoride (>1.5 mg/l)	Aurangabad, Banka, Buxar, Bhabua(Kaimur), Jamui, Munger, Nawada, Rohtas, Supaul
Iron(>1.0 mg/l)	Aurangabad, Begusarai, Bhojpur, Buxar, Bhabua(Kaimur), East Champaran, Gopalganj, Katihar, Khagaria, Kishanganj, Lakhiserai, Madhepura, Muzafferpur, Nawada, Rohtas, Saharsa, Samastipur, Siwan, Supaul, West Champaran
Nitrate (>45 mg/l)	Aurangabad, Banka, Bhagalpur, Bhojpur, Bhabua, Patna, Rohtas, Saran, Siwan
Arsenic(>0.05 mg/l)	Begusarai, Bhagalpur, Bhojpur, Buxar, Darbhanga, Katihar, Khagaria, Kishanganj, Lakhiserai,Munger, Patna, Purnea, Samastipur, Saran, Vaishali
Assam	
Fluoride (>1.5 mg/l)	Goalpapra, Kamrup, Karbi Anglong, Nagaon,
Iron(>1.0 mg/l)	Cachar, Darrang, Dhemaji, Dhubri, Goalpapra, Golaghat, Hailakandi, Jorhat, Kamrup, Karbi Anglong, Karimganj, Kokrajhar, Lakhimpur, Morigaon, Nagaon, Nalbari, Sibsagar, Sonitpur
Arsenic(>0.05 mg/l)	Dhemaji

Source: Central Ground Water Authority (2010)

Constraints to efficient management of water in the eastern region

A substantial portion of the eastern region comprises of hills and valleys. The intense rains during rainy season generate rapid overland flows on the unprotected hills resulting into sheet, rill and gully erosion. Deforestation and shifting cultivation in the region further accelerate the problems. Water-related constraints are different for different geographical entities. From water management point of view, the eastern region may be categorized into three distinct geographical entities: (i) Plains of eastern UP, Bihar, West Bengal and Assam; (ii) Hilly tracts of *Vindhyas* in eastern UP, Kamoor hills of Bihar, plateau region spread over Bihar, West Bengal, Odisha and Chhattisgarh region; and (iii) Coastal plains of West Bengal and Odisha. Water management related constraints of different geographical entities, identified by Singh *et al.* (2009) are listed below:

(i) Plain Region

1. Groundwater exploitation is low in most of the areas except in a few districts.
2. Field-to-field irrigation is a common practice and control structures are missing.
3. Water-use efficiency of canal water is very low (<30%)
4. Waterlogging and water congestion in canal commands
5. Low energy and input use
6. Large flood-prone areas (>15 %)
7. Resource poor farmers, majority being small and marginal, with no money to invest in water resource development
8. Absentee landlords, sharecroppers not willing to invest in water resource development

(ii) Plateau and Hill Region

1. Probability of drought occurrence is very high (about 50%)
2. Very less irrigated area (10-15% only)
3. Groundwater exploitation is very low (<10%)
4. Resource-poor farmers
5. Fragmented land holdings discourage farmers to invest in water resource development
6. Low crop and water productivity
7. Large-scale migration

(iii) Coastal Plains Region

1. Groundwater exploitation is about 30%
2. Risk of intrusion of salinity due to over-exploitation of groundwater
3. Saline groundwater near the coastline
4. Poor water fall conditions resulting in waterlogging and water congestion
5. Saline soils near the coast
6. Very low water-use efficiency in canal commands

Technological options for efficient use of water in agriculture

In general, the eastern region receives adequate rainfall and has favourable ground water reserve. However the amount and timing of precipitation is highly erratic. Drought is a frequent event in the plateau areas due to erratic distribution of rain. Some areas do not receive enough rainfall, and many areas have scarce groundwater availability. Waterlogging occurs in the deltaic alluvial area near the coast due to high rainfall, reverse flow from canal irrigated high land and the saucer shaped physiographic nature of the land. Large temporal and spatial variations with co-existence of acute scarcity and excess of water call for immediate action. Number of technologies has been developed for efficient use of water resource in agriculture in this region. They include appropriate integrated land and water management practices like (i) soil-water conservation measures through adequate land preparation for crop establishment, rainwater harvesting and crop residue incorporation, (ii) conservation tillage to increase water infiltration, reduce runoff and improve soil moisture storage, and (iii) adequate soil fertility to remove nutrient constraints on crop production for every drop of water available through either rainfall or irrigation. In addition, novel irrigation strategies such as supplementary irrigation (some irrigation inputs to supplement inadequate rainfall), deficit irrigation (omitting irrigation at times that have little impact on crop yield) and drip irrigation (delivering irrigation water to plant rooting zones) can also minimize soil evaporation thus making more water available for plant transpiration. In sandy soils of low fertility, nutrient deficiencies often override water shortage as the main factor limiting crop productivity. Crop growth may be so poor that it can only absorb 10 to 15% of total rainfall, the remaining being lost through evaporation, deep percolation and runoff. The resulting water productivity may be very low as the amount of water required for food production would be higher than the average value of 2000–5000 kg water kg^{-1} food. Under such situations, increasing nutrient supply often leads to an increase in both crop production and water productivity. Fertigation, which combines irrigation and fertilization, maximizes the synergy between these two farm inputs increasing their efficiencies. Some of the selected low-cost and eco-friendly water saving technologies which proved effective in different parts of the region are briefly discussed hereunder.

1. Rainwater harvesting and water conservation technologies

(i). Moisture storage pits technology for coastal areas of West Bengal

The coastal areas of the eastern region, particularly the Sunderban area in south Bengal suffer chronically from scarcity of soft/fresh water. The Sunderban Development Board of Govt. of West Bengal launched a project involving excavation/re-excavation of ponds/tanks for harvesting of rainwater. It was implemented by a local NGO 'Tagore Society for Rural Development'. So far more than 1000 ponds, tanks, canals, nullahs, etc. have been excavated in the agar, Basanti and Gosaba blocks in south 24 Parganas district and water storage capacity has been substantially enhanced. In addition to excavation/re-excavation of ponds/tanks, etc. the society has adopted small plots for introducing 'moisture storage pits technology' in uplands and midlands by dividing large stretches of land into small plots. The moisture storage pits are dug at the lower most corner of each plot to collect runoff rain water. Through farmers' initiative, large number of such runoff water storage pits have been dug all over the islands. The technology has yielded several benefits, viz.

1. improved ground water level in low lands
2. harvested rain water for most part of the year
3. increased irrigation and farm productivity
4. promotion of sweet water fishery
5. creation of employment opportunities

All the Village Users Committees/ Self Help Groups have now taken over the use and maintenance of the community assets ensuring sustainability of the project.

(ii). Rainwater harvesting and water conservation technology in drier tracts of West Bengal

The Heerbandh Development Board in Bankura district, West Bengal introduced this technology to farmers to harvest rainwater excavating small tanks under 30-40 model (i.e. 30 ft x 40 ft plots) on their own land.

Principles and benefits of the technology:

1. During the monsoon season, rainwater is harvested in small tanks dug and used to irrigate the *rabi* season crops. As a result of introduction of this method, an area of about 100 acres has been brought under double cropping- *kharif* paddy followed by low water requiring *rabi* crops like oilseeds.
2. Tube wells sunk in the area 5 years earlier which dried up and rusted due to lowering of water level, have started functioning now due to recharging of groundwater level.
3. Using this technology many farmers are now raising mango orchards to augment income
4. The technology has provided farmers with means not only for a better livelihood but also for water conservation and green cover development.

(iii). In-situ rainwater conservation in paddy fields for multiple uses

DWM, Bhubaneswar standardized the technology for*in-situ* rainwater conservation in paddy fields for multiple uses. In 8% of the total paddy field, small dugout ponds of 2.5 m depth and 1:1 side slope has been found beneficial. The pond is used for short-duration aquaculture during monsoon and its embankment is used for growing horticultural crops. The conserved rainwater in the pond is used for giving supplemental irrigations to *kharif* paddy and irrigating *rabi* crops. Total cost for construction of a pond in 800 m^2 in 1 ha area will be about Rs 67,000/- involving labor input of total 900 man days. The yield of *kharif* paddy increased from 1.8 to 4.9 t ha^{-1}, it also gave fish yield of 1.4 t ha^{-1}. The cropping intensity increased upto 200%.

(iv). Subsurface water harvesting structures for coastal lowlands

High to very high salinity of water is the major constraint to agricultural production in the coastal lowlands of eastern region. Fresh water floats above the saline water below ground in such areas which could be tapped through construction of subsurface water harvesting structures (SSWHS) to meet the irrigation demand of*rabi* season crops as well as pisciculture. To extract water from these structures, pump of capacity upto 2 HP is suitable to avoid saline water ingression into the fresh water layer. The depth of structure should be restricted upto 5 meter below ground within sandy zone. To create a water harvesting structure of 4000 m^3 capacity in an area of 0.1 ha with 4 m depth, 550 man days of labor will be required. Average cost for construction of SSWHS is Rs 14 m^{-3}. It results in higher area of irrigation and higher cropping intensity and crop productivity. Average water productivity of SSWHS involving pisciulture and *rabi* vegetables is Rs 36 m^{-3}. Participatory approach of implementing SSWHS improves the financial status of the poor farmers living below poverty line in coastal waterlogged areas and also gives better employment opportunity.

2. Rainwater conservation and management in sloping land

(i). On-farm rainwater management technology for sloping land:

Rainwater is harvested through construction of small scale water harvesting structures (WHS) called on farm reservoirs (OFR) along the slope of farmers fields. Ground water structures like dug wells and ditches are also excavated to store the runoff rainwater. This technology has been successfully implemented in Keonjhar district of Odisha and Darisai block of Jharkhand.

Benefits of the OFR Technology:

1. The OFR technology helps in conservation and utilization of harvested rainwater. Ground water level in the project area has improved due to recharge
2. Stored water in the OFRs can be used both for saving *kharif* rice during drought and also to raise *rabi* crop, thus increasing cropping intensity

3. The cost of this technology could be recovered by additional income generated from the project in three years with adoption of improved packages of practices for *kharif* paddy and *rabi* crops like gram, wheat and vegetables.

(ii). Rainwater management in Chhattisgarh:

The model of rainwater harvesting in the farm ponds at different toposequeces developed by IGKV Raipur depicted in the figure below may help the rainfed farmers of Chhattisgarh state greatly. Construction of on-farm reservoirs (OFRs) in series from top to lower level, helps in harvesting excess runoff. Water harvested in the OFRs also recharges the ditches, wells and ponds located in the recharge zone. This system may help in drought mitigation in *kharif* and growing second crop in *rabi* season. The impact of water harvesting model on crop productivity and farmers profit is presented in the Table 5 below.

Fig. Location wise on-farm reservoirs (OFR), open dug-wells and ditches at Bagbahara in Chhattisgarh

Table 5. Effect of rainwater harvesting on crop productvity and economic returns from rainfed rice production system (*Source*: Singh et al. 2009)

Year	Rainfall (Jun-Sep) mm	Area served by WHS* (ha)		Rice yield (t/ha)		Cropping intensity (%)		Net return to cost on WHS (%)	
		Rice	Rabi crops	Without WHS	With WHS	Without WHS	With WHS	FP	IP
2000-01	573	-	-	0.53	-	-	-	70	76
2001-02	1144	39.6	15.4	3.20	5.62	-	-	30	105
2002-03	452	45.4	11.8	0.24	5.12	100	126	73	141
2003-04	1359	39.6	15.0	3.04	4.86	105	138	30	70
Total/Average		40.4	11.6	1.72	5.20	103	128	203	392

*Water harvesting structure, FP- farmers practice, IP- improved practice

(iii). Rainwater harvesting technologies for eastern plateau region ('Jaldhar' models)

Located in the eastern plateau region, Purulia district is characterized by soil with low water retention capacity, low and erratic rainfall, undulating landscape with high runoff, high soil erosion and depleted vegetative cover. All these factors have caused frequent water stress/ droughts affecting agriculture. In this soil and agro-climatic situation, rainwater harvesting and moisture conservation through 'Jaldhar 30x40 Model' and 'Jaldhar 5% Model' were found effective and encouraged farmers to adopt the technology in their own fields.

The Jaldhar Models have been designed and implemented by an NGO, PRADAN, working in the dry land plateau areas in the eastern region. They originally designed the model more than a decade back. Since then the model has undergone modifications and its utility has been continually enhanced. These technologies are user friendly and within the financial reach of poor farmers. They have large scale replication potential in water scarce plateau land. Salient features of the Jaldhar Water Saving Technologies are given below.

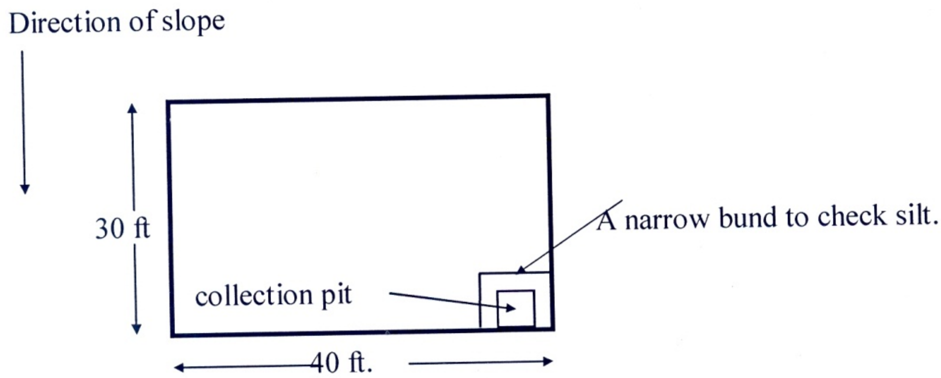
(a)<u>Jaldhar 30x40 model</u>:

Unterraced and unbunded upland with varying degrees of slopes is divided into smaller plots, each 30 ft along and 40 ft across the land slope. Hence each plot will be 1200 sq ft. In each plot, water collection pits are dug at the lowest point of the plot. The volume of each pit is about 100-110 cft. The earth excavated out of the pit is used to construct bunds on the plots. The pit area should not be more than 3-4% of the individual plot. Layout of the plot is designed in staggered fashion as far as possible to facilitate uniform seepage of water collected in the pits across the slopes. This technology helps to arrest runoff rainwater from the plots. The runoff water gets deposited in the pits. The water from large number of such plots travels below the earth downstream to recharge the aquifer. It has made possible growth of permanent agroforestry as well as raising of upland paddy, vegetables, pulses, oilseeds and several other crops.

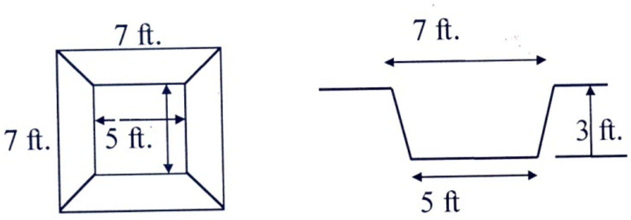
(b)Jaldhar 5% model:

Here water bodies (pits) are dug at the lowest point of each plot covering only 5% of its area. Minimum depth of each pit is 5 ft. But most farmers who are raising a second crop after paddy may choose to dig pits with a depth of even 10 ft. Such pits of larger depths under 5% Model have been preferred for implementation under govt. sponsored programmes like NREGA, RKVY and others.

Design of a plot:



A standard pit design:



Design of the bunds:

Benefits of Jaldhar technologies:

They are user friendly, within the financial reach of poor farmers and have large scale replication potential in water scarce plateau land. Large number of farmers in the drier tracts of West Bengal in the districts of Bankura and Purulia have adopted. With small pits dug in 5% of area of a farm of 1200 to 2000 sq ft may increase farmers income by Rs 15,000 to 25,000 (through intensified cultivation of rice and vegetables). Many farmers have even switched from low yielding *kharif* rice to high value vegetables for higher income. Application of this water harvesting pit technology in large number of contiguous plots enhance moisture regime in the area and often pits at the lower reaches show characteristics of perennial water sources.

(iv). Micro level water resource development through tank-cum-well technology

For rainwater harvesting and utilization, the tank cum well system technology along the drainage line in a watershed is recommended for plateau areas having slope of 2 to 5%. Developed by the Water Technology Centre, Bhubaneswar this technology involves a system of tanks and dug wells in sequence. While tanks store runoff water which is recycled for irrigation, the open dug wells harvest water seeped in from tanks. Application site for the technology should be selected in such a way that the area should have a well defined valley where the runoff flows either as overland flow or channel flow. The well is constructed about 100 to 300 m downstream of the tank to tap the water that is lost by seepage from the tank. A set of 15 tanks and wells is required for a catchment area of 500 ha to irrigate 60 ha area. With an investment of Rs 55,000 ha^{-1} of net command area, it can increase the cropping intensity to 166%. Rs 30,000/- extra gross income/ha/year can be achieved with an additional employment generation of 115 man days. Farmers in Keonjhar district of Odisha have successfully raised a second crop through the irrigation facility created by the harvested rainwater in tanks and wells. Farmers could recover about 80% of total investment on this technology by the second year. This system can be constructed and maintained by locally available skill rendering it easily adoptable.

III. Land shaping technologies for crop diversification

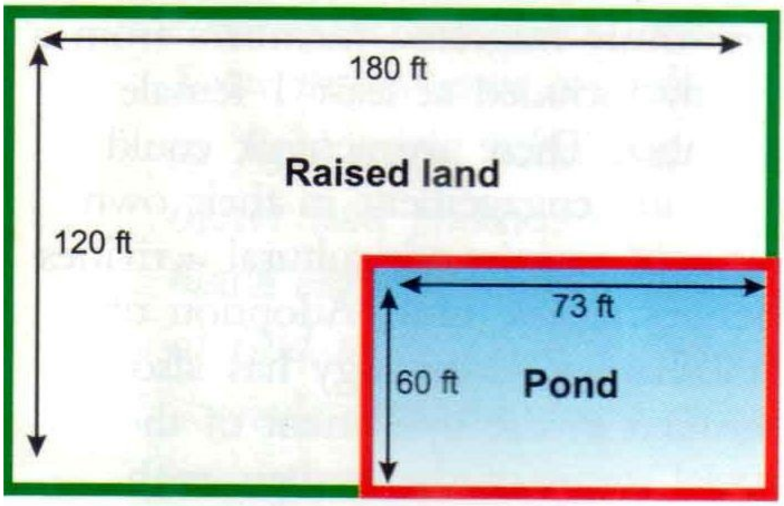
(i). Land shaping technology for lowlying coastal region

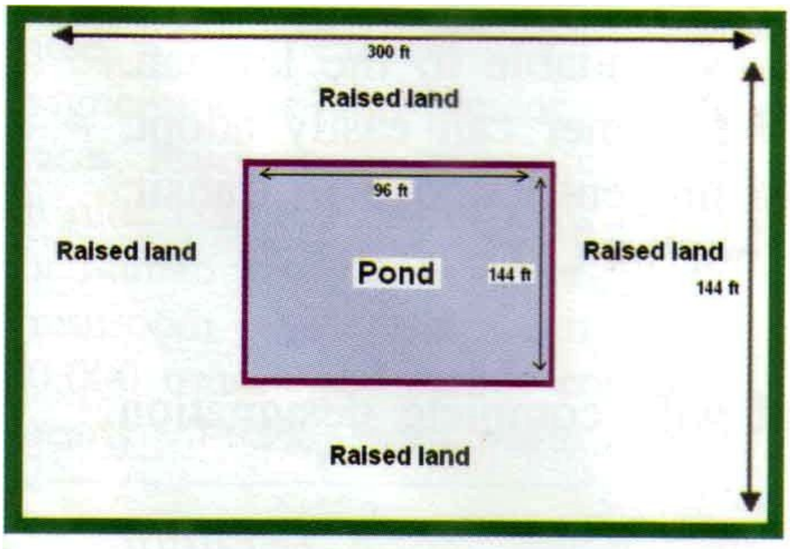
Krishi Vigyan Kendra (KVK) of the Ram Krishna Ashram conceptualized and developed the ‘Land Shaping Technology’ in 1980 to address the twin problems of raising the level of cultivable land and harvesting rainwater in Sunderban area of West Bengal for multiple cropping. Over the years, the technology has undergone modifications and fine tuning through collaborative participation of the farmers and KVK scientists. This is a multi-faced method by which HYVs of rice replaces low yielding indigenous rice in rainy season and makes growing of high value vegetable crops possible during winter season. At the same time, pisciculture and duck rearing in ponds and growing of fruit crop plants are possible on the embankment developed by the dug-up soil.

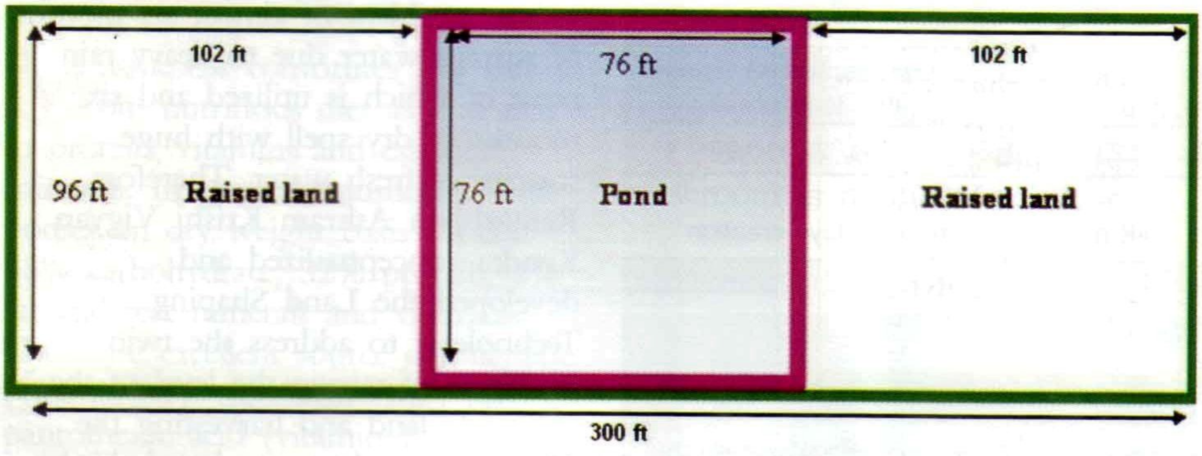
Principles of land shaping:

1. Excavation of 1/5th area of the lowlands up to a depth of 9 ft

2. Height of the adjoining lowland raised up to 1.5 ft
3. Pond embankment dimension: 5 ft wide and 4 ft high
4. Land embankment around the are:a 3 ft wide and 2 ft high
5. About 6 to 9 acre inch of rainwater can be harvested and stored in the pond







Benefits of the technology:

1. Engineering solution for productive use of the lowland
2. Three dimensional (land, water, air) option for cropping
3. Diversified cropping possibilities with integrated approach
4. Introduction of double and triple crops
5. Additional crop in ponds and land embankments
6. Off-season crops fetching higher market price
7. Water and energy saving module

This technology has made significant positive impacts on agriculture, ecology and economy of the coastal areas in Sunderban. Farm income has increased several times. The technology requires an investment of about Rs 20,000/- for a farm of 1.5 bigha (0.2 hectare).

(ii). Raised and sunken bed technology for medium and lowlands

In medium and lowland of eastern India, saturated and oversaturated soil conditions do not permit cultivation of any other crop than lowland rice. Farmers in such areas can hardly grow any other crop than rice. Productivity of water in rice cultivation is very low and rice farming as such is not very remunerative. To make farming more remunerative in such areas, this technology has been developed by Directorate of Water Management, Bhubaneswar. The land is converted into alternate sunken and raised beds (1: 1) each of 30 m length and 5 m width. Different vegetable crops of local importance may be grown on the raised beds. Sunken beds are used for growing lowland rice or other aquatic crops like Colocasia. Fish spawn can also be raised upto fingerling stage in the sunken beds together with rice. Adoption of this technology increased productivity (rice equivalent yield) of farm. Singh *et al.* (2005) reported a 600% enhancement in the productivity of water by practicing this technology at small and marginal farms of Khurda district, Odisha (0.36 kg m^{-3} for rice cropping, and

2.62 kg m^{-3} for diversified cropping). In addition, fish yield of 1 t $ha^{-1}$was obtained. Additional income of Rs 60,500/- per ha per year can be achieved.

Table 6. Water-use efficiency and net water productivity in original and modified lowland at Balipatna block of Khurda district, Odisha

Land treatment and cropping systems	Crop yield (t ha^{-1})	Rice equivalent yield (t ha^{-1})	Water expense (mm ha^{-1})	Water expense efficiency (kg m^{-3})	Gross water productivity (Rs m^{-3})	Net water productivity (Rs m^{-3})
Original lowland						
Rice (Ra) +	4.40	8.18	2,262	0.36	1.45	0.56
rice (Kh)	3.78					
Modified lowland						
Rice (Ra) +	5.40	24.59	2,150	1.14	4.58	2.64
rice (Kh) +	4.85					
pointed gourd +	12.37					
Papaya	4.00					
Rice (Ra) +	5.40	35.75	2,435	1.46	5.87	3.49
rice (Kh) +	4.11					
Cabbage +	26.87					
Snake gourd	20.07					
Colocasia +	42.27	51.16	1,949	2.62	10.50	7.88
pointed gourd +	12.37					
Papaya	4.00					

Source: Singh *et al*. (2005)

(iii) Farm pond based agricultural diversification model for rainfed areas

For rainfed medium and lowland, rainwater harvesting system was designed and agricultural diversification model (on-dyke horticulture, fisheries, cultivation of diversifies field crops, short term fruits like papaya, banana, floriculture like marigold, tube rose etc.) with harvested rainwater was developed by the Directorate of Water Management, Bhubaneswar for small and marginal farmers through multiple use of water. Cost of developing the water harvesting system is about Rs 40 m^{-3}. The model was implemented in Bahasuni watershed of Dhenkanal, Odisha and cropping intensity increased upto 200%. Due to harvesting of spring water and rainwater, irrigated areas of two villages of the watershed increased from 3.2 ha to 26.5 ha, where 55 tribal farm families were benefited. Additional income: Rs 25,000-30,000 ha^{-1}. The technology has been included under the 'National Rural Employment Guarantee Act (NREGA) for implementing in watersheds of eastern states of India.

(iv) Pond based farming system for deep waterlogged areas

Due to poor drainage, saucer shaped topography and high monsoon rainfall, some parts of east coast of India remain waterlogged (>1 m water logging above surface) and unproductive. To stabilize and enhance net income from such waterlogged ecosystem, pond based farming technology (deep water rice in *kharif* + salt tolerant vegetables like watermelon, ladies finger, spinach, chilli in winter + on-dyke vegetables-fruits + fish inside pond) was developed and implemented in deep waterlogged areas (1-2.5 m water depth) of coastal Odisha, India. It increased cropping intensity to 200%, gave water productivity of Rs 7.2 m^{-3} and generated additional income of Rs 25,000 ha^{-1} $annum^{-1}$.

IV. Technologies for conservation of soil moisture and its efficient use

(i) Vegetable cultivation on bunds of paddy fields utilizing retained soil moisture

Bunds or 'ails' of paddy fields are raised and broadened to conserve soil and water. On an average 5-10% of the fields is available for vegetable cultivation. Nimpith Krishi Vigyan Kendra provided technical support to farmers to grow vegetables on the bund or 'ails' of paddy fields. The farmers modified and developed some practices including crop varietal, nutrient use, intercropping and multi-tier cropping system according to their individual situations. Seeing the benefits, farmers of the neighbouring villages have started adopting this technology. An annual income of Rs 15000/- from 1x400 m bund is reported by farmers.

(ii). Zero tillage technology for water management

This technique aims at enhancing and sustaining farm production by conserving and improving soil, water and biological resources. Essentially it maintains a permanent or semi-permanent organic soil cover (e.g. a growing crop or dead mulch) that protects the soil from sun, rain and wind, and allows soil microorganisms to take on the task of 'tilling' and soil nutrient balancing. After harvesting of kharif rice, wheat is sown on the rice field with minimum or zero tillage. This is facilitated by the increased moisture content in the soil due to mulch debris kept on the field from the preceding crop. It also helps minimizing soil erosion.

In a field study on the effect of sowing time and method on water productivity of *rabi*horsegram conducted at Balipatna in Khurda district, Odisha, water productivity was found to be higher under minimum tillage than under no tillage. Then within the minimum tillage treatment, early sown crop recorded higher yield and water productivity obviously due to better utilization of residual soil moisture and/or efficient tapping of water from shallow water table. Thus when irrigation water is not available for raising dry-season crops, early sowing of seeds using minimum tillage can enhance water productivity.

Benefits of zero tillage technology:

1. The zero tillage technology helps in retaining soil moisture content at 26 to 32% which is required for germination of wheat seed within the normal sowing period i.e. in November.
2. Irrigation water can be saved by 25% compared to conventional tillage system.
3. Grain yield also increased by more than 50%.

(iii). Mulching for reducing evaporation loss of soil moisture

Comparative effects of using one 30 mm irrigation and paddy-straw mulch @ 5 t ha^{-1} on field surface on water productivity of sweet potato during *rabi* season were studied at Balipatna in Khurda district. Water productivity of the crop was highest under straw-mulch treatment. While early application of the irrigation water produced moderate benefits, late application of irrigation had no significant effect on tuber yield and water productivity of the crop (Table 7). Use of mulch thus can enhance water productivity several folds during dry season when no irrigation water is available.

Table 7. Tuber yield, water use efficiency (WUE) and productivity of sweet potato in *rabi* season (2002-03) as influenced by irrigation and mulching treatment at Balipatna in Khurda district, Odisha

Irrigation and mulching treatment	Tuber yield (t ha^{-1})	Total ET (mm)	WUE (kg m^{-3})	Water productivity (Rs m^{-3})
No irrigation, no mulch	10.22	366.8	2.79	5.39
One irrigation of 30 mm at 30 DAP, no mulch	14.22	378.8	3.75	9.99
One irrigation of 30 mm at 60 DAP, no mulch	12.40	382.6	3.24	7.42
No irrigation, straw mulch @ 5t ha^{-1}	19.74	362.2	5.45	16.12

Source: Singh *et al*. (2008)

V. Novel irrigation methods and other agro-techniques

(i). Reducing Water Use in Rice Cultivation:

Sustainability of rice production in India is threatened by declining availability of fresh water for irrigation. Irrigated agriculture accounts for about 84% of total diverted freshwater, and more than 50% of the same is used in irrigated rice. It is therefore imperative to reduce water use in rice cultivation and increase its productivity. It is important to understand various ways and means for reducing water use in rice cultivation without impairing yield.

Water use in rice: The dominant system of rice production in India is transplanting in puddled land that is kept continuously submerged with 5-10 cm floodwater throughout the growing season. Water requirement for land preparation consisting of soaking, ploughing and puddling of soil is theoretically 150–200 mm, but it can be as high as 650-900 mm when the duration of land preparation is long, i.e. 24 to 48 days (Bhuiyan *et al.* 1995). Water input during crop growth varies from 500-800 mm to more than 3000 mm. Water outflows from a rice field are evaporation, transpiration, seepage, percolation and surface run-off. Of various outflows of water from a rice field, only transpiration is productive as it directly results into crop growth and yield formation. Seepage is the lateral flow of water through field bunds and percolation is the vertical flow of water to below the root zone. It has been estimated that seepage and percolation together account for 50-80% of the total water input to the field (Sharma 1989) and these flows are unproductive as they do not contribute to crop growth and yield. For a rice crop of 100 days duration, total water requirements vary from 675 to 4450 mm, depending on the season and soil characteristics. Water requirement for rice growing in many lowland areas is 1500–2000 mm.

Irrigation water requirement of rice crop depends on several factors. Soil texture and percolation losses play a major role in this respect. Results of several field experiments conducted in lateritic sandy loam of Kharagpur, alluvial sandy loam of Ludhiana and alluvial loam of Delhi showed percolation loss to be 74, 79 and 71%, respectively of total loss, i.e. ET plus percolation (Prihar and Sandhu 1987). By and large, coarser the soil texture, greater is the percolation loss and irrigation requirement. Total water requirements and specific water use for rice production under different ecologies can be roughly estimated on average (evapotranspiration 550-950 mm crop^{-1}, which is the water actually consumed by the plant) at:

1. Rained upland rice: 5500 m^3 ha^{-1} (evapotranspiration only) for 1.25 t ha^{-1}. Specific water use: 4.4 m^3 kg^{-1}
2. Rainfed lowland rice: 10000 m^3 ha^{-1} (evapotranspiration + impounded rainwater) for 2.5 t ha^{-1}. Specific water use: 4.0 m^3 kg^{-1}
3. Irrigated upland rice: 10000 m^3 ha^{-1} (evapotranspiration + supplementary irrigation) for 2.5 t ha^{-1}. Specific water use: 4.0 m^3 kg^{-1}
4. Irrigated lowland rice: 16500 m^3 ha^{-1} (evapotranspiration + full irrigation) for 4.5 t ha^{-1}. Specific water use: 3.7 m^3 kg^{-1}

Irrigated lowland is the dominant ecosystem, the most productive in terms of yields and specific water use (the most water productive), but is the least efficient if one considers water use per cultivated area or the amount of water required for evapotranspiration divided by the amount of water diverted into the system. Research has concentrated in the past on this ecology where the greatest potential gains could be achieved per hectare and globally. Early research was focused on ways to improve water productivity by developing improved varieties and improving agronomic management, then more recently on improving water productivity (which considers yields or income per m^3 of water consumed) at all levels.

Reduction in seepage and percolation loss: Large reduction in water use in rice production can be achieved by reducing seepage and percolation loss during the crop growth as well as fallow periods. Therefore, most of the field-level water-saving strategies concentrate on the reduction of these losses, which can be achieved by increasing the resistance to water flow in the soil, and by decreasing the hydrostatic pressure of the ponded water. Generally farmers have a tendency to maintain a ponding depth of 10–15 cm which causes large percolation loss of water accompanied with leaching loss of mobile nutrients, especially in light-textured soils. Thus an optimal depth of ponding water needs to be worked out for different locations. While comparable rice yields are obtained with water ponding of 5 and 10 cm, irrigation water requirement is much higher in the latter treatment. Increasing the ponding depth to 15 and 20 cm causes progressive reduction in rice yield, with a marked increase in irrigation water requirement. Decreasing the floodwater depth in rice fields from 5–10 cm to zero reduces the hydrostatic pressure, thereby reduces water loss through percolation. Rice grown under saturated soil culture or alternate wetting and drying (intermittent flooding) treatments will have little water loss through seepage and percolation.

Saturated soil culture and alternate wetting and drying: The 'water-saving irrigation techniques' for rice production aim at reducing seepage and percolation rates by (i) reducing the depth of floodwater in field, (ii) keeping the soil just saturated, or (iii) alternate wetting and drying, i.e. allowing the soil to dry out to a certain extent before re-applying irrigation water. Water-saving irrigation techniques, however, run the risk of reducing rice yield from possible drought-stress effects. Establishment of relationships between water input and rice yield is needed to know the extent of water input reduction without reducing yield and to optimize use of scarce water in rice production. The optimum intermittent period for delaying irrigation and saving of irrigation water in *kharif* rice has been worked out. The optimum period is 2 days for locations with light textured soils, 3 days for locations with medium-textured soils and as high as 5 days for locations with silty loam soils. Intermittent flooding saved 21-66% water as compared to continuous flooded condition. In saturated soil culture, soil is maintained as close to saturation as far as possible by providing shallow irrigation (to obtain about 1 cm floodwater depth) a day or so after the disappearance of standing water. In alternate wetting and drying treatments, irrigation water is applied to obtain 2–5 cm floodwater depth after certain days of disappearance of ponded water.

Both saturated soil culture and alternate wetting and drying treatments resulted in decreased water input but at the expense of decreased rice yield. Saturated soil culture decreased water use by 5-50% (average 23%) but reduced rice yields by 0-12% (average 6%). However, cultivation of rice under saturated soil culture requires good water control and it is labour intensive. It has been found that construction of 120 cm wide raised beds separated by 30 cm wide and 15 cm deep furrows and near-continuous irrigation through the furrows keep the soils of raised beds saturated. Growing of rice on saturated raised beds saved 34% water but lost 16–34% yields compared to that grown under flooded field conditions.

Alternate wetting and drying practices resulted in both water savings and rice yield losses of 0–70% compared with the continuous flooding treatment, depending on the irrigation intervals and existing soil conditions. However, the yield losses are generally smaller than the reduction in water inputs and therefore water productivity is increased significantly. There is a trade-off between land productivity (yield) and water productivity. Data on grain yield of rice, saving of irrigation water and use productivity of applied water under different water management practices (continuous submergence, irrigation supplied 1, 2 and 4 days after subsidence of standing water) were gathered from a field experiment conducted at Balipatna, Khurda district in Odisha during *rabi* season. Saving of irrigation water and enhancement of water productivity were the highest when irrigation water was given 4 days after disappearance of standing water. The yield decrease due to intermittent flooding was not significant.

Aerobic rice: With the development of suitable varieties and improved management practices, there is increasing interest in aerobic rice cultivation. In a field study conducted in Deras Irrigation Command Area in Khurda district of Odisha, grain yields of rice under aerobic condition were 2.57–3.95 t ha^{-1} and there was a yield reduction of 18.7–47.1% compared to flooded condition. Irrigation water input was 540-700 mm under aerobic and 1250 mm under flooded soil conditions. As reduction in water use was more pronounced than that in grain yield, water productivity under aerobic cultivation increased by 22.4–45.0% compared to flooded condition (Table 8).

Table 8. Grain yields of rice and water productivity under flooded and aerobic soil conditions in Khurda district, Odisha, India. Dry season 2007 (*Source*: Swarup *et al*. 2008)

Rice variety	Soil water regimes*			
	Flooded	Aerobic-I	Aerobic-II	Aerobic-III
Surendra				
Grain yield (t ha^{-1})	4.86	3.95	3.62	2.57
Water applied (mm)	1250	700	660	540
Water productivity ((kg m^{-3})	0.39	0.56	0.55	0.48
Lalat				
Grain yield (t ha^{-1})	4.76	3.82	3.60	2.63
Water applied (mm)	1250	700	660	540
Water productivity ((kg m^{-3})	0.38	0.55	0.54	0.49

* Aerobic-I: soil moisture level maintained at 80-90% FC (field capacity) throughout growing season, Aerobic-II: soil moisture level maintained at 60-70% FC (field capacity) during vegetative and 80-90% FC during reproductive stage, Aerobic-III: soil moisture level maintained at 60-70% FC (field capacity) throughout growing season

(ii). Supplemental and deficit irrigation for rainfed areas:

Deficit irrigation, a strategy which maximizes the productivity of water by allowing crops to sustain some degree of water deficit and yield reduction, holds promise for severely water-short areas. The ICARDA studies in Syria have shown that applying 50% of the supplemental irrigation requirement only reduces yields by 15%. For deficit irrigation to function as a realistic strategy, we need to understand better the relationship between yield and water deficit and we need to identify the types of support and incentives that farmers need to adopt the practice. Increased water productivity of field crops in the dry season may be achieved through proper irrigation scheduling at critical growth stages. Extensive experimentation conducted over years has identified critical growth stages of various crops in respect of their water demand (Table 9). Irrigation needs to be applied at critical growth stages of the crops to realize maximum water productivity. Field experiments were conducted by the Directorate of Water Management in Dhenkanal district, Odisha to compare water productivity of maize, groundnut, sunflower, wheat and potato. Among all the five crops, the highest water use was by sunflower crop probably due to its deeper root system.

Table 9. Critical growth stages of selected crops in respect of water demand

Crop	Critical growth stage(s)
Rice*	Transplanting to tiller initiation, panicle initiation to flowering
Wheat	Crown root initiation, booting, milking, grain formation
Maize (*kharif*)	Silking
Maize (*rabi*)	4-5 leaves, knee-high, taselling, silking, grain formation
Sorghum (*kharif*)	Booting
Sorghum (*rabi*)	Vegetative, booting
Pearl millet	Flowering
Pigeonpea	Flower initiation, pod development
Chickpea	Branching, pod development
Kidney bean	Vegetative, flowering, pod development
Green gram (summer)	Vegetative, flowering, pod development
Soybean	Flowering
Sesame	Flowering
Mustard	Branching, siliqua development
Groundnut (*kharif*)	Pegging, pod development
Groundnut (*rabi*)	Vegetative, branching, flowering, pegging, pod development
Sunflower	Vegetative, disc formation, flowering

*For maintenance of submerged soil condition

Source: Yadav *et al*. (2000)

(iii) Practice of mixed cropping system:

A new cropping system of corn mixed with grasses was advanced to make full and efficient use of water in grain and forage feed production practices (Lei *et al.* 2003). The water productivity in the mixed cropping fields of corn-grasses was much higher than those in the fields where only corn or grass was grown. Averaged water productivity was 3.71 kg m^{-3} from the corn and rye mixture fields, 30% higher than that from the plots where only corn or rye had been grown. Averaged water productivity was 4.55 kg m^{-3} from the alfalfa and corn mixture fields, 60% higher than that from the fields where only corn or alfalfa was grown. Under the same conditions of irrigation, yields from the rye and corn mixture plots were increased by 33%, as compared with those from the fields where only corn or rye had been grown. And the yields from alfalfa and corn mixture fields were 61% higher than those from the fields where only corn or alfalfa was grown. The experimental results also indicated that corn and alfalfa mixture cropping is better than corn-rye mixture system. Intercropping of maize, green gram, etc. with jute increased jute equivalent yield and use efficiency or productivity of water in alluvial soil at Barrackpore, West Bengal under deficit moisture conditions (Ghorai et al. 2013).

(iv) Removal of nutrient constraints:

Effects of nutrient-water interaction on water productivity of groundnut crop were studied in *rabi* season. Mean water productivity in irrigated plots was significantly higher than that of unirrigated plots. Both N and P significantly increased water productivity over that of no-nutrient control. Application of N and P together was more beneficial than the application of either of the two or no nutrients. Interaction between irrigation and nutrients had positive effect on water productivity. In another field trial conducted in Khurda district, Odisha water productivity in summer sesame significantly increased with use of recommended fertilizers (Singh *et al.* 2008).

(v) Improved irrigation methods:

The performance of drip and conventional furrow irrigation methods in maize, cowpea, sunflower and tomato was evaluated at Deras Minor irrigation command in Khurda district, Odisha (Mandal et al. 2013). Though the crop yields under drip and furrow irrigation methods were similar, substantial saving of irrigation water was recorded under the drip method. Saving of water under drip against the conventional furrow irrigation method was 29% in maize and 30% in tomato. Use efficiency of irrigation water increased by 36% in maize and 32% in tomato when water was applied by drip than conventional furrow method. About 40% irrigation water in cultivation of medicinal plants stevia (*Stevia rebaudiana* Bertoni.) following rice could be saved in Khurda district, Odisha by practicing drip compared to conventional surface irrigation method (Behera et al. 2012).

(vi). Improved planting pattern:

Field studies on the effect of planting patterns on yield and water use efficiency of groundnut and potato in Khurda district, Odisha revealed that ridge & furrow and paired row planting were superior to the conventional flatbed planting (Mandal et al. 2013). Besides significant increase in pod and haulm yields in groundnut, irrigation water saving was 27% in ridge & furrow and 41% in paired row method of planting compared to the flat bed method. Then the paired row method of planting in potato at 75 cm x 20 cm saved 21-32% irrigation water without reducing tuber yield compared to the conventional flatbed method.

(vii). Integrated farming systems:

Six farming system models for marginal and small rainfed farmers having 0.40, 0.80 and 1.0 ha land holding with only farm pond and farm pond with shallow dug well were evaluated in Chhattisgarh (Ramarao *et al*. 2005). Crop cultivation was done in 88% area of the farm (33% rice, 12% soybean, 2% pigeonpea, 16% tomato/brinjal/okra, 10% green fodder, 1% marigold and 14% drumstick) and the remaining 12% area was for pond, shallow dug well and livestock shed. In 0.40 ha farming system model, average crop production increased to 125% and net return to Rs 11,350-38,322; in 0.80 ha model by 127% and net return Rs 24,390-72,206; and in 1.0 ha model by 137% and net return Rs 35,689-74,238 compared to traditional rice farming. The study further confirmed that in lowland situation, a marginal farmer can earn Rs 11,755 per annum from 0.4 ha area with rice-poultry-fish-mushroom integration as compared to Rs 6,334 per annum from traditional farming.

In lowland farms of Odisha, water is available up to April after rainy season. Paddy-cum-fish culture study revealed that in addition to good paddy harvest, farmers may harvest fish (1.86 t/ha in 180 days) with additional water available in refuge for irrigating rabi rice, green gram, black gram and pumpkin. The cropping intensity may increase from 100 to 200%. Papaya and banana are also grown on embankment of the refuges. The dikes of paddy-cum-fish farm can be utilized for planting of fruit trees, By adopting such models of integrated farming system in waterlogged area, farmers may earn a net profit of Rs 12,038 per year compared to Rs 3,450 per year from conventional cropping system: rice-rice-pulse/maize (Patro *et al*. 1999).

In wetland ecosystem, water productivity can be improved by introducing fishery. With the same quantity of water used in rice cultivation, it is possible to increase the water productivity by several times if it is used for fish production. Conversion of 50% of lowland area prone to waterlogging into pond by digging to

100 cm depth and construction of 2.5 m high peripheral dykes with the excavated soil offer scope for development of a profitable, integrated agri-horti-aquacultural production system. In such a production system, deepwater rice and fish are grown in waterlogged area and ponds, horticultural crops like coconut, papaya, banana, brinjal, ladies finger, etc. are grown on the peripheral dykes, and a low-duty second crop like black gram is grown in lowland during dry season after harvesting of *kharif* rice. In a farmer's field at Khentalo in Cuttack district, Odisha performance of several treatments on water productivity in lowland prone to waterlogging was studied by the Directorate of Water Management. While net productivity of water in traditional deepwater rice cultivation was only Rs 0.46 m^{-3}, it increased to Rs 7.30 m^{-3} for newly developed agri-horti-aquacultural and Rs 8.17 m^{-3} for aquacultural production system (Table 10).

Table 10.Productivity of water in deepwater ecosystem under different uses. Odisha, India

Treatment	Gross water productivity (Rs m^{-3})	Net water productivity (Rs m^{-3})
Rice-fish (with cull harvesting) + black gram + on dyke horticulture	12.52	7.30
Rice-fish (without cull harvesting) + black gram + on dyke horticulture	11.32	6.90
Rice only	0.96	0.46
Fish and prawn culture only (without cull harvesting)	16.83	8.17

Source: Mohanty *et al*. (2008)

Gross annual income from integrated rice-fish farming system model at Gerua, Assam during 2002-03 to 2005-06 ranged from Rs 62,948 to 92,828 per ha with employment generation of 700 man-days, while gross income from sole rice cropping was Rs 25,000 o 30,000 per ha with employment generation of 100 man-days (Pathak *et al*. 2004)

Constraints faced by farmers and their alleviation

Farmers have reported various constraints that bottleneck the adoption of recommended scientific water management technologies in their specific farming systems (Ghosh *et al*. 2005). Following constraints were perceived by more than 80 per cent of farmers:

1. Adoption of soil and water conservation measures requires a community approach, which is still not common in practice as response of community is often poor.

2. Unassured supply of irrigation water in canal command and unpredictable water availability during rainy season hinders adoption of scientific irrigation schedules for different crops.
3. Free-flooding method of irrigation, uncontrolled supply of water in irrigation command often do not allow following the scientific water management practices.
4. There is high initial expenditure to construct water conservation/harvesting structures.
5. Farmers prefer to grow rice crop mostly instead of growing low duty crops because of their marketability and better management practices.
6. Regulation of irrigation/drainage is not feasible at individual level and requires group action.
7. Farmers face difficulty to get inputs like mulching material, lining material, etc.

For efficient management of water in agriculture, farmers' participation through formation of local level water user institutions *viz.*pani panchayat/ water users association (WUA) in the management of irrigation water will be vital. The equity concept of water distribution will assume importance under the irrigation commands. Benefits and cost sharing will form the basis of water distribution in future. The central and state governments in collaboration with other institutions and line departments have already formulated policies for participatory irrigation management (PIM). Overcoming the energy constraints by an individual is a difficult proposition, especially in case of small and fragmented holdings. Formation of farmers' groups in term of pump users group, tube well users group, etc. is of paramount importance in this regard. Participatory operation and maintenance of resources also ensure sustainability.

Conclusions

Formulation of sound strategy for efficient management of water resources to improve agricultural production in the eastern region will require addressing of the following important issues:

1. Even though the total rainfall received by the eastern region is sufficient to meet the evapo-transpirational requirements of crops, spatial and temporal variability of the rainfall often causes surface flooding of fields on one hand and water scarcity at critical crop growth stages on the other. Submergence or waterlogging of soils, especially during the *kharif* season, creates unfavorable environment for plant growth.

2. Water delivery and distribution systems through the canals are highly inadequate and inefficient in eastern India. Improved delivery schedules and distribution of canal water in the fields by micro and pressurized irrigation methods are required to enhance use efficiency of water.
3. The utilization of groundwater resource for agriculture is meager in eastern India. It must be intensified for increasing crop production especially during post-*kharif*' season.
4. The implementation of soil and water conservation measures in the hilly tracts and sloping lands of eastern India is inadequate. Integrated watershed management for efficient water harvesting and restoration of degraded lands are needed to enhance agricultural productivity of this region.
5. Problem of soil salinity in coastal areas due to intrusion of sea water and waterlogging arise due to excessive surface irrigation. Reclamation of these areas by engineering measures and identification of suitable cropping systems will contribute to enhancement of productivity in this unfavorable ecology.
6. Adoption of novel irrigation technologies for crop production and multi-uses of water with introduction of fishery, dairy and other enterprises in the farming can further enhance productivity and use efficiency of water in agriculture.
7. Besides technological advancement, favorable public policy to create conducive socio-economic environments is required for enhancing water use efficiency in the agriculture sector of the eastern region. Socio-economic constraints to adoption of water management technologies need to be identified and policy guidelines prescribed for integration of improved technologies with socio-economic environment of the region.
8. The participatory irrigation management (PIM) with farmers' participation in the management of irrigation water holds the key to judicious and economic use of water in agriculture in this region.

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Water resources and Agriculture

1. K. Sarkar

India is dependent on its water resources for its economic development and poverty alleviation programme. Post-independence,India has made significant progress in developing its water resources and supporting infrastructure.Irrigation potential,which stood at 22.6mha in 1950-51 has now reached to more than 100mha.This has resulted in a rapid increase in food grain production from 50mt (1951) to about 230mt in 2013.Among the Indian states, Tamilnadu(100%),Punjab(84%) and Rajasthan (74%) have achieved high irrigation potential. Four other states,Haryana,Jammu&Kashmir,Karnataka, and West Bengal are in the range of 60 to 70%.States like Bihar, Gujarat, Odisha, M.P., and Assam have achieved 50% of their potential. Area wise, it is necessary to provide to about 130mhafor food crops to address the food security concerns of the growing population. As per report of the Central water Commission, the ultimate irrigation potential that can be created through major, medium and minor projects would be about 75.9mha.Irrigation potential making use of groundwater resources is assessed at 64mha.Thus, it is assessed that the total irrigation potential from surface and groundwater resources would be about 139.9mha.

Irrigation constitutes the main use of water and accounts for about 84% of the total water withdrawals. During the past ten years or so, with increasing urbanization and per capita demand, water use for domestic, industry and other sectors are increasing rapidly and becoming competitive with the irrigation sector.

India has about 16% of the world population and 4% of the global water resources. With growing population and demand of water for meeting human and animal needs is increasing rapidly in several sectors i.e.,drinking,livelihoodsecurity,industry,irrigation,small scale sector etc.According to Ministry of water resources(MOWR),the total utilizable water in India is about 1123 BCM,out of which 634BCM is under current use(Planning commission, 2010).Narasimhan (2008) calculate the water budget using the evapotranspiration rate of 65% as against 40% used in the official estimates (Table-2).

Table 2 Water budget in India

	Analysis based on MoWR	Analysis based on MoWR Estimates bases on worldwide comparison
	Values in BCM	
Annual rainfall	3,840	3,840
Evapotranspiration	3,840 – (1,869 + 432) = 1539 (40%)	3,8402,500 (65%) worldwide comparison
Surface runoff	1,869 (48.7%)	Not used in estimate
Ground water recharge	432 (11.3%)	Not used in estimate
Available water	2,301 (60%)	1,340 (35%)
Utilisable water	1,123 (48.8% of 2,301)	654 (48.8% of 1,340)
Current water use	634	634

Remarks	Current use (634) well below 1,123	Current use (634) well below 654

Surface Water and Ground Water

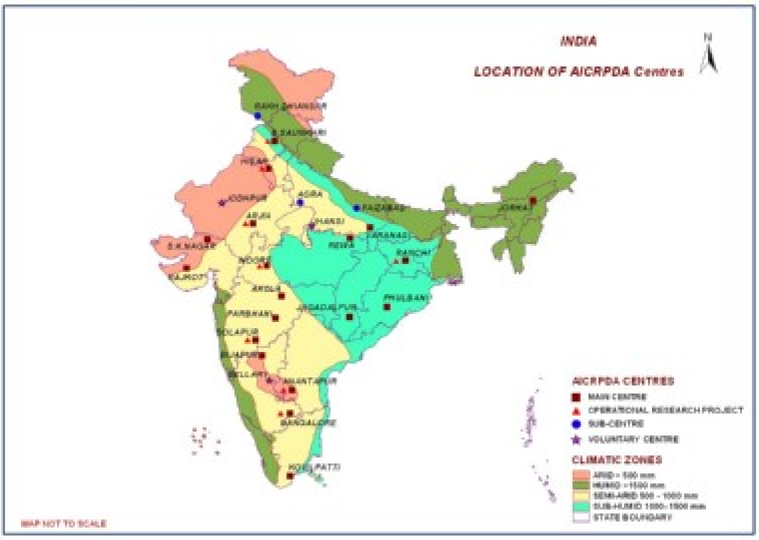
Surface water resources comprise of river,lake,tank,canal,reservoirsetc.In India,there are twelve major rivers with a catchment area of 252.8 mha.These rivers are Indus, Ganga-Brahmaputra Meghna,Godavari,Krishna,Cauvery,Mahanadi,Pennar,Brahmani,Baitarani,Sabarmati,Mahi,Narmada,and Tapi.The Ganga-Brahmaputra-Meghna basin accounts for 60% of the Country'swater resources. The catchment area of Godavari (31.3mha),Krishna (25.9mha),Mahanadi (14.2mha) andIndus (10mha) are also substantial.

India is the largest consumer of groundwater in the world. About 60% of the demand of Agriculture and allied sectors for irrigation and about 80% of the domestic water demand is met from groundwater resources.

Per capita average annual availability of water in India is decreasing rapidly over the years. In this regard, less than 1700m3 water is termed as water stress and less than 1100m3 water is termed as water scarcity. In 2001, available water was 1816m3/year for a population of 1029million.In 2011; it was 1545m3 /year for a population of 1210 million, showing clearly a decreasing trend. It is projected that by 2025 and 2050,the available water per capita annually will be 1340m3(for an expected population of 1394 million) and 1140m3(for a population of 1640 million),respectively.

Rain fed Agriculture

Rainfed agro ecosystems cover 80mha in arid,semi-arid and sub-humid climatic zones.57% of the net cultivated area is under rain fed agriculture. Rainfed area in India contributes almost 100% of the forest produce,85% of coarse cereals and pulses,80% of horticultural produce,77% of oilseeds,60% of Cotton and 50% of cereals such as Rice,Wheat,Maize,sorghum (SirnivasRao etal.2010).rain fed regions support about 60% of livestock and 40% of human population.



19 Main centres 3 Subcentres 8 ORPS
Located across
Arid, Semi-arid (dry and moist), Sub-humid and Humid AESRs

It is estimated that about 114km3 of runoff is generated from 28mha of rainfed area in central and eastern India alone(Venkatesharlu and Prasad, 2012).The average annual rainfall in India is 1160mm.however; there exists wide temporal and spatial variability in the country in the rainfall-its intensity,anddistribution.More than 80% of the annual runoff of the rivers occurs in the monsoon months from June to September,often causing floods.However,acute shortage of water is faced in many parts of India,during rest of the year. This intermittent and prolonged draughts are among the major causes of poor agricultural output from rainfed areas.

A report published in the Economic Times Newspaper in 2013 from Cherrapunji explains the rainfall behaviour and water quality related issues in the following manner:

“Almost no place on Earth gets more rain than Cherrapunji, a small hill town in Meghalaya. Nearly 40 feet falls every year-more than 12 times that Seattle gets. Storms often drop more than a foot a day. The monsoon is epic.But,during the dry season from November to March, the residents struggle to find water. Some are forced to walk long distances to fill jugs in springs or streams. Taps in Shillong,the capital of Meghalaya spout water for just a few hours a day. And when it arrives, the water is often not drinkable. That people in one of the rainiest places on the planet struggle to get portable water is emblematic of the profound water challenges that India faces.”

Water Pollution

70 percept of surface water and parts of groundwater is contaminated by organic, inorganic and biological pollutants. This is due to industrial effluents, householdwastes, agricultural inputs and residues.66% of diarrhoea is caused by contaminated water. Every year,about 6 lakh children die because of diarrhoea or pneumonia, often caused by toxic water and poor hygiene according to UNICEF.

In coastal regions, dissolved solids in drinking water more than500mg/l causes health problems. Iron, 7mg/l, Nitrate>45mg/l, Fluoride>1mg/l, and arsenic>0.01mg/l in water is injurious for human beings, animals and crops.

Water pollution is mainly caused by human activities. Solid waste disposal, waste water disposal,industrialwastes,fertilisers and pesticides,make water forhumanbeings and animals unsafe.As per estimates, about 13% of drinking water in rural areas is contaminated by fertilisers especially urea and its decomposition products.

Prevention and control of Pollution is a priority area and there are legislations to control this. Some of such regulations are: water prevention and control of pollution Act, 1974; Water Cess Act, 1977; The Environmental protection Act or EPA, 1986.Right to information (RTI) is also used to address water pollution related issues.

Addressing water availability in agriculture

The National water Policy intends to promote conjunctive use of water resources. Water resources are river, surface and groundwater, seawater, recycled waste water etc. The use of stored rainwater and surface water improves cropping intensity during Kharif season and groundwater during Rabi and summerseasons. Integrated water resources management is vital for reaping rich harvests from each drop of available water. The timing and reliability of water availability is critical in food crops, because one can achieve stability in crop production to bring about food security.

For ensuring adequate availability of irrigation water for crops, technologies that reduce evaporation losses need to be adopted. These could be use of sprinkler or drip irrigation, direct seeding or dry seeding of crops and conservation tillage practices. Efficient farm-water management practices, such as deficit irrigation(to reduce evapotranspiration), reduction in on-farm storage losses, use of organic or plastic mulches, adoption of water harvesting and improved crop management practices, improveddrainageetc. need to be promoted based on the site specific needs.

Some of the important issues that need to be addressed are:

1. Farmers need to grow crops based on the availability of water.
2. Water use efficiency should be high.
3. Strict legislation should be thee to check exploitation of ground water resources.
4. Sand mining and mineral exploration in rivers should be checked.
5. Conservation of rainwater, recharge of groundwater and re-cycling-re-use of stored water need to be practised.
6. Rainfed farming technologies need to be promoted in a large scale in a system perspective.
7. Regular monitoring,correctivemeasuresand follow up actions should be ensured for irrigation schemes.
8. Use of waste water (after treatment) for irrigating crops need to be taken up on a large scale.
9. Climate Change Implications on water Resources
10. The National water Mission (NWM), a part of the action plan on climate Change (NAPCC) has identified the possible threats to water resources due to climate Change.

Expected decline in the glaciers and snow fields in the Himalayas. Three major rivers of India-Indus, Brahmaputra and the Ganges originate from the Himalayas. Increased temperature may result into increased flow initially (causing Floods) with reduced flow later as the glacier disappears. This may affect

1. Water availability in J&K, Uttarakhand as well as north-eastern states.
2. Increased draught like situations due to overall decrease in the number of rainy days over major parts of India.
3. Increased flood events due to increase in rainy day intensity.
4. Effect on groundwater quality in alluvial aquifers due to increased flood and draught events. This is a challenge for the Scientists to build resilience to such climatic variability.
5. Impact on groundwater recharge due to changes in precipitation and evapotranspiration.
6. Increased saline intrusion of coastal and inland aquifers due to rising sea levels (NWM,2009).Salinity ingress is already a major problem in the coastal regions of Tamilnadu and Saurastra,while inland salinity is a major problem in regions of Rajasthan,Haryana,Punjab,and Gujarat.

7. Rising temperature(due to climate change) will result in higher evaporation rates, shorter crop seasons in medium and low latitudes, but longer crop seasons at higher latitudes.

There will be potential to increase the number of crop seasons per year at all latitudes, where sufficient rainfall or water resources permit, although yield potentials for most crops in the mid and low latitudes will decline due to shorter seasons, higher evaporation rates and increased evaporative demand.

Finally, it is absolutely essential to involve the communities with a participatory approach with water users in rural and urban areas. Poor governance is likely to lead to a complex situation. Practical way is to work together with a mission to "Save Water, Maintain its quality, Conserve and Manage".

Water Productivity

Water productivity is a broad concept. It is the focus of attention in countries with limited land and water resources(Molden etal.2010).water-use-efficiency concept was largely used in 1960s and 1970s,as a measure of improved crop performances(Salter and Goode,1967),where the main focus was on enhancing harvestable yield(land productivity).There is a great scope to improve the land and water productivity of rainfed crops by improving the soil moisture status through efficient soil and water conservation as well as water harvesting technologies. Crops requiring more water (Rice or sugarcane) are often associated with low water productivity.

The ratio of crop output (say, 1 kg grain) to the volume of water used to produce it (m3/kg or mm/ha/kg) can be termed as physical water productivity. Economic water productivity assesses the value of output per unit of water used and reflects crop choice, market demand and the effectiveness of water management. The specific water use per unit of food produced(inverse of water productivity) for different crops/food items(Table....) in terms of both kg of production and a more uniform measure per 1000 kcal of energy contained in that food(Rockstrom etal.,2007).the latter measure is less ambiguous than measurements per kg,even when adjusted to constant moisture contents.

Table.. Specific water use for crops, meat and dairy products per kg output and energy value

Food type	M3 /KG	M3/ 1000 K Cal
Cereals	1.5	0.47
Starchy roots	0.7	0.78
Sugar Crops	0.15	0.49
Pulses	1.9	0.55
Oil crops	2	0.73
Vegetable oils	2	0.23
Vegetables	0.5	2.07
Meat		4
Dairy Products		> 6

Reference: Rockstrom etal., 2007

More crop per Drop of water

Dr.M.S.Swaminathan, the noted agricultural scientist as Chairman of a sub-committee on water resources (MOWR, 2006) submitted a report on “More Crop and Income per drop of water ”.The Report outlined among others, the scope for improving the efficiency of Irrigation water in a manner that both productivity and profitability of farming is enhanced.

Improvements in irrigation systems will bring about better crop production opportunities. Water saving technologies such as sprinkler and drip irrigation increases the efficiency of water use. This has enabled regions with limited water supplies to shift from low-value crops with high water requirements to high value-crops with low water requirements, such as fruits,vegetables,oilseedsand pulses. As per estimates, 10% increase in the efficiency in irrigation projects (canal or surface or groundwater) will bring an additional area of about 14mha under irrigation at a very moderate cost.

In India, the cultivated area with micro-irrigation is about 8 lakh hectares, with major share of the states like Maharashtra, Karnataka, AndhraPradesh and Tamilnadu.Micro-irrigation is common in horticultural crops. The cost of installation of the drip irrigation system varies from Rs.20000 to Rs.25000 per hectare for wide-spaced crops (coconut, mango)to rs.50, 000 to Rs.70, 000 per hectare for closely spaced crops(sugarcane, cotton, vegetables).the benefit cost ratio varies from 2 to 5 with saving of 25 to 50% water compared to surface irrigation.

Groundwater Depletion and Recharge

The Central Soil and water conservation research and training Institute (CSWCRTI) of ICAR,Dehradun in 2003 has very clearly outlined the implications of groundwater depletion and methods for its recharge. Long term water level trends during the pre and post monsoon periods reveal that water table in several states has gone down to more than 20cm/year. Extraction of groundwater at such a hugh rate cannot be recharged by the rainfall received during a year. As per estimates, annual rainfall below 40cm/year does not contribute to direct recharge of groundwater. In the coastal plains, over-withdrawal of water exceeding the natural annual recharge disturbs the hydro-chemical balance leading to seawater ingress causing salinity hazards in these tracts.

In India, the total annual rainfall is of the order of 370 Mha-m, out of which, the total surface runoff is about 185Mha-m. The percentage of rainfall infiltrating into the groundwater varies from 2%in Rajasthan to only 20% in the Indo-Gangeticplains. There is need to divert more of surface runoff to replenish groundwater. Although groundwater is annually replenishableresource, its availability is not uniform in time and space.

India has divergent groundwater situations in different parts of the country. The topography and rainfall controls the runoff and groundwater recharge. Sloppy terrain of northern and north-eastern regions and the hilly tracts of Rajasthan and peninsular region have high runoff potential and little scope for rainfall infiltration. The groundwater potential in these terrains is limited to inter-mountain valleys. The alluvial tract of the Indus, Brahmaputra and the Ganges extending over a distance of about 2000 km from Punjab to Assam constitutes one of the largest and most potential groundwater reservoirs in the world. The groundwater systems here are extensive, thick and moderate to high yielding potential. Almost the entire Peninsular India is occupied by a variety of hard and cracked rock formations. Ruggedtopography, compact and cracked nature of rock in these areas give rise to discontinuous groundwater occurrences with limited to moderate yield potentials.In the eastern coastal plains and estuarine areas of Gujarat, highly productive groundwater formations occur. However, salinity hazards due to sea water ingress impose constraints for groundwater development in these areas (CSWCRTI, 2003).

The Groundwater recharge methods can be grouped under: water spreading, sub-surface recharge and indirect methods. The suitability of these methods depends on groundwater formation and quality of available water (Table....)

Table .... Suitability of Recharge methods

Category	Suitability	Technique
Water Spreading	Shallow or deep alluvial plains	By natural or artificial flooding of area
Hard, and fractured rocks	Inferior from canal or river	By engineering structures , source water quality
Sub-surface recharge	Deep ground water formation	By pumping in tube wells, open wells
Small scale or location specific recharge		
Indirect methods	Ground water recharge especially to reduce contamination	By induced recharge from surface water or aquifer formation.

Category Suitability Technique

Water spreading Shallow or deep alluvial plains, By natural or artificial flooding of area

Hard,and fractured rocks,inferiorfrom canal or river,by engineering structures

Source water quality

Sub-surface recharge Deep groundwater formation By pumping in tubewells,open wells

Smallscale or location specific recharge or injection wells.

Very good quality source water

Indirect methods Groundwater recharge especially By induced recharge from surface

To reduce contamination water or aquifer formation

Of these methods, water spreading through small scale engineering measures of soil and water conservation practices has been found effective in groundwater recharge in drylandareas. The basic concept of this method is to increase area and length of time for water to remain stagnated, which helps in increased rate and amount of deep percolation. Water spreading is the most commonly used practice for recharging groundwater. Some of the methods employed to recharge groundwater are: Flooding, Ditch and Furrows, Percolationtanks, Gully plugs and Check dams, Farm or village ponds, Trenching, sub-surface methods-recharge pits, trenches, injection wells, open wells, hand pumps, Indirect methods-roof top water harvesting in urban areas etc.

Water Conservation Practices

The CSWCRTI, Dehradun has conducted extensive research on the water conservation practices under rainy as well as hilly areas of India. Forrainfedagriculture, water conservation ensures a crop for farmers; otherwise most of the rainwater is lost into the sea through flow in rivers, evaporation and seepage. Water conservation includes all aspects of agricultural land uses, soil conservation and maintenance or enhancement of the production potential of the land resources.

Water conservation practices in any area serve two major functions: control of runoff and conservation of rainwater in the field for crop growth, and control of soil erosion to prevent depletion of soil fertility. Bio-engineering measures for water conservation have been found to be very effective under varied soil, topographic and climatic conditions of the country. Such measures have been broadly grouped under i. Agronomic measuresand ii.Mechanical measures.Agronomicmeasures, such as contour cultivation, mulching, strip, mixed and inter-cropping are preferred in mild sloping land and involve least disturbances to the land. Mechanical measures, such as, contor and graded Bunding, vegetative barriers, conservation ditching, conservation bench terraces etc.are recommended to reduce the length and /or degree of slope to prevent erosion and to conserve runoff (CSWCRTI, 2003).

Watershed Management

Watershed is a catchment area from which water drains into a common point, making it an attractive hydrological unit for technical efforts to manage water and soil resources. People and animals control the watershed-its use and sustainability to meet livelihood concerns. There is interdependence among people and the resources of the watershed. Proper planning and execution of the water and soil management programmes is necessary to effectively manage a watershed to meet the development needs of rural communities engaged in agriculture and allied activities. Data from different sources, such as, Soil survey organization, remote sensing, water resources, agriculture, forestry, rural developments can be effectively integrated with the help of GIS(geographical information system), simulation models(crop, water, soil, runoff etc.) and biometric models for sustainable development and management of watersheds(Wani etal. 2008).

Analysis of 311 watershed case studies from different agro-eco regions of India have shown that farmers have been benefitted through increased irrigated area by 33. 5%, increase cropping intensity by 63%, reduced soil loss to 0. 8 t/ha, and reduced runoff loss by 13%, associated with increased groundwater availability (Joshi etal. ,2005). Now, the watershed development programme is looking beyond soil and water conservation, to a range of activities,such as enhancement of agricultural output, food and nutritional security, farming system, community organization and gender equity. Wani and Sidhu (2012) suggests that watersheds, as an entry point should lead to exploring multiple livelihood interventions. Participatory community watershed is consortia based approach involving people, leading to human, social, physical and economic resources improvement. Large scale community participation is essential for the success of the watershed development programme, since finally it is the people, who have to manage the resources.

The activities in the watershed management approach, where convergence is the key, are: i. rainwater conservation and harvesting ii. Improved crops and cropping systems iii. soil test based INM approach for soil health enhancement iv. soil conservation v. crop diversification, introducing high value crops vi. Processing and value addition vii.Rehabilitation of degrade lands with grass and plantation crops viii. Livestock improvement programmes ix. Poultry, goatry, piggery activities x. seed production and xi. Skillupgradation and empowerment activities for farmers xii. women empowerment programmes.

Adoption of integrated watershed management has a positive impact on the resource poor farm households of the rainfed/dryland regions (Wani and Sidhu, 2012). Benefits have been recorded in i. reducing rural poverty ii. Building on social capital iii.Increase in crop productivity iv. Improvement in water availability v. environmental sustainability vi. Biodiversity conservation vii.social harmony.

Future Outlook

Water resources are vital to Indian economy. Agricultural development in the country is dependent on the availability of water for irrigation of crops. In fact, irrigation water security is vital for livelihood and food security. Proper management of water resources and promotion of efficient and economic water use are of greatest concern for productivity and profitability of Agriculture.

The present paper analyses the present situation in the above context. But, lot needs to be done to sustain and improve the situation. Some of the important areas of concern are enumerated below:

1. Water will continue to be a scarce commodity. There is need to properly partition the requirement of water for three major purposes: drinking, irrigation, and industry.
2. While recommending a farming system or cropping system, one must assess the status of water availability, so that there is less exploitation of groundwater to meet the systems requirement.
3. There is need to emphasize water as well as soil productivity for sustainable growth.
4. River systems are central to meet needs of surface water for irrigation. These must be protected against illegal sand and mineral mining practices.
5. City sewage and Industrial wastes pollute the rivers. It is estimated that only 10% of the waste water generated is treated and re-used and the rest is discharged into river bodies.
6. Therehas been an encroachment of water courses and bodies leading to less water flow. This needs to be addressed to avoid conflict and distress among communities.
7. Vii Proper estimation of water availability and its use especially I watersheds is important. For this, measurement of stream flow, precipitation, runoff coefficients and evapotranspiration is required but not done in most cases.
8. viii. While working in the watersheds, indigenous practices of water conservation must be paid due attention, since these are time tested and sustainable. Efforts should be made to reclaim degenerated water bodies and rejuvenate the watersheds to conserve soil and water.
9. Groundwater access and control needs to be regulated especially in places from where over-exploitation is reported.

10. In most cases, planning and execution of Irrigation Projects is poor. This needs to be seriously looked into. Linkage of communities with implementers should be cordial and strong.
11. Emphasis should be on low water requiring crops and dry land farming technologies developed by CRIDA (ICAR) and other Institutions, such as ICRISAT, SAUs. (Srinivasraoetal. 2013) for 60% of the cultivated area in India, which is rainfed.
12. Climate change impacts need to be regularly assessed in the context of increasing water demand and limiting crop productivity in major parts of the country.
13. Training and empowerment of water professionals dealing with domestic water supply, sanitation, water quality and irrigation is important for a better vision on Water Management.
14. Participatory irrigation management need to be promoted and practised for better conservation, management and delivery of water in farmers' fields.

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Soil and Water resources and management in North Eastern region

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Introduction

The contribution of agriculture to the overall Gross Domestic Product (GDP) of India has fallen from about 30 per cent in 1990-91 to less than 15 per cent in 2011-12, which is expected in the development process of any economy, yet it forms the backbone of development. The experience from BRICS countries indicates that a one percentage growth in agriculture is at least two to three times more effective in reducing poverty than the same growth emanating from non-agriculture sectors (http://pib.nic.in/ newsite/efeatures.aspx?relid=100059 extracted on 5th Nov, 2013)). Given that India is still home to the largest number of poor and malnourished people in the world, a higher priority to agriculture will achieve the goals of reducing poverty and malnutrition as well as of inclusive growth.

Land, water resources, soil and biodiversity which are the natural resources for agriculture are under considerable strain. India's total gross cropped area is about 192.2 million hectares and the net sown area is 140 million ha. Over the last three to four decades, net sown area remains stagnant and possibility of increasing it is minimal due to increasing demand on land for other purposes. The ultimate irrigation potential of the country is estimated to be about 140 million ha out of which about 76 million ha is met by surface water and remaining 64 million hectare from ground water sources. Presently, about 63 million ha (45%) of cropped area, is reported to be irrigated.

The variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries. It comprises the diversity of genetics resources (varieties, breeds) and species used for food, fodder, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators), and those in the wider environment that support agro-ecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agro-ecosystems (FAO, 1999).

North east region of India offers one of the widest spectra of biodiversity in the world. This natural resource is still under-explored and unexploited for sustainable production in agriculture including forestry, veterinary and fisheries.

Strength:

1. One of the 12 mega bio-diversity hot spot areas.

2. Abundant natural resources (in Lakh ha.)

1.	Geographical area		: 262.18
2.	Forest		: 171.08
3.	Agricultural Land		: 39.08
4.	Water bodies		
	1.	River	: 19150 km
	2.	Reservoirs	: 0.24
	3.	Tanks/ lakes/beels	: 1.43
	4.	Ponds	: 0.41
	5.	Paddy cum fish culture	: 0.03

Total Water Resources : 42.50 mil. ha water

1.	Indigenous crop Germplasm	: 4500 (Approx.)
2.	Orchids	: 600 (175 rare spp)
3.	Medicinal & aromatic plants including flowering species	: 5000

1. Bamboo resources : 50% of the country

4.	Total Livestock (100% Mithun, 28.22% Pig and 24.61% Yak of the country)	: 21.03 million
5.	Total Poultry	: 36.46 million
6.	Fish germ plasm including Ornamental fish	: 347 species
7.	Agroclimatic zones	: 06
8.	Alpine zone	: More than 3500 masl
9.	Temperate and sub-alpine zone	: 1500 – 3500 masl
	Sub-tropical hill zone	: 1000 -1500 m asl
	Sub-tropical plain zone	: 400 – 1000 m asl
	Mild-tropical hill zone	: 200 – 800 m asl
	Mild-tropical plain zone	: 0 – 200 m asl

Vision 2025, ICAR Research Complex for NEH extracted from http://www.kiran.nic.in/pdf/reports/Vision_2025_ICARNEH.pdf on dt 5.11.2013

The north east region of India has a total geographical area of 262180 km^2 comprising eight states *viz.*, Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Tripura and Sikkim which is 8% of the total area of the country having about forty million population. The Siliguri Corridor in West Bengal, with an average width of 21 km to 40 km, connects the North Eastern region with the mainland Indian sub-continent. The region shares more than 4500 kilometres of international border (about 90 per cent of its entire border area) with China (South Tibet) in the north, Myanmar in the east, Bangladesh in the southwest, and Bhutan to the northwest. The region is characterized by hilly terrains in about sixty five percent of the total area in the region. The region has unique distinction of having diverse hill ecosystems covering more than two-third of total geographical area. The hill areas have wide range of altitude up to 5,000 metres. Physiography of North East India can be divided into three regions *viz.* Meghalaya Plateau, the North eastern Hill and basin of the Brahmaputra Valley.

The first two accounts for 78% of the region. Based on the topography, rainfall and temperature, the region has been divided into following three categories:

1. Himalayan Hills comprising of Sikkim and Darjeeling district of West Bengal.
2. NE Hills and plains comprising of Arunachal Pradesh, Hill districts of Assam, Meghalaya and Nagaland.
3. Southern hills and valleys comprising of Manipur, Mizoram and Tripura.
4. The riverine plains, swamps, tilla land and char areas are the other agro-ecological situations

On the whole, the north east region is typified by fragility, marginality, inaccessibility, cultural heterogeneity, ethnicity and rich biodiversity. 82% of its population lives in rural areas. Paucity of large industries in the region, the society is agrarian and depend on agriculture and allied activities for their livelihood.

Agriculture is the dominant economic activity providing employment to 64.3 per cent of total workers. The region has 3.73 per cent of the total population of the country and contributes 2.6 per cent to the Net Domestic Product.

Weaknesses of the Region:

1. Inaccessibility, marginality and fragility.
2. Overexploitation of forest for fuel, timber and fodder.
3. Improper land use practices.
4. Shifting cultivation on hill slopes.
5. Poor infrastructural development.

6. Inadequate Agricultural Mechanization.
7. Absence of storage and agro processing activities.
8. Limited availability of quality seeds.
9. Lack of policy frame work for Channelization of production-processing-marketing components.
10. Lack of commercialization and value addition

Climate and Rainfall:

The region geographically comprises of extensive network of rivers, valleys and hills. The weather in the North Eastern region does not follow the pattern as observed in other places and show large spatial and temporal variability due to the presence of hill and mountain ranges on the synoptic system. The region is climatically classified as Sub-tropical Humid in general. The South West Monsoon is the most dominating factor due to which the region receives very high rainfall during the monsoon period. Average annual rainfall is 150-250 cm, which is almost 60-65% of the total annual rainfall. Because of high rainfall received, the climatic variability is less than 15% for the entire region. The region also receives considerable amount of rainfall during pre-monsoon (March –May) and post monsoon (October-November) periods due to localized low pressure belts and North East monsoon, respectively. The annual maximum temperature ranges from 10-20°C during winter and 25 – 35°C during summer season over different places. The annual minimum temperature ranges from 5 – 8 °C during winter and 15 – 25°C during the summer months. The average bright sunshine hours received in the NE region is lowest in the country (2- 5 hours during monsoon and 7 -8 hours during winter). The range of average wind speed is 2 – 10km/h only. The average relative humidity of the region remains in the range of 60 -80% for most of the period of the year. The average annual potential evaporation is 140 – 160 cm over most part of the NE region.

Food security concerns

Around 56% of the area is under low altitude, 33% mid altitude and the rest (11%) under high altitude. Agricultural production system is, by and large, of CDR type. The system is characterized by low cropping intensity (114%), subsistence level and monocropping. Average landholding is 2.5 ha compared to national average of 0.69 ha. Although the landholding appears to be higher, the entire holding cannot be used for agricultural purposes due to topographical disadvantages. Land use pattern is relatively faulty for which annual loss of top soil is much higher (46 tonnes/ha) than all India average of 16 ton/ha. Similarly, due to lack of proper water harvesting measures, only 0.88 mhm out of 42.5 mhm water is used. There is no reliable assessment of total irrigated area. Record gathered from different sources indicates that around 20.74% area is irrigated out of which 18.78% is irrigated through surface flow, 1.82% through surface lift and 0.14% through groundwater lift irrigation. Farmers also use an indigenous technique called bamboo drip irrigation particularly for less water demanding crops. Fertilizer consumption in the region is also very low and stands at around 11 kg/ha ranging from as low as 2.7 kg/ha in Arunachal Pradesh to a high of around 72 kg/ha in Manipur.

The land use pattern of NE is influenced by the elevation, climate and mountainous terrain. The forestry is the most dominant land use followed by agriculture, horticulture, animal husbandry and non-agricultural uses like urbanization and/or infrastructural developments. Many of the land use systems are not conducive to sustained production. The physiography coupled with high rainfall, varied temperature and altitude resulted into diversity and richness of forests of north east. The area under agricultural use is significantly low (35%) in NE states compared to all India level of 63% of total reported land area. Two important agricultural practices of the region are settled farming practiced in the plains, valley, foot hills and terraced slopes and shifting cultivation in the slopes.

The State wise land use classification is given in Table 1 and 2. It is evident that out of a total reporting area of 175.4 lakh hectare net sown area is 42.8 lakh hectare with a total of 34.94 lakh hectare area not available for cultivation.

Table 1 State-wise Land Use Classification in NER, (2008-2009), 000 ha

States/Year	Geographical Area	Reporting Area for Land Utilisation Statistics#	Forests	Not Available for Cultivation		
				Area Put to Non Agri. Uses	Barren & Un-Cultivable Land	Total ##
Arunachal Pradesh*	8374	5659	5154	25	39	64
Assam	7844	7850	1853	1218	1408	2626
Manipur	2233	1965	1693*	26	1	27
Meghalaya	2243	2227	948	91	134	226
Mizoram	2108	2109	1594	124	9	133
Nagaland	1658	1621	863	95	3	98
Sikkim*	710	723	319	143	107	250
Tripura*	1049	1049	606	131	3	134

India	328726	305687	69635	26308	17017	43324

Note : *# :* Reporting area for land utilization statistics is the sum of land under forests, area not available for cultivation, other uncultivated land excluding fallow land, fallow land and net area sown.

: Area not available for cultivation is the sum of area put to non-agricultural uses and barren & uncultivable land.

**:* The figure related to area under forest, other categories of land use, net irrigated area, gross irrigated area, net area sown and area under crops as the case may be, are taken from latest forestry statistics publication, agriculture census or are estimated based on latest available year data received from the state/uts respectively.

Source : Ministry of Agriculture, Govt. of India.

Table 2 State-wise Land Use Classification in NER, (2008-2009) in '000 ha

States/ Year	Net Area Sown	Total Cropped Area	Area Sown More than Once #	Cropping Intensity	Agriculture land/ Cultivable land/ Cultivable land	Cultivated Land	Uncultivable/ Unculturable land**	Uncultivated land***
Arunachal Pradesh	211	276	65	-	422	251	5237	5409
Assam	2753	3984	1231	-	3211	2879	4639	4971
Manipur	236	236	-	-	243	237	1721	1728
Meghalaya	284	337	53	-	1053	343	1174	1884
Mizoram	95	95	0	-	377	155	1732	1954
Nagaland	316	402	86	-	659	389	961	1231
Sikkim*	107	118	10	-	150	112	573	611
Tripura*	280	295	15	-	310	281	740	768
India	141364	195104	53739	-	182385	155905	123302	149782

About 35% area in the region is plain while in Assam, plains account for 84.44% of its total geographical area. That is why, the Net sown area is highest in Assam (34.12%) followed by Tripura (23.48%). Arunachal Pradesh has lowest net sown area in the region. Cropping intensity is highest in Tripura (156.5%) followed by Manipur (152.1%), Mizoram (136.36%) and Assam (123.59%). About 1.6 million hectare area is under shifting cultivation in NE region. Out of 4.0 million hectare net sown area of the region, roughly 1.3 million hectare suffers from serious soil erosion problem.

Farming is predominantly rice-based with little exception in the state of Sikkim where maize is a dominating crop. Mixed farming system is the order as most of the farmers want to produce his household food and nutritional need without having to depend on outside sources. The system, therefore, supports a large horticulture and animal husbandry base partly due to benefiting from the complementarities and partly due to meeting their animal protein requirement as most of the population (almost 100% tribal) is non-vegetarian. With this production practices, the region produces a total of 5.8 million ton of food grain against a requirement of around 7.40 million tons. The deficiency is, therefore, around 1.6 million tons of food grain. Similarly, in spite of a desired aptitude towards animal husbandry practices, per capita availability of milk, meat, egg and fish per annum is only 31.53 litres, 9.36kg, 33.50 numbers and 4.12 kg, respectively.

Table 3. : Area, production and yield of major food grains and decadal growth

State	1990 – 91			2000 - 01			2009 - 10			% decadal change in production	
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	2000-01 over 1990-91	(09-10 over 2000-01
Arunachal Pradesh	1.83	2.14	1173	1.84	2.03	1103	198.6	3.09	1555	-5.14	52.22
Assam	27.19	34.42	1226	28.88	41.67	1443	2695.6	44.81	1662	21.06	7.54
Manipur	1.62	2.85	1763	1.64	3.78	2305	188.7	3.39	1796	32.63	-10.32
Meghalaya	1.33	1.53	1147	1.31	2.03	1550	132.2	2.39	1809	32.68	17.73
Mizoram	0.59	0.77	1296	0.61	1.24	2033	59.6	0.62	1047	61.04	-50.00
Nagaland	1.70	1.97	1161	2.11	2.77	1313	282.1	3.54	1256	40.61	27.80
Sikkim				0.76	1.03	1355	78.4	1.17	1496		13.59
Tripura	2.89	5.15	1783	2.54	5.23	2059	254.7	6.48	2544	1.55	23.90
NE Total	37.14	48.83	1315	39.69	59.78	1506	38.90	65.50	1646	22.42	9.57
All India	1275.2	1762.3	1392	1197.83	1959.2	1636	1213	2181	1798	11.17	11.33
% share of NE	2.91	2.77	-77*	3.31	3.05	-130*					
Area : Lakh ha; Production : lakh ton; Yield: kg/ha											
Source : NEDFi Databank											

Agriculture and allied activities are the main source of livelihood for the people of NE region and any attempt to reduce poverty as well as to place the region in developmental paradigm shall have to have a base on system wide and eco-regional planning of agriculture sector development. While planning this, the strength of farming system approach to judicious utilization and conservation of natural resources of the region with concurrent policy and research back up to increase production, add value to the produce and their disposal /sale management shall be of paramount importance.

Trends in food grain productivity in NE

For an ‘on the spot’ assessment of the decadal growth pattern in major food grains, available information is given in Table 3. It has been observed from the above record that area, production and productivity of major food grains in the region recorded a growth of 13.65, 34.00 and 25.89% between 2000-01 and 1980-81. Considering the fact that only 12% of the reported area is sown in the region, there is scope to increase the area under cultivation and thereby the food production.

Projection Study n production and the requirement of food grains for decades in north-eastern states was conducted to estimate the gap between supply and demand of food grains. State-Wise compound growth rates (CGR) of food grains (including rice, wheat, maize and pulses) were estimated using time series data for 1984-85 to 1997-98 period (Basic Statistics of NER, 2006). Cereal requirement is estimated by multiplying the recommended amount of food grains per capita basis with the population at that point in time (eg, 2010, 2015, etc..) The base population was estimated by CGR for the same time

Table 4 Projected food grains production and requirement in North eastern states

State	CGR	Production *				Requirement *			
	(Prod.)	2010	2015	2020	2025	2010	2015	2020	2025
Arunachal Pradesh	1.30	231	246	263	280	246	276	310	348
Assam	2.58	5375	6105	6934	7876	5703	6214	6770	7377
Manipur	1.96	459	505	557	613	554	630	718	817
Meghalaya	1.19	229	243	257	273	534	608	692	787
Mizoram	10.37	-	-	-	-	-	-	-	-
Nagaland	6.57	524	720	990	1360	565	720	917	1169
Tripura 2.25	584	730	816	911	620	667	717	771	829
All	--	7471	8549	9817	11315	8269	9165	10178	11326

* Thousand Tonnes.

Table 5: Production, requirement and gaps in NE

A. Agricultural Production (Major crops as in 2005)

Area (m ha)	Production (Million ton,	Yield (Kg/ha)	Requirement (Million tonnes,	Deficit (%)

	projected)		Projected)	
3.90	6.54	1509	7.47	13

B. Horticulture Crops

Sectors	Area (in lakh ha)	Production (million tonnes)	Yield (ton/ha)	Country Average (ton/ha)
Fruits	2.70	2.33	8.65	11.01
Vegetabls	3.68	4.05	11.98	15.16
Spices	0.69	0.44	--	--
Plantation Crops	1.15	0.10	--	--

2. Animal Husbandry and Fishery

Sectors	Production (Million tonnes)	Requirement (Million tonnes)	Deficit (%)
Meat	0.22	0.439	49.7
Milk	1.06	2.14	50.50
Egg (Million Nos.)	902.09	7027.21	87.20
Fish	0.21	0.38	55.26

There are many constraints why the NE region faring much below its’ potential. They can be categorized as Environmental, Technical, Physical and Economic constraints as shown in the box.

(A) Environmental Constraint

1. **Acidic soil-** low availability of P. Also has high concentration of Fe and Al and low Zn.
2. **High rainfall and humidity-** Harbors pests, diseases and weeds.
3. **Shifting cultivation-** Both strength as well as weakness.
4. **Land tenure system-** Lack of sense of belongingness to the land due basically to absentee land ownership as well as allotment of land for cultivation on time scale basis.

(B) Technical Constraint

1. **Seed and planting material.**
2. **Disease and pest management.**
3. **Farm mechanization.**
4. **CDR type of agriculture.**
5. **Constraints of Various Kinds in Transfer of Technology.**

(C) Physical Constraints

1. **Infrastructural-**Road and communication, procurement and distribution, processing and storage, value addition and marketing.
2. **Undulating Topography-** Leads to inaccessibility with resultant constraints in service delivery.

(D) Economic Constraints

1. **Lack of commercialization-** Leading to small-scale household production system.
2. **Limited credit flow** - The farmers do not have easy access to credit flow as yet for which they are, many a times, compelled to continue small scale cultivation practices.
3. **Market constraint -** Most of the places in the region do not have proper market to dispose off the farmers produce. The result is that the farmers are forced to resort to distress sale of their produce.

Vision 2025, ICAR Research Complex for NEH extracted from http://www.kiran.nic.in/pdf/reports/Vision_2025_ICARNEH.pdf on dt 5.11.2013

Soils of NE

Proper use of important resources like land or soil is the is the primary requirement for socio-economic development of any country or region and for resilient life supporting systems as well. Soils are dynamic natural bodies comprising the uppermost layer of the earth, exhibiting distinct organization of their mineral and organic components including air and water, which formed in response to atmospheric and biospheric forces acting on various parent materials under diverse topographic conditions over a period of time (Yaalon and Arnold 2000). The important factors for development of soil are parent rocks (geology), climate, topography, vegetation and time (Jenny 1941). The parent material has strong influence on soil composition and it’s properties which is discussed with respect to NE soils.

The soils of the region are broadly represented by four groups, viz. Inceptosols, Ultisols, Entisols and Alfisols. Soils are usually rich in organic matter and are acidic to strongly acidic in reaction. It is now well documented that soil acidity leads to deficiency of some essential plant nutrients as well as creates elemental toxicity thereby adversely affecting the crop growth. The optimum pH congenial for nutrient availability to crop plants remains non-existent in acid soils. It is indicated (Fig. 1) that 95% of soils of NE states excepting Nagaland (77%) are acidic in reaction. Majority of the acid soils in the region have pH below 5.6 and remaining between 5.5 and 6.5. North East India has, in diversified climatic environs, the largest stretches of acid soils with a variation in pH from 4.0 – 6.8.

Parent materials of NE Region

North East India underwent orogenic movement caused by geodynamic forces during the Cretaceous period (60-110 million years). The ridges and basins on the floor of the earth were the deformed long accumulated sediments. The orogenic movement of earth had marked effect on the surface configuration during the subsequent periods. Geological mapping and chrono-strategraphic studies have revealed that rock formations ranging in age from the Precambrian to the Quaternary have gone into the making of the geological substrata. Genetically, the rocks cover a wide spectrum; uplifted sediments and sedimentary rocks, formed by exogenic processes, and metamorphic and magmatic rocks formed by deep-seated endogenic processes. The metamorphoses include the meta-sediments and veins and the magmatic rocks represent diverse members, ranging from ultramafic to acidic variants.

The soils of the North Eastern region of India have developed in situ in different types of rocks of geological ages from Paleozoic to recent formation, ancient rocks are inter - layered with tertiary and quaternary formations The rock formation in Nagaland, Manipur, Mizoram and Tripura is represented by Disang, Barail, Surma, Tipam and Duptila series. In the Naga Hills, the Eocene beds are the Disang shales - a great thickness of very well bedded dark gray shales with thin well-cemented sandstones. Tipam series is widespread in Tripura, Nagaland and Arunachal Pradesh. The rock type includes grits, sandstones, conglomerates and clay with plant remains. The Tipam formation of Tripura consists of medium to coarse-grained straw yellow colour sandstone. The hill ranges of Tripura are formed from the rocks belonging to Surma and Tipam series. The Tipams are overlain uncomfortably by ferruginous Duptila sediment. In the North Eastern part of Assam, the Tipam series is entirely non-marine, consisting of ferruginous sandstones, mottled clay and mottled sand.

The rocks formed under shelf faces occur in North Cachar, Jaintia hills and along the southern slope of Shillong plateau. They are known as Jaintia series and comprise sandstones, calcareous sandstones and limestone. Both Jaintia and Disang series are overlain by Barail series, which is of considerable economic importance as it contains thick seams of coal. This series contains thick hard sandstones, which give rise to Barail range. In Mizoram, the sedimentary rocks of Barail series consist of shales, locally enclosing bands of weathered micaceous, feldspathic sandstone, relatively soft medium grained sandstone interbedded with siltstone. The Shillong series (which includes a large part of Garo Hills and the Khasi and Jaintia Hills) is a widely developed formation of Archaean gneissic complex, consisting of a thick series of quartzites, slates and schists masses of granitic intrusion and basic interbedded traps. The Shillong series is, for greater part of its extent, overlain by horizontally bedded cretaceous sandstones. The lower Gondwana consist of pebble bed, sandstone and carbonaceous shale with streaks of coal.

The Surma series has a wide extent in Naga Hills, North Cachar Hills and Surma valley of Assam. It is composed of sandstones, sandy shales, mudstones and thin conglomerates, generally free from carbonaceous content. In the Garo hills, a small range of beds in the Surma series has yielded large number of marine fossils and fossiliferrous bed has also been described from a slightly lower horizon in the Surma valley. In Mizorarn, the Surma series consists of hard, compact, medium grained sandstones, shale, siltstone and ferruginous current bedded sandstones.

In Manipur, the oldest rocks found along the eastern part of the State belong to cretaceous group. They include mainly variegated shale, slates, siltstone with some amount of sandstones and quartzite. Limestone of cretaceous age occurs in a number of places around Ukhrul. The rock type of this region is shales, mudstones, siltstones and sandstones of Disang series. The Barail series occur over considerable tracts of Senapati, Churachandpur and

Tamenglong districts of Manipur. Manipur valley soils have developed from the transported material formed from shale (Patiram and Datta 2006)

The meta sedimentary sequence, developed extensively in Arunachal Pradesh, have been assigned various nomenclature e.g. Potin, Bomdila, Tenga etc. which as a group could be correlated with the Daling-Buxa sequence and its equivalent described from Sikkim-Darjeeling-Bhutan. The dominant members are low-grade schist (locally graphic) of the Daling status, and the ortho quartzite-carbonate association equivalent to the Buxa. This pile is also affected by granite intrusive of variable dimension, which locally imparted the effects of thermal metamorphism. The rocks around Bomdila consist of gneisses, mica schist, thin calesillicated, marbles, graphitic schist, metaphases and quartzite. The Tenga unit consists of gneisses, low-grade schist, amphibolites and phyllites and fine-grained sericitic quartzite. Besides, there are also units of rocks like Bichom group, occur along Bichom river, Gondwanas and Tertiaries in West Kameng and East Kameng districts. Most of the rocks of Subansiri comprise Precambrian schist's, magmatites and younger granites intensive of Se-La group of Kameng at some places. Rocks of Siang district are mostly either carbonised or semi-carbonised. Lignite to peat materials are recognised in various sections of across Tertiary formation of the districts of West Siang and East Siang. The Lohit plain of north eastern part have been characterised as schistose meta sediments, chloritic quartz and mica schists, carbonate rocks and lime rocks etc (Patiram and Datta 2006) .

The Daling series consisting of much contorted slates and chloritic and sericitic phyllites with hornblende-schists and quartzites extends along the Teesta valley into Sikkim and then to Bhutan. Some loads of copper are associated with rocks, which are commercially workable in Sikkim. The Daling series of this region includes overlying group schists copiously injected as with gneiss of Darjeeling series. The Daling and Darjeeling series of Sikkim are highly metamorphosed slates, magmatics, granities and schists, containing such metamorphic minerals as garnet, sillimanite and staurolite. The lower Gondwana in West Sikkim is associated with thick of coal seams, underlying the dolomites and phylHtes of Daling series. The North Eastern and western portion of Sikkim is made up of hard massive gneiss rocks, which are comparatively more resistant to denudation. The gneiss of south Sikkim is highly micaceous, muscovite and biotite being present.

Soil Distribution

In NE region, the physical factors of land like topography, slope, drainage, geological materials and forest cover are solely responsible and directly or indirectly related to soil properties. The steep slopes, high relative relief feature and higher density of drainage of the mountain and hill areas stimulate soil erosion risks with higher degree of sediment loss and also decrease the fertility of the soil to a large extent. The National Bureau of Soil Survey and Land Use Planning (NBSS & LUP, 2002) and their Regional Centres at Jorhat and Kolkata surveyed the soils of the hilly states of this region based on three tier approach (land form analysis, field survey, laboratory investigation and cartography) and soil resource maps of the states (on 1:250,000 scale) have been prepared. The upper tier represents the diagnostic properties of the dominant soils and their phases, elucidating the information on soil order, suborder, great group, subgroup including phases (like soil depth, particle size class) of family control section. The middle tier shows the landform characteristics, whereas the lower tier represents the soil family association number (polygon number). The map units (polygons) on the soil map represented the associations of two families. The soil resource maps and the thematic maps generated are not only useful for optimising land use but also form an important base for delineating agro-climatic zones at the state level for effective crop planning and transfer of agro-technologies.

Table 6 Major soil orders found in North East

Soil Order	% Geographical area of the State						
	Arunachal Pradesh	Manipur	Meghalaya	Mizoram	Nagaland	Sikkim	Tripura
Inceptisols	37.3	38.4	45.7	37.3	76.0	33.4	80.0
Entisols	35.6	23.1	10.7	21.5	4.0	43.0	8.0
Ultisols	14.2	36.4	40.0	-	17.2	-	7.0
Alfisols	0.3	0.2	3.6	2.6	4.8	-	5.0
Mollisols	-	-	-	38.6	-	23.6	-
Misc. Land	12.6	1.9	-	-	-	-	-

According to old soil classification, there are 5 types of soils present in NE region. Now, the USDA classification indicated that the soils of the region were of 5 orders, 22 great groups and 45 sub groups and distribution of soil orders in different state are given in Table 3.4 and Fig.3.3. Thus the soils of this region are quite variable depending on the variability of climate, physiography, parent materials and native vegetation. The depth of soils at different places varies considerably because of differences in physiographic position and slope. Geographical erosion generally exceeds soil formation except under forest cover.

Mass movement of soil in the form of slips, glides, and mud flows and solution forms are common in this region due to high rainfall, jhuming on sloppy lands, deforestation, faulty methods of cultivation and road construction. In the north eastern region, so far podzolic soils are not reported at higher elevation under coniferous forests. It was found that there is limited downward migration of Fe and Al along with humus and absence of spodic horizon indicating the juvenile stage of podzolisation (Datta et al, 2004).

Soil Properties

The fertility of the soils depends much on the geological formation of the underlying rocks from which soil is derived. The soil texture varies from loam to sandy clay loam depending upon the slope. The darkness of soil colour and coarseness in texture has the tendency to increase with rise of altitude. The soils are acidic as a result of humid climate and heavy rainfall. The content of soil organic matter, cation exchange capacity, and exchange acidity have the tendency to increase with, altitude while pH has the reverse tendency (Gangopadhyay et al., 1990). The soils are generally deficient in bases particularly those soils which are under the conifers.

The soils are formed in situ excepting at foothills and near the rivers and streams, which are colluvial and alluvial in origin.. The soils on steep slope in the upper part of the hills are of shallow to very shallow in depth. On hill terrain, the soils are light coloured, highly leached, poor in bases low cation exchange capacity with low active clays.

The soils are quite rich in organic carbon with decreasing trend as the depth of soil increased. Soils in the valleys and thick forest are fairly rich in organic matter and well drained. Most of these acidic soils possess high amount of exchangeable Al3+ throughout soil column with almost increasing trend, thus indicating that they still have preserved some weatherable minerals which liberate Al ions from the edges of clay mineral through weathering processes. The occurrence of high amount of potential acidity (Misra and Saithantuaanga, 2000) would have resulted from combined effect of organic matter, free sesquioxide and terminal hydroxyl groups associated with Si and/or Al, and/or the ruptured Si-O-Al bonds of low active clays (Sen et al, 1997). North East India has, in diversified climatic environs, the largest stretches (Fig. 2) of acid soils with a variation in pH from 4.0 – 6.

The soils developed on Bomdila group of rock are rich in clay content as compared to others. The soils developed from Bomdilla group (granite and gneisses) are high in clay content (Nayak and Srivastava, 1995). The physico-chemical properties of soils in Arunachal Pradesh are presented in Table 3.19. Soils on upper piedmont, upland and gently sloping plain are moderately to slightly acidic in nature (pH 4.6 to 5.8) and moderate to high organic matter (1.3 to 3.7 % OC). The CEC of the soils ranges from 3.7 to 15.2 c mole (p+) kg'1 and they are moderate to poor in base saturation. On the contrary, the soils are slightly acidic and have moderate to high base saturation (Sharma et al 2006).

In Assam, soils of hot perhumid agro ecologicalsub regions cover parts of upper Assam, surrounding Dibrugarh and North Lakhimpur in the north east and parts of Barak valley in the south. Soils are developed in recent alluvium and are very deep, imperfectly to well drained, light textured, dark gray to dark grayish brown with Fe/Mn nodules, slightly acidic to neutral Jow CEC and moderate to high base saturation. Soils of the hot humid agro-ecological zones with varying LGP cover a large area in Assam and are acidic, low to medium in CEC with poor base saturation and moderately rich in organic matter. Soils of hot moist sub humid regions are acidic, low to medium in CEC, low base saturation and low moisture availability. Soils of warm humid agro-zones cover the North Cachar Hills. Like other hilly areas of the NEH region, shifting cultivation is also practised in this part of Assam. The soils in the South Bank of Brahmaputra valley are very deep, acidic (pH 4.5 - 6.5), fine textured with CEC ranging from 5 to 20 c mol (p+) kg-1, mostly dominated by Inceptisols (Sen et al., 1992). Phosphate fixation and low availability of micronutrients are the major problems.

Jhum (Shifting Cultivation) has resulted in heavy loss of organic matter from the soils that suffer from erosion hazards. The amount of day and soil pH tends to decrease as the elevation increases with an increase in sand, organic matter and cation exchange capacity of soil (Singh and Datta, 1988; Gangopadhayaya et al, 1990). Steep slopes accelerate the removal of soil separates and exchangeable cations through various agencies like high intensity of rainfall, hill agriculture and movement of human and animals etc. Clay content is invariably low in the narrow valleys, because run off sediments do not get chance for setting and are ultimately diverted to the main drainage. However, in wide valleys, poorly permeable or n poorly drained soils are heavy in texture or colluvial or alluvial origin formed from the eroded materials of the adjoining hills. In Manipur (Sen et al., 1996), the soils are acidic with high organic matter content. Available phosphate is very low in the soils of upper reaches, while it is medium in the soils of narrow valleys. Valley and flood plain soils derived from the alluvium are deep to very deep, poorly to moderately well drained. The adjoining hills are acidic in reaction while valley soils are acidic to neutral in reaction due to deposition of bases brought by surface runoff water and eroded materials. (Sharma et al 2006)

In Meghalaya, soils of hill top/upper hill slopes are shallow to deep, severely eroded, excessively drained and acidic in nature. Soils of the valley are deep, poorly drained, acidic and slightly eroded. In Mizoram. soils are strongly to moderately acidic in nature, high in organic matter content, high in exchangeable Al and poor in base saturation. Similar is the soil characteristics noted in Nagaland. In Sikkim (Das et al, 1996), soils are developed in hill top, side slopes and valleys. Soils are acidic in nature and high in humus. Surface stoniness and soil erosion are also noted in the soils of Sikkim. Soils of Tripura (Bhattacharyya et al, 1996) are, unlike other places of the NEH region, deficient in organic matter. The differentiating characters of the soil series as reported by (Bhattacharyya et al, 2004).

Among Ultisols having 19 soil series, soil pH underwent a variation from 3.7 to 5.1, CEC, 4.6 to 12.3 cmol (p+) kg-1, clay, 17 to 55.9 % and base saturation,14 to 36 %. There are 23 soil series under Inceptisols and 5 soil series are also grouped under Entisols. Alfisols contain only one soil series. Soil pH under Inceptisols underwent a variation from 3.2 to 6.6, CEC, 3.0 to 32.0 cmole (p+) kg-1, clay, 23.2 to 65.0 % and base saturation, 25 to 64 %. In Entisols, soil pH showed a variation from 3.8 to 5.9, CEC, 3.3 to 6.5 cmole (p+) kg-1, clay, 17.1 to 28.3% and base saturation, 37 to 65.3%. Soil acidity is more pronounced in Ultisols than other soil orders. Some soils under Entisols are neutral in reaction. It is revealed (Table 3.23) from the soil testing report (Laskar et al, 1982) that pH values of Tripura soils vary from 4.05 to 6.05 and in more than 90 per cent of the soils of Tripura, pH is below 5.6. On an average, 52.1 percent of soils are medium, 22.5 percent soils are low and 25.4 percent soils are high in organic carbon content. The available phosphorus index values varies from 1.34 to 1.82 and 60.5 percent soils, are deficient, 26.9 percent soils are medium and 12.6 percent are high in available phosphorus content. Low available phosphorus content is related to strongly acidic soil condition. The available potash index values vary from 1.20 to 1.76. All the soils in different Blocks are low in available potash content except Dumbernagar block which is characterized as medium in available potash content. In the state as a whole, 67.3 percent soils are low, 24.7 percent soils medium and only 8 percent soils, high in available potash content. Shifting cultivation prevalent in the region is responsible for removal of most fertile top soils from hill slopes (Sharma et al 2006).

Available research data on the soil characteristics depicts that pH dependent acidity constitutes the major part of acidity. The soils are medium to high in organic carbon and the total N content; low to medium in available P content (Table 7) and medium to high in available K content. Almost all the soils of Meghalaya, Tripura, Manipur, Arunachal Pradesh, over 50 % of Nagaland, 40 % of Mizoram and 30 % of Sikkim are rated low in available phosphorus.

Table 7. Different forms of Phosphorus in NEH Region

State	Range of Phosphorus (ppm)				Source
	Total	Organic	Bray P1	Bray P2	
Manipur	349-1993	67- 454	-	3.0- 26.7	Kailash Kumar and Mausumi Raychaudhuri 1997. J. of Indian Soc. Soil Sci. 45, 574-77.

Meghalaya	375-1575	118-718	0.5-15.0	0.5- 87.0	Patiram, Prasad, R. N. and Munna Ram 1993. J. Indian Soc. Soil Sci. 41. 430-3.
Mizoram	154-341	1.1-111	2.0- 13.9	-	Singh, O. P. and Datta, B. 1987. J. Indian Soc. Soil Sci. 34. 700-05.
Nagaland	480-1920	---------	3.1- 48.6		Anonymous
Sikkim	376-1650	68-864	2.5-101	-	Patiram, Rai, R. N. & Prasad, R. N. 1990. J. Indian Soc. Soil Sci. 38. 237-42

In most of the soils N and P are the limiting factors for optimum crop yield. The deficiency of K occurs on highly degraded soil where the topsoil is completely eroded due to heavy leaching or landslides. The Scientists of the National Bureau of Soil Survey and Land Use planning have estimated that 42 % of the area in NEH region covering Meghalaya, Manipur, Nagaland and Tripura and eastern part of Arunachal Pradesh is affected by water erosion. Sikkim and parts of Arunachal Pradesh are heavily damaged both by water erosion and landslides. The soils, which are strongly acidic in nature, are not favourable for crop growth, thus, left barren leading to excessive soil erosion and degradation.

Very little information is available about the micronutrient status of this region. The DTPA extractable Zn, Cu and Mn ranges from 0.72-3.28, 0.6-2.8 and 3.0-162 ppm respectively. Most of the soils of Sikkim are high in available Fe, Cu, Zn and Mn content. The distributions of the available status of these elements in different hill soils are presented in Table 8. The availability of micronutrients viz., Zn, Fe, B, Mn, Cu, Mo are also affected by the acidity and becoming a yield limiting factor in these soils.

Table 8 Micro-nutrients status of NE soils

State	Micronutrients (ppm)				Source
	Fe	Cu	Zn	Mn	
Arunachal Pradesh	7.0-73.6	0.14-4.07	0.11-1.12	1.6-64.6	Anonymous
Manipur	17.8-244	0.4-7.6	0.4-5.8	27.5-249	Original Data
Meghalaya	21-77	0.06-3.64	0.03-3.3	0.8-110.0	Patiram & Prasad, 1984. Lyngdoh, & Shukla1993
Nagaland	10-92	0.2-2.5	4.5-55.6	10.5-34.7	Ghosh & Ghosh 1982.
Sikkim	6.8-139	0.3-5.8	2.1-11.8	3.8-132.1	Patiram et al 2000
Tripura	1.8-62	0.2-2.2	2.1-4.0	11.4-33.6	Datta & Ram 1993.

Patiram & Prasad, R. N. 1984. J. Indian Soc. Soil Sci. 32. 194-6; Lyngdoh, J. C. & Shukla, L. M. 1993. J. Indian Soc. Soil Sci. 41 707-9 ; Ghosh, G. & Ghosh, S. K. 1982. Indian Agric. 26. 91-9. ; Patiram, Upadhyay, R. C. Singh, C. S. and Ram, M. 2000. J. Indian Soc. Soil Sci. 48 246-9. ; Datta, M. & Ram, M. 1993. J. Indian Soc. Soil Sci. 41 776-7.

Soil Management

The soils are rich in organic carbon content but the availability of N is not adequate due to low mineralization rate and the crops show deficiency symptoms of stunted growth and yellowish green colour. The crops are highly responsive to nitrogenous fertilizers. The total consumption of chemical fertilizers (N, P2O5 and K2O) was highest in Manipur and has increased from 1,741 tonnes in 1975-76 to 13,185 tonnes in 1997-98 to 22,670 tonnes in 2001-2002 followed by Tripura (13520 tonnes in 2001-02 @ 30.5 kg/ha). The gross cropped area, total food grain production and the total consumption of chemical fertilizers (N, P2O5 and K2O) of different states of NEH Region are presented in Table 9 (Raychaudhuri 2005).

Table 9. Gross Cropped Area, Fertilizer Consumption of NEH States for the year 2000 - 01

State	Gross Cropped Area ('000 ha) under different crops	Total fertilizer consumption ('000 Tonnes)	Fertilizer consumption / unit gross cropped area (kg/ha)
Arunachal Pradesh	194	0.60	2.4
Manipur	261	22.04	102.0
Meghalaya	298	3.86	14.5
Mizoram	82	1.44	12.4
Nagaland	219	0.40	1.4
Tripura	297	9.2	20.7

Application of chemical fertilizers (2001-02) in the ratio of 13.4: 1.9:1 compared to that of FAO standard i.e. 4:2:1 as Nitrogenous: Phosphatic : Potassic fertilizers in selective pockets, mostly in wet land paddy in Manipur covering only 10 per cent of the gross cropped area @ 105 kg / ha, not only increases the acidity of the soil but also induced insect pest incidences. Use of nitrogenous fertilizers alone lowers the soil pH. This is because they do not have a basic cation to counteract the acidity produced during their breakdown to simpler forms. Thus, its injudicious use in these soils is a total disaster at the cost of the ecology of the soil. On the other hand the lowest consumption was recorded in Nagaland (610 tonnes) @ 2.1 kg/ha followed by Arunachal Pradesh (720 tonnes) @ 2.9 kg /ha during 2001-02 showing an immense scope to increase the production with judicious fertilizer application.

Urea is widely used nitrogenous fertilizer in this region, which is subjected to heavy losses due to leaching, run off and denitrification processes. This is a major constraint for efficient use of native as well as applied N. In general, percent recovery of applied N is hardly 10-15 per cent in this region and major portion is lost by the above methods. The use of slow release nitrogenous fertilizers viz., rock phosphate coated urea, urea super granule in place of urea are recommended. Organic inputs like, Azolla @ 10 t /ha, suitable strains of Azotobacter, Azospirillum, Blue green algae, green manure and farm yard manure increased the N use efficiency and can supplement 15-30 kg N/ha to wet land rice grown in this soil. Incorporation of paddy straw @ 5 t/ha is also beneficial in mobilizing the nutrients for plant uptake. Thus, application of N fertilizers through a combination of organic (50 %) and inorganic (50 %) means is recommended for this region (Raychaudhuri & Raychaudhuri 2006).

The deficiency of phosphorus in crops are seen in crops as poor tillering in rice and wheat, purplish colour in leaves of maize and poor growth to most of the crops. The crops are highly responsive to phosphatic fertilizers. Experimental results indicates that the application of 50-80, 120, 50-80, 80 and 60 kg P2O5 /ha for rice, potato, wheat, maize, soybean and french bean respectively. Mixture of rock phosphate and SSP (3:1) is more efficient in Tripura and Manipur because of reduced P fixation. The initial requirement is met by SSP and then gradually by slow release from rock phosphate. Liming increases the availability of phosphorus to the plant. Liming @ 0.25 LR (Lime Requirement) for cereals through broadcasting and 500 kg /ha in furrows for legumes are recommended. Suitable strains of P solubilising microorganisms viz. Bacillus polymixa, Pseudomonas striata are also found effective when applied in combination with lime, organic and inorganic fertilizers. Application of 60- 80, 40-50 and 30-40 kg/ha K2O / ha are recommended for wet land paddy, maize and oilseeds/pulses based cropping systems respectively for K deficient soils. But recommendations on the basis of the soil test values are more efficient and balanced than the general recommendations.

Balanced Fertilization

Balanced fertilizer is the application of all those nutrients, which the soil cannot supply to meet crop demand. It is an integrated approach with the use of inorganic and organic inputs that nourishes the soil in many ways. It supplies all the essential nutrients to the crops in sufficient amounts and make the nutrients readily available during crop growth. Paddy is the staple food of this region and mostly grown during pre-kharif and kharif season. Under waterlogged condition, the acidity of the soil reduces and the pH rises up providing a congenial environment for crop growth. With judicious fertilizer management the optimum as well as potential yield can be achieved. Experimental results suggest that Azospirillum (C2 strain) and Phosphatika (Pseudomonas striata) alone and in combination increased the grain yield by 20.8, 14.6 and 22.8 respectively over control. In addition to half and full recommended doses of N, P_2O_5, K_2O the yield increases by 33 and 50 per cent respectively over control. Farm yard manure (FYM) @ 10 t/ha along with biofertilizer (Azospirillum + Azotobacter) increased the yield of maize by 144 per cent. When coupled with half and full recommended doses of N, P_2O_5, K_2O the yield further increased by 21.4 and 34.3 per cent respectively. Inter-cropping of paddy and maize with groundnut/soybean/ beans are advisable in low fertility soils. Other than the combination of farmyard manure and suitable strains of biofertilizer a combination of farmyard manure along with furrow liming @ 500 kg/ ha has been recommended for oilseeds and pulses (Raychaudhuri and Raychaudhuri 2008)).

Organic inputs in addition to retaining soil fertility, increases moisture and cation holding capacity of the soil and improves soil structure. Experimental data revealed that the soil pH increased from 4.8 to 5.63 with lime @ 500 kg/ha and further to 5.81 when combined with FYM @ 10t/ha thus providing a congenial environment for the nutrients to be available to the plants. The soil exchangeable Ca + Mg content increased significantly with FYM @ 10t/ha, Lime @ 500 kg/ha and Lime + FYM from 2.27 to a maximum of 3.58 cmol (p+) kg^{-1} with lime. FYM and lime alone and in combination increased the organic matter content in the soil significantly by 28.3, 17.7 and 32.3 per cent respectively over control (1.19 percent). Average quality FYM contains 0.4-0.6% N, 0.2-0.3 % P_2O_5 and 0.6-0.8 % K_2O i.e. 12 –17 kg nutrients per tonne. Lime @ 500 kg/ha + FYM @ 10t/ha was the best treatment found as it increased the pH, available nutritional status and the yield to a maximum.

As agro-ecosystems are open and dynamic systems, balanced fertilization can only aim at nutrient supplementation in order to assist crop performance and at the same time to minimize losses. The balanced of nutrients in soil ecosystem can be described by the following equation,

$$NRth = \sum th \, (NPt + NA\Delta t - NU\Delta t - NL\Delta t)$$

Where, NR is the soil inorganic and organic nutrients at time (th), NA is the soil inorganic and organic nutrients added or returned to the soil during the time interval Δt. NP is the soil organic and inorganic nutrients present at time t. NU is the uptake of nutrients by the harvested product during the time interval t. NL is the inorganic and organic nutrients lost during the time interval Δt, t is the time of sowing and th is the harvesting time and Δt is the time interval between t and th. The equation simply states that if nutrients removed are greater than additions, the reservoir of nutrients remaining within the soil pool will decline.

Thus, on the basis of the fertility status of the soil a judicious application of nutrients in the form of organic and inorganic in a balanced way to overcome the deficit in the soil is recommended for sustainable crop production in this region.

Possible Actions

All this land is beyond amelioration by individuals. The aid of science and technology is inevitable to ameliorate these acid soils (pH < 5.5). Intensive action in terms of liming, balanced fertilization and soil health management, improved seeds irrigation is essential to achieve the goal. More attention should be given on organic inputs as the entire north east has been identified for promotion of organic farming. Effort should also be given to integrated approach, recycling of wastes and soil health card for maintenance of soil health. Government laws should be framed and implemented to ensure lime quality, to issue Soil Health Card and also to restrict Jhum cultivation. Subsidies should be given to farmers to promote liming and balanced fertilization.

Soil Health Card

Soil Health Card (SHC) is the need of the hour. The soil science division of ICAR Research Complex for NEH Region, Manipur Centre has released SHC on 5th November 2007. Likewise State Government should also strengthen soil testing laboratories to reach the farmers of every village. Mobile soil testing facilities will also administer the soil status where no soil testing facilities are available. Establishing soil testing laboratories will not only generate job opportunities for specialist, technicians and extension workers but also improve the awareness skills and job status of the farmers. It will enable the farmer to plan his cropping system according to the nutrient status of the soil as well as on the basis of the inputs available. Working together the scientists, the administrators and the peasants will definitely help us to achieve the goal of maintaining soil health.

Water Resources in NE

The Eastern Region is rich in rain, surface and ground water resources. The average annual rainfall ranges from 1100 to 2000 mm, which is sufficient to meet the agricultural water requirement. However, spatial and temporal variations cause a lot of uncertainty and instability in agricultural productivity and production in the region. In one hand, occurrence of long drought spells during crucial periods is quite common, on the other hand, heavy monsoon rains cause water congestion and flooding, making cultivation in the kharif season an uncertain proposition. Annual surface water flow is abundant (117 M ha-m), but much less is utilizable (36 M ha-m) of which only about one-third has been actually utilized.

Table 10: Water Resources – availability and utilization.

Total Water resources potential	537.2 km^3
Per capata water availability	18,400 cu m as against 2,208 cu m of the country
Hydropower potential	44% of the country's total (66,065 MW out of country's total of 1,48,701 MW) source : NHPC
Hydropower Potential developed so far	Only about 3% as against 16% of the country
Irrigation potential	4.26 million hectares (m.ha)
Present coverage of irrigation	0.85 m. ha (20% of the existing potential against the national average of 65.4%)
Total replenishable Groundwater Potential	26.55 km3 /year against 431.42 Km/year of the country (6% of country's total)
Ground water potential developed so far	4.3% (against the national average of 32%)

Source : Goswami, 2001

Table 11 Inland Water Resources of NER

States	River & Canals (kms)	Reservoirs	Tanks & Ponds (lakh ha)	Flood plain Lakes & Derelict Water bodies (lakh ha)	Brackish Water (lakh ha.)	Total Water Bodies (lakh ha)
Arunachal Pradesh	2000	-	2.76	0.42	-	3.18
Assam	4820	0.02	0.23	1.1	-	1.35
Manipur	3360	0.01	0.05	0.04	-	0.1
Meghalaya	5600	0.08	0.02	Neg	-	0.1
Mizoram	1395	-	0.02	-	-	0.02
Nagaland	1600	0.17	0.5	Neg	-	0.67
Sikkim	900	-	-	0.03	-	0.03
Tripura	1200	0.05	0.13	-	-	0.18
India	195210	29.07	24.14	7.98	12.4	73.59

Source: Annual Report 2010-11, Department of Animal Husbandry, Dairying and Fisheries

Ground water potential is also high (30 million ha-m) of which less than 20 percent is being utilized. The total overall utilizable surface water potential for irrigation is about 15 M ha m while it is 12 M ha m for ground water resource. The Eastern region is crisscrossed by large river systems. There are seven major rivers which have catchment area larger than 20,000 sq.km. and four medium rivers which have catchment area larger than 5000 sq. km. The topography of the region renders it vulnerable to recurring floods and waterlogging. In the areas adjoining Nepal, floods are an annual feature during monsoon months, with all the rivers spilling over into adjacent areas. While the floods do cause considerable distress, to which the affected population has become rather accustomed, the floods facilitate beneficial rabi operations due to silt deposition.

The North-Eastern region has two major river basins, the Brahmaputra and Barak. The Brahmaputra basin drains an area of 194,413 sq. km stretching through entire Arunachal Pradesh, the greater part of Assam, Meghalaya and Nagaland. The Barak and other basins, draining an area of 78,150 sq. km occupy the northern and western part of Manipur, southern part of Meghalaya and Assam. Both river basins cover 86% of the geographical area of the North East. Per capita and per ha runoffs are 21,060 m3 and 44,232 m3 from Brahmaputra and 7,475 m3 and 53,680 m3 from Barak basin respectively. The bulk of the annual rainfall in the region (65%) is received during June to September. Though the North-Eastern states have 5.60% of the total geographical area of the country, they receive 12.13% of the total precipitation in the country. The region has sizable surface and ground water resources mainly because of its location in the high rainfall area with an extensive river system. But the water resources are largely unutilized on account of inaccessibility and difficulty in construction of reservoirs. The total surface water potential of the region (except Sikkim, for which data is not available) is 928,873 Mm3. The region has a total ground water potential of 855 Mm3 (excluding Sikkim).

Table 12: Ground Water Resources (Dynamic) of NE India

S No.	States	Total ...nsihab ...ound ...ter ...urce BCM/yr	Provision for domestic, industrial & other uses BCM/yr	Available ground water resources for irrigation BCM/yr	Net Draft BCM/yr	Balance ground water resource for future use BCM/yr	Level of ground water ...en (%)
1	Arunachal Pradesh	1.44	0.22	1.22	--	1.22	Neg.

2.	Assam	24.89	3.71	21.01	1.84	19.17	8.75
3.	Manipur	3.15	0.47	2.68	Neg.	2.68	Neg.
4.	Meghalaya	0.54	0.08	0.46	0.02	0.44	3.97
5	Mizoram	Under estimatinon	--	--	--	--	--
6	Nagaland	0.72	0.11	0.62	Neg.	0.62	Neg.
7	Tripura	0.66	0.10	0.56	0.19	0.38	33.43
8.	Sikkim	Under Estimation	--	--	--	--	--

Source ; Central Ground Water Board 2011

The largest consumptive use of water in the Bramhaputra – Barak basin is irrigation accounting about 91% of total water consumption. However, most of the waters withdrawn for irrigation are lost as non-beneficial depletion. This loss can be reduced through use of effective irrigation practices like, precision irrigation techniques, crop planting adjustments matching less evaporative demands, soil mulching. The overall irrigation efficiency of Bramhaputra Basin is 32% and potential annual evapotranspiration is worked out to be 1,114mm, which is lowest among the basins (Amarasinghe 2005). Irrigation accounts 91% of the total withdrawals of 9.9 km3 in the Bramhapura basin. Potentially utilizable water resources (PUWR) of the basin are worked out to be 50 km3, in which 90% is not developed at present. Part of PUWR is withdrawn at present and depleted through various processes. These include evapotranspiration from irrigation fields and consumptive use by the domestic and industrial sectors and account for 3% of the PUWR for the Bramhaputra basin.

Table 13: Total gross and net water demands.

Sector		**Gross Demand (bem)**	**Consumption (%)**	**Net Demand (bem)**
Domestic water supply				
Rural				
	Domestic	2.92	--	--
	Livestock	0.694	--	--
	Total (rural)	3.614	50	1.807
Urban		1.533	30	0.459
Sub Total (1)		5.147		2.266

Industrial (2)	5.147	20	1.06
Agricultural Surface water irrigation	35.20	44	15.50
Ground Water	16.90	50	8.50
Sub Total (3) agriculture	52.10	--	24.30
Total (1+2+3)	62.39		27.63

Mohile 2011

The total irrigation potential of North East is estimated to be 36.65 lakh ha by Central Water Commission (NEDFI 2002). Assam has the largest irrigation potential of 2,670 km^3. In Assam and Arunachal Pradesh both, the ratio of gross irrigated area to gross cropped area has declined over the years indicating that many secondary crops are not irrigated due to the absence of adequate facilities.

Table14State wise irrigated area in NER (2006-2007) 000,ha

States	Net Irrigated Area	Gross Irrigated Area	Area Irrigated More than Once	Net Un-Irrigated Area	Total/Gross Un-Irrigated Area
Arunachal Pradesh	52	52		157	223
Assam	52	52		157	223
Manipur	140	190	50	2613	3364
Meghalaya	51	51		173	173
Mizoram	67	72	5	146	193
Nagaland	16	18	1	75	74
Sikkim	65	106	42	258	300
Tripura	9	12	3	104	112
India	60857	85783	24926	79441	107940

NER Statistics

There is need for irrigation during both the kharif and rabi seasons. During the spell of moisture stress in non-rainy periods the crop yield per ha is much lower than those in other parts with established irrigation. The projected values indicate that the irrigation potential likely to be created at the presented rate will fall considerably short at 16.12 lakh ha of the total net sown area of 27 lakh ha, even at the end of 2020 AD. The total irrigation requirement for the Bramhaputra basin will be 5.2 million ha-m (1.95 m ha-m for kharif and 3.25 m ha-m for rabi) (Goswami et al 2004).

Ground water resources

In the eastern part of the country in the Brahmaputra valley water level generally ranges from 2-5 m bgl, except in isolated pockets where depth to water level is less than 2 m bgl. However, in upper Assam, isolated pocket of deeper water level, 5-10 m bgl has been observed**.** Replenishable Groundwater resource is significantly high in the Indus–Ganga–Bramhputra alluvial belt in the North, East and North East India covering the states of Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal and valley areas of North Eastern States, where rainfall is plenty and thick piles of unconsolidated alluvial formations are conducive for recharge. Annual Replenishable Ground Water Resource in these regions varies from 0.25 to more than 0.5 m. An analysis of ground water draft figures indicates that in the states of Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, ground water draft for domestic & industrial purposes are more than 15%.

The entire foot hill belt in **Arunachal Pradesh** running along the Himalayan front can be correlated to Bhabar belt with the exception of some area. Unconsolidated Quaternaries and Upper Tertiary form the main hydrogeological unit. Open Wells in Namsai and Miao sub-division tapping saturated sand generally yield in the range of 1000 to 3000 lpd (0.035 to 0.10 lps). Ground water assessment has been carried out in the valley areas of the districts. The Annual Replenishable Ground Water Resource of the state is estimated as 4.45 bcm and Net Annual Ground Water Availability is 4.01 bcm. The Annual Ground Water Draft is 0.003 bcm and Stage of Ground Water Development is 0.07%. All the districts have been categorized as Safe. There has been increase in the Replenishable resources which is attributed to the inclusion of more districts in the present assessments as compared to the previous assessment.

Major areas of **Assam** are underlain by unconsolidated formations in Brahmaputra valley other than consolidated and semi-consolidated formations in the hilly areas. Shallow tube wells constructed in alluvial areas yield to the tune of 6-8 lps. Ground water assessment has been carried out in the valley areas of the districts. The Annual Replenishable Ground Water Resource is 30.35 bcm and Net Annual Ground Water Availability is 27.81 bcm. The Annual Ground Water Draft is 6.03 bcm and Stage of Ground Water Development is 22%. All the districts have been categorized as Safe. A relatively high stage of ground water development has been recorded in the districts of Bongaigaon, Barpeta, Kamrup, Morigaon and Nalbari district. There has been marginal increase in both recharge and draft components as compared to the previous estimates. Thus the Stage of Development in present estimate remains almost same as compared to the 2004.

Assessment of ground water resources in **Manipur** has been done in the valley areas of blocks. The Annual Replenishable Ground Water Resource is 0.44 bcm and Net Annual Ground Water Availability is 0.40 bcm. The Annual Ground Water Draft is 0.004 bcm and Stage of Ground Water Development is 1%. All the blocks have been categorized as Safe.

In Manipur, annual replenishable ground water resources have increased by 16% as compared to previous estimate, because of the inclusion of additional area feasible for natural recharge of ground water. Ground water draft has also increased in the State by many folds because of the same reason.

The northern part of the **Meghalaya** is covered by consolidated formations with basic and acid intrusive. The semi-consolidated sandstone with other sedimentary rocks covers the entire south-western and south eastern part of the state. The unconfined zone in river fill areas is tapped with shallow tube wells; the yield varies from 7 to 12 lps. Assessment of dynamic ground water resources were carried out in the valley areas of the districts. The Annual Replenishable Ground Water Resource is 1.23 bcm and Net Annual Ground Water Availability is 1.11 bcm. The Annual Ground Water Draft is 0.002 bcm and Stage of Ground Water Development is 0.15%. All the districts (Valleys) in state have been categorized as Safe. There is no significant change is the present estimates as compared to 2004 assessment.

Major part of **Mizorum** is occupied by hills and semi-consolidated rocks of Tertiary age and state of Mizoram are an abode of springs. Studies indicate good scope of tapping ground water in river beds with sumps connected to infiltration galleries. The ground water of the unconfined zone mostly emanates in the form of springs which are being used as source of water supply. Ground water assessment in Mizoram was carried out in the valley areas of the administrative blocks. The Annual Replenishable Ground Water Resource is 4388 ham (0.04 bcm) and Net Annual Ground Water Availability is almost unchanged. The Annual Ground Water Draft is about 43 hams (0.0004 bcm) and Stage of Ground Water Development is 1%. All the districts (valley area) in state have been categorized as Safe. There is no significant change is the present estimates as compared to 2004 assessment.

Nagaland is mostly covered by hilly terrains having slope more than 20%. The consolidated / semi-consolidated formations are confined to south eastern part of the state along the Burma border and the unconsolidated alluvial plains in the northern part of the state. The open wells are not very common structure. However, in the valley area it can yield up to 15 lps.

Ground water resources assessment was done in the valley areas of the districts. The Annual Replenishable Ground Water Resource is 0.42 bcm and Net Annual Ground Water Availability is 0.38 bcm. The Annual Ground Water Draft is 0.01 bcm and Stage of Ground Water Development is 2%. Entire state has been categorized as Safe. There is no significant change is the present estimates as compared to 2004 assessment.

Sikkim is a small mountainous state characterized by rugged topography with series of ridges and valleys. Ground water occurs largely in disconnected localized pockets and in deeper fractures zones, springs are the main sources of water. The total discharge of the springs is about 0.046 bcm and its annual utilization for domestic purpose is about 0.01 bcm. The stage of development is 21%. There is marginal decrease net annual ground water availability in the state in 2009 as compared to 2004.

In **Tripura** the semi-consolidated formations consisting of friable sandstone, sandy shaleetc. of tertiary age forms the main rock type of the area. The unconfined aquifer is mainly tapped through shallow wells with a discharge of 5 to 15 lps in the valley areas whereas in the sandstone, the yield varies from 2 to 4 lps. Ground water resources in the state have been assessed in the block-wise. The Annual Replenishable Ground Water Resource is 2.97 bcm and Net Annual Ground Water Availability is 2.74 bcm. The Annual Ground Water Draft is 0.16 bcm and Stage of Ground Water Development is 6 %. All the blocks in the state have been categorized as Safe. There has been 36% increase in the assessment of replenishable resources because of the inclusion of additional area feasible for natural recharge of ground water.

Potential of rainwater harvesting

Heavy monsoon notwithstanding the people of NE hills suffer from acute water shortage during non rainy seasons every year. The geological formation does not permit water retention, runoff is quick, springs and small streams dry up quickly without rain. Many indigenous rain water harvesting system is used for irrigation in which some are ingenuous. The typical water management techniques based on local skills and resources are prevalent in the region. The techniques are developed based on their long experience under the existing soil and climatic conditions and availability of large number of hill streams which are effective in the prevailing topography and terrain. Some of those practices, mostly confined to the places of their origin are documented by Prasad and Sharma (1994), are

1. Bamboo Drip Irrigation System
2. Zabo System of Rice Cultivation
3. Water Management Practices of Apatani Valley
4. Panikhetu
5. Stream Flow Lift Irrigation

Table 15 Indigenous water management system of North East

Systems	States	Water Conservation methods	Crop productivity
Panikheti system of rice cultivation	Nagaland, Sikkim and Manipur	Terracing, diverting water from hills to terraces.	2. 5 to 3 t/ha
Apatani method of rice cultivation	Apatani plateau of Arunachal Pradesh	Developed by Apatani tribe for rice-fish together at 1525 above msl	4 – 4.5 t /ha
Zabo farming	Phek district of Nagaland	Protected forest land at top of hill, water harvesting tanks in middle and cattle yard and paddy field at lower side.	3.0 – 3.5 tons/ha
Bamboo drip irrigation	Jaintia hills of Meghalaya	Drip irrigation using bamboo/banana pseudo stem	Good harvest of Arcanut
Stream flow lift irrigation		Harnessing hill stream in monsoon with temporary check dams for diversion and conveyance through earthen channels. The portable water lift system with pump/engine on tyred wheeled bullock cart cum trolley	-
Das et al 2012			

Recurring water crisis in every year compelled Mizoram Government to take up rain water harvesting on a serious note. The method envisages fitting semicircular rain gutters fabricated with galvanized sheets to the caves of roof to collect rainwater, which are to be stored in reservoirs for use during dry seasons. Sikkim over the years evolved efficient water harvesting system together with their traditional land management systems.

Water demand

In almost all sub-basins (Bramhaputra), maximum available irrigated area is expected to be constant up to 2050 and significant fluctuation is not expected in future water requirements. A gross demand of 62.4 and a net demand of 27.6 bcm has been projected to meet domestic, industrial and agricultural requirements including livestock by 2050. The dependable flow of Bramhaputra and Barak in the lean flow period is estimated to be of the order 3000 m^3/sec and 45 m^3/sec respectively at their exit point. The total ground water potential of the two sub-basins, at about 31 bcm per year, can support for 240 days/annum, a draft of about 1500 m^3/sec. From a simple hydrologic point of view, the ground water draft in the long run may be lead to reduction in surface flows. But together from both the sources, 3000 m3/sec water is available. The net withdrawal from the system, including groundwater, would be of the order 239 m^3/sec in February, which is lower than the lean flow of 304 m^3/sec.

The population of NE India in 2050 would require 16 million tons food grain calculated on 500 g per capita per day consumption for 80 million people. However, the foodgrain production in 2010 is only 6.55 million tons which is well short of desired production which needs adequate attention.

Epilogue

Soil management

The entire north-east region is acidic in reaction. The problem of acidity needs to be managed by liming and discouraging shifting cultivation and deforestation. The nitrogen and phosphorus requirements can be managed by the judicious and efficient combination of the organic inputs. The use of lime, FYM, biofertilizers along with organic fertilizers proved to be beneficial in managing these soils. Owning Soil Health Card should be encouraged. This will help the farmers in building up confidence among them to manage the soil judiciously. The fundamental reasons for the failure of farmers to adopt technology to increase crop production was found to be in the fact that they have lacked resources and even more so the agro-services, which are a must for the adoption of several of these components. Development of the institutional framework and the physical infrastructure, needed to provide a wide range of agro-services to the small and marginal farmers to alleviate the problems and improve the agricultural growth. Development of closer linkages between the research organizations viz., ICAR, CAU, SAUs and Department of Agriculture in the States will empower the cultivators in uplifting the social, economical and mental status not only through suitable technologies, but also through appropriate policies to adopt those technologies.

Water management

Even though the entire north eastern region receives the maximum amount of rainfall but still most of the area is under monocrop due to severe moisture stress in the rabi season. A very few area (approx 35% of the total cultivated paddy area in Manipur) is under irrigated condition that can produce double crop (rabi crop). The key to the problem lies in our relatively inefficient management of water. Some of the important efficient technology to be extended to restore soil and water loss relating both to the use of irrigation and conservation of water are 1) construction of small scale runoff/rainfed tanks, 2) construction and alignment of field channels for irrigation and drainage 3) recycling of drainage water for irrigation 4) crop and land use planning suiting to the water availability.

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Soil and Water Resources Management for Improved Agricultural Productivity in Bihar State

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Bihar is a very important state in India, with rich cultural and historical heritage. The name 'Bihar' has its origin from the name ‘Vihara' which means a Buddhist monastery. No wonder this state is therefore blessed with bountiful natural resources of fertile soil, abundant river water and climate most suitable for agriculture. Bihar is the fifth largest state in India in terms of area and is second in population. Agriculture is vital for Bihar since 76% of its population is engaged in agricultural pursuits. The farmers are intelligent and hard working. Therefore, agriculture has been described as the core competence of Bihar. Bihar's productive contribution in food grain, fruit, vegetables, spices and flowers can increase manifold with improved methods and system management. The state is endowed with rich biodiversity. Though endowed with good soil, adequate rainfall and good ground water availability, Bihar has not been able to relized its full agricultural potential. Its agricultural productivity is one of the lowest in the country, leading to rural poverty, low nutrition and migration of labour. Agriculture is prone to natural disasters, particularly flood in north Bihar and drought in south Bihar. Risk of natural disasters is being minimized through use of appropriate crop technology and extending crop insurance to all farmers. The strategic road map has been made which is aimed to trigger processes of development in agriculture and allied sectors.

Geographic Location:

Bihar is located between 24º 20' 10” and 27º 31' 15" latitudes and 83º 19’ 50” and 88º 17' 40”E longitudes and at an altitude of 53.0 m above MSL, covering an area of 9.36 million hectares. It is an entirely land–locked state, although the outlet to the sea through the port of Kolkata is not far away. Bihar lies mid-way between the humid West Bengal in the east and the sub humid Uttar Pradesh in the west which provides it with a transitional position in respect of climate, economy and culture. It is bound by Nepal in the north and by Jharkhand in the south. For 90 per cent of the total population living in rural areas, agriculture as the primary feeder of rural economy continues to operate not only on margins of land but also on the margins of human enterprise, its productivity is far below the potential. Without increasing returns to these margins, not much can be done realistically to develop the agricultural sector. Thus, agriculture continues to define both the potentialities and constraints to development in Bihar.

Climatic Zone and its characteristics:

Agriculture in Bihar is crucially dependent on monsoon. Although around 61 per cent of its gross cultivated area is irrigated, irrigation itself is crucially dependent on monsoon as it largely depends on the use of surface water. Bihar falls in the Agro Climatic Zone–IV of the country, which is called "Middle Gangetic Plains Region". Based on the soil quality and climatic conditions of the relevant areas, Bihar has been classified in 3 agro-climatic sub-zones :

North-West Alluvial Plain (Zone I),

North-East Alluvial Plain (ZoneII), and

South Alluvial Plain (Zone III),

Monsoon arrives earliest in the north eastern sub-Zone II, which also receives the highest rainfall among all three zones. Zone III receives monsoon showers last of all three zones and also the least amount. Total irrigated area in the State is 46.46 lakh hectares, of which nearly 20 per cent is fed by canal water. This highlights the monsoon dependence of even irrigated lands as catchment areas of nearly all the major rivers in the State are outside the state.

Climate :

Climate is an important factor affecting plant growth, water availability, water demands and land degradation. The State has three distinct seasons, viz. Winter (December to February), Summer (March to May) and Rainy season (June to September). The rainfall (Southwest monsoon) occurs during the months of June–September. The average rainfall in this state is recorded as 1,176.4 mm and the average number of rainy days in a year is 53. Summers is generally quite hot and winter is fairly cool. The identified indicators related to climatic conditions that can create large water deficits and affect land degradation and desertification are: (a) temperature, (b) annual rainfall, (c) aridity index, (d) annual potential evapotranspiration (ETo), (e) rainfall seasonality, and (f) rainfall erosivity.

Temperature in combination with other climatic characteristics affects the xerothermic index and the vulnerability of an area for desertification. It is a critical environmental factor in determining water stress and transpiration of the growing vegetation as well as soil water evaporation and soil salinity and alkalinity. The maximum temperature during summer season ranges from 32-44oC and the minimum ranges from 20-26oC, while RH during this period is between 50-75%. The monsoon or rainy season, the maximum temperature during this period ranges from 30-34oC and the lowest ranges from 25-26oC, while RH during this period is between 75-85%. The post monsoon period is followed by winter season (December to February) and during this period the maximum temperature falls marginally in the range from 31-28oC, but the minimum falls from 21-15oC. The winter is cool and dry and at times temperature falls to 4oC (range 2-9oC) while RH during this period is between 70-85%.

Climate change effects in the regions :

Four representative centres namely Pusa (Zone-I), Madhepura (Zone-II), Sabour (Zone-IIIA) and Patna (Zone-IIIB) have been selected to study the impact of climate change and the effects of adaptation measures to overcome its effect on important cereals, pulses and wheat crops grown in Bihar. Simulation results using 'Info Crop' projected decrease in wheat yield from baseline yield i.e. 3.3 % for 2020, 14.3% for 2050. Since, climate change is projected to reduce yield in the study region, it is crucial that the adaptation strategies to minimize the adverse impacts are decided . To facilitate this, with the help of simulation analysis was taken with different adaptation strategies, i.e. change in sowing time and nitrogen level etc were studied. Yield was simulated for 7 and 14 days advanced sowing in combination with 120, 150 and 180 kg of nitrogen. The current level of modelling studies on rice, wheat varieties are on in ICAR Research Complex for Easter Region (Patna). The response indicated that for all the varieties of rice and wheat, it was positive with increase of CO_2, however, with increase in temperature, yield was reduced. In nutrient management practices, split application of fertilizer showed higher yields in comparison to other nutrient practices which were 125 % chemical, INM and conservation technologies. The study is also in progress to understand the changes in Pest interactions and dynamics in important fruit crops such as mango and litchi, due to climate changes.

Table: Cultivated area, cropping intensity, soil and climatic conditions of different agro-climatic zones of Bihar

SN	Particulars	Zone - I	Zone - II	Zone - III
1	Area ('000 ha) Net cultivated Gross cultivated area	 2281 3260	 1147 1677	 2416 3408
2	Cropping intensity (%)	142.9	146.2	141.0
3	Soil texture	Sandy loam to loam	Loamy sand to clay loam	Sandy loam to loam with clay in some area
4	pH	6.5 to 8.4	6.5 to 7.8	6.8 to 8.8
5	Organic carbon (%)	0.5-1.0	0.2-1.0	0.7-1.0

6	Available N (kg/ha)	150-350	150-300	200-400
7	Available P_2O_5 (kg/ha)	0.04-0.20	0.02 – 0.15	0.04 – 0.17
8	Available K_{2O}(kg/ha)	200-300	200-300	150-300
9	Climate			
10	Rainfall- June to September October to November December to February March to May	1344.35 1077.30 0121.15 0035.15 0110.75	1381.90 1105.90 0112.30 0028.70 0135.00	1165.45 0935.55 0111.95 0031.95 0086.00
11	Temperature (ºC) Daily average Max. Min.	 25.3 41.8 07.1	 24.5 40.1 04.4	 26.4 42.8 05.7
12	Relative Humidity (%) 08.30 AM 05.30 PM	 67.30 58.80	 75.00 57.00	 66.40 50.90

Land Holdings:

Bihar houses a population of 82.9 million, with a population density of 880 persons per sq. km (Census 2001). Gross sown area in the state is 77.19 lakh hectares, while net sown area is 56.65 lakh hectares. There are around 104.32 lakhs landholdings in the State, of which around 83 per cent are marginal holdings of size less than 1 hectare. The area sown more than once is 2.052 million hectare with the cropping intensity of 136%. About 3.462 million hectare net area and 4.646 million hectare gross area receive irrigation from different sources. The Bihar plain is divided into two unequal halves by the river Ganga which flows through the middle from west to east. The distribution of number of operational holdings and area operated with all social groups of Bihar, shows highest 13.14 million under marginal category (<1 ha) covering an area of 3.31 m ha, followed by small (1-2 ha) with 9.78 m numbers and area covering about 12.24 m ha, semi medium (2-4 ha) with 4.38 m numbers and area 11.35 m ha, medium (4-10 ha) with 0.098 m numbers and area 0.505 m ha and very less under large (10 ha & above) with 0.004 m numbers and area 0.074 m ha respectively (Table).

Table : Land Use Pattern in Bihar

S. No.	Land Use	Area (lakh ha)	% of TGA
1	Total geographic area (TGA)	93.60	--
2	Net Area Sown	56.64	60.50
3	Gross Cropped Area	78.79	84.17
4	Forest	06.22	06.60
5	Misc. Tree crops and groves	02.35	02.50
6	Area sown more than once	22.33	23.86
7	Land put to non-agricultural use	16.42	17.50
8	Barren and non-cultivable land	04.36	04.70
9	Cultivable waste land	0.46	0.50
10	Other fallow land	1.35	1.50
11	Current fallow	5.63	6.00
12	Permanent pasture	0.17	0.20

2. Land utilization status:

Land use pattern:

The Land Use Pattern in this state exhibit inside variations. If we consider the percentage of net sown area, we would find that in 9 districts have more than 70 percent of the land area is under cultivation. These districts are Nalanda (74.4 per cent), Buxar (85.6 per cent), Bhojpur (79.6 per cent), Jehanabad (73.3 per cent), Saran (70.9 per cent), Gopalganj (70.3 per cent), Siwan (75.9 per cent), East Champaran (70.4 per cent) and Madhepura (72 per cent). On the other hand, districts with less than 50 percent of net sown area are Gaya (38.2 per cent), Nawada (41.8 per cent), Munger (37.1 per cent) and Jamui (20.4 per cent). The districts with low irrigation facilities have less cropping intensity. Cropping intensity Jamui (110%).

The area under forests has remained unchanged at 6.6 per cent and so has the area under non-agricultural use at 17.6 per cent. The area under net sown area has undergone a marginal change. In 2007-08, net shown area was 60.5 per cent as compared to 59.4 per cent in 2005-06. Cropping intensity (%) has also shown a marginal increase from 133 in 2005-06 to 137 in 2007-08. Land under both fallow and current fallow have registered a decrease in 2007-08. This indicates that, with growing population, the pressure on land is high.

In this state, there is virtually no scope for bringing additional land under cultivation. The Gross Cropped Area (GCA) can be increased only by enhancing the cropping intensity. Cropping intensity needs to be increased by undertaking measures like expanding irrigation network, and developing and disseminating stress-tolerant varieties of crops, among other things. The area under non-agricultural use is very high, and is expected to increase further due to urbanization and industrialization. The extent of cultivable area, which comprises fallow land, other fallows and the net sown area needs to be kept intact, by reducing the area under 'Other than Current fallows', in view of the low per capita availability of cultivable land. Despite the small size of holdings and over-dependence on agriculture, vertical intensification is still lower, indicating the lack of basic infrastructure like roads and markets as well as other agricultural inputs. These pressures pose a long-term threat to the sustainability of agricultural systems and rural livelihoods.

A substantial part of the agricultural land, that is, nearly 2.21 million hectares out of nearly 9.36 million hectares, suffers from mild to serious degradation. Salinity and alkalinity pose a serious problem in some of the command areas. A large part of the land gets water-logged, especially after the rainy season.

Land use systems based on fertility mining practices of low input are usually unsustainable. Special attention should be given to vast stretches of tal (backwater), water-logged areas of diara (lands in the flood plains of the rivers Ganga and Ghaghra) and the chawarlands (remnants of the old river course). Together these comprise nearly 9.0 lakh hectares.

Natural Resource Base and Agriculture

Though, agriculture is leading economic sector in Bihar, it is facing many problems including stress on natural resources and its growth rate is also not consistent, rather declining.

With the introduction of high yielding crop varieties many traditional and local varieties were replaced. The on-farm narrow genetic base has further led to the emergence of new pests and diseases. Maintaining agricultural biodiversity is important for long term food security. The challenge is further compounded with climate change and agriculture will have to cope with increasing weather fluctuation.

Crop production management deals with how farmers combine land, water, machinery, structures, commercial inputs, labour and management skills to produce crop commodities. Management systems embody some of the more important decisions related to production, and include nutrient management, soil management, water management, weed management and the like. Production decisions concerning what crops to produce, how much effort and resources to invest/use and which physical/agronomic practices to follow have immediate consequences for the farm and long term effects on the environment.

Bihar is one of the densely/highly populated (populous) state of India. Keeping in view the decline in land: human ratio, the future food fibre fuel and fodder requirements have to be met through enhancement of the productivity with the efficient use of natural resources.

Though, the state is endowed with rich natural resources and biodiversity, but the condition is declining with fast pace due to many factors and now situation has become alarming for present and future both. To conserve and improve the natural resources for increased and sustained production, the analysis of resource base becomes of great relevance particularly, the resource base of highly productive plains of Bihar. Out of five natural resources (soil, water, climate, vegetation and livestock), the two i.e. soil and water are most important which controls the paradigm of successful food security.

The area specific soils coupled with prevailing climatic conditions and availability of water determine the adaptation of agricultural, horticultural and forest vegetation. Similarly, water – a renewable resource, continually reprocessed and delivered – is a biological necessity and supreme wealth.

Soils and their fertility:

Sustainable management of soil resources implies maintaining high productivity per unit area on a continuous basis by maintaining its health and soil fertility status for use on a long term basis, by meeting present needs without jeopardising future potential.

The topography of Bihar can be easily described as a fertile alluvial plain occupying the Gangetic Valley. The plain extends from the foothills of the Himalayas in the north to a few miles south of the river Ganges as it flows through the State from the west to the east.

Soil related constraints in crops and cropping system :

Availability of nutrients in soil and method of fertilizer application are important for annual and perennial nature of crops grown in the state. The soil health is mainly governed by flooding, salinity and sodicity in fairly large part of Bihar. In Bihar soils, the zinc deficiency has received maximum attention, as soil tests and field experiments have indicated wide spread Zn deficiency in both agricultural and horticultural crops across soil types and agro-ecological zones. Extent of boron deficiency is next to zinc in order and its deficiency is most widespread in highly calcareous and old alluvial soils of Bihar. Poor land and water management have shown the declining trend of crop productivity due to consistent decrease in fertilizer use efficiency (Tiwari, 2012).

Table : Different types of problematic soils (with area) in Bihar

Type of problematic soil	**Area (lac. ha)**
Acid soils	0.02
Salt affected soils	3.20
Tal land soils	1.00
Diara land soil	9.30
Water logged soil	4.00
Chaur land	1.00
Calcareous soil	1.00
Eroded soils	0.20
High bulk density soil	1.00
Total	**20.72**

Cropping Pattern:

The Bihar state is endowed with rich biodiversity. There is dominance of paddy – wheat cropping system. Among cereal crops maize also holds the key position. This state also growing considerably sugarcane, oil seeds, jute at its region specific basis. The recent trend of crop diversification with horticultural crops has also changed the scenario of the state, as this state is the third largest producer of vegetables and fourth largest producer of fruits in the country. It is the largest producer of litchi, makhana, guava, lady's finger in India. The state already exports litchi, basmati rice and snow pea. It has competitiveness in maize, rice and fruit such as banana, mango, litchi and vegetables like onions, tomato, potato and brinjal. But on the whole, the principal agricultural crops are paddy, wheat, jute, maize and oil seeds. Cauliflower, cabbage, tomato, radish, carrot, beat etc. are some of the vegetables grown in the state. Sugarcane, potato and barley are some of the non-cereal crops grown. The entire agricultural operations are divided into two crop seasons i.e. k*harif* and r*abi*. The k*harif* season starts from the third week of May and lasts till the end of October followed by the r*abi* season.

Food grains production trend:

Food grain production in Bihar has shown high volatility, but there is a long-term trend of falling production but increasing productivity in the State. The food grain production recorded 122.29 lakh MT in 2001-02, 115.29 lakh MT in 2001-02 to169.69 lakh MT in 2010-11 (Table). Larger part of the fall in production and area is explained by the fall in production of and area under rice. Though production of wheat too has fallen, but area under it has largely been unchanged around 20 lakh hectares. Fall in production of wheat been due to its falling yield. Pulses too have seen a fall in production and acreage, but the fall has been moderate. The inconsistent production has fallen from an acreage falling in the corresponding period from 6.94 lakh hectares to 6.78 lakh hectares. While there has been a marginal fall in the productivity of pulses, but their yield rates have remained significantly above the national average. Acreage and production of coarse cereals have largely been unchanged over the last few years. Acreage and production of oilseeds has more or less hovered around 1.4 lakh hectares and 1.39 lakh MT in recent years with moderate fluctuations.

The observed trend of fall in acreage and production of cereals, it might be noted is not incidental. There has been a deliberate effort by the State government during the last five years, to divert land under rice and wheat cultivation towards horticulture. Plan of crop diversion has been given priority in 12 districts of the state. About 30 percent of area under wheat in the districts of Muzaffarpur, Darbhanga, Samastipur and Madhubani (Zone 1 districts) is being considered for diversion towards mango, litchi and makhana. Similarly 20 percent of crop area in the districts of East Champaran, Samastipur, Khagaria, Muzaffarpur and Vaishali is being considered for diversion towards banana. Further, about 20 percent of rice-wheat area in the districts of Buxar ,Bhojpur, Sasaram etc. is likewise being considered for diversion towards vegetable production. Finally, about 30 percent total area of the state is being considered for diversion from current crops towards new crops.

Major soil orders:

Based on recent classification, major soils of Bihar belong to 4 orders, 10 sub-orders, 18 great groups, and 66 families. The Inceptisols cover nearly 41.9 per cent area followed by Entisols, Alfisol sand Vertisols covering 36.8, 16.7, 0.8percent of total geographical area, respectively. The soils of different agro climatic zones in Bihar can be categorized in two groups i.e. (A) North Bihar and (B) South Bihar.

A. North Bihar : Seven types of soils in this region has been categorized as follows :

1. Sub-Himalayan hill and forest soils: This soil is found in the north-west corner of the state (West Champaran district). It is moderately acidic to neutral in reaction, dark brown to yellow coloured, coarse textured and shallow to medium deep. Most of the soils are covered by forests with occasional rice fields in the valleys.
2. Recent alluvial taraisoils: This soil is located in a thin strip along the northern border of the state. It is a mixture of highly disturbed recent alluvium and the old finer tarai soils. The recent alluvial soils are acidic to neutral in reaction and coarse textured. These soils are medium to fine grey in colour and have well developed genetic horizons.
3. Recent alluvial soils: These recent alluvial, non-calcareous, non-saline soils are found in the alluvial plains of Purnea, Katihar, Madhepura, Saharsa, northern parts of Bhagalpur and Khagaria and eastem part of Darbhanga and Madhubani districts. The soils are mostly coarse to medium textured, acidic to neutral in reaction and yellowish white to light gray in colour. In basin shaped flood plains, soils are gray coloured, medium to fine textured and shallow to medium deep soils over sand. The up land coarse textured soils are poor in fertility status as compared to low land soils.
4. Young alluvial soils : These young alluvial, non-calcareous, non-saline soils are found in the northern portions of the districts of Darbhanga, Madhubhani, Muzaffarpur, Sitamarhi and portions of Champaran district. It has poorly developed genetic horizons. The soil is coarse to medium textured, neutral to moderately 'acidic and moderately good to highly fertile soils.
5. Young alluvial calcareous soils: This is found in the districts of Samastipur, Muzaffarpur, Vaishali, Siwan, Gopalganj, Saran, Champaran and northern part of Begusarai district. It is coarse to heavy textured, containing moderate (10%) to high amount (60% or more) of free calcium carbonate (CaCo3) in their silt and clay fractions. These are highly fertile soils.
6. Young alluvial calcareous saline-alkali soils: The young alluvium calcareous saline and saline-alkali soils are found in western part of Siwan and

Gopalganj districts. The characters are similar to those of young alluvium calcareous soils but having numerous and extensive patches of salinity and/or alkalinity.

7. Recent alluvial calcareous soils: These soils are found in the first cycle flood plains of the Ganges, Gandak and Ghaghra rivers. It is a disturbed, coarse textured, well drained soil with little amount of (3-8%) of free calcium carbonate.

B. South Bihar : There are six soil types which are associated with this region. They are briefly described here.

1. Recent alluvial calcareous soils: The recent alluvial yellowish to reddish yellow, non- calcareous, non-saline soils are located along the banks of the rivers flowing through the' alluvial plains of south Bihar. The soils are generally sandy to loamy sand, moderately acidic to neutral in reaction and low to moderate in fertility.
2. Tal land soils: These soils are found along the southern bank of the Ganges River, behind its natural level, vast stretches of land which gets inundated during rains. Soils are inundated for a period of 2-4 months. The soils are grey to dark grey in colour, medium to fine textured, slight to moderately alkaline with good fertility status.
3. Old alluvial cracking soils :The old alluvial grey to greyish yellow, fine textured cracking soils are found in the districts of Rohtas, Patna, Bhojpur, Gaya, Monghyr, Nalanda, Bhagalpur and Godda sub-division of SanthalParaganas. The soils are characterized by greyish yellow to grey colour, medium fine to fine textured, neutral to slightly alkaline reaction having weakly developed profiles. These soils on drying develops cracks. The cracks are 5 to 8 cm wide and 60-120 cm deep.
4. Old alluvial catenary soils : The old alluvial catenary soils are generally found in Bhojpur, Rohtas, Patna, Gaya, Aurangabad, Monghyr, Bhagalpur, Nalanda, Nawadah and northern part of SanthalParganas districts. It is reddish yellow to reddish grey in colour and strongly to moderately acidic in reaction. It has well developed B horizon. They are low land soils, slightly acidic to slightly alkaline, greyish in colour and contain large concretions.
5. Old alluvial yellowish red-yellow soils: These soils are found at the foot hills separating the alluvial plains from the plateau regions extending in the west from Rohtas to Sahebganj in the east. Soils are developed on colluvial

deposits in alluvial fans. These are shallow to medium deep, moderately acidic to neutral, poor to moderate in fertility status.

6. Old alluvial saline and saline-alkali soils: These soils are found in the western parts of Rohtas district. The characteristics are same as that of old-alluvial catenary soils with extensive patches of saline and alkali soils.

While in an another attempt, depending upon elevation, slope and ruggedness of the terrain, the state has been divided into four major physiographic regions, namely the Eastern Himalayas (Siwalik range), Indo-Gangatic plain, Eastern(Chotanagpur) plateau and central high land comprising of the Vindhyan range.

1. The Himalayan Foothill Region: It comprises subdued hills with sloping piedmont plain in the North-Western corner of Bihar. The hilly region consists of relatively young sedimentary rocks.
2. The Indo-GangeticPlain: It covers about 80.4 percent of the state territory extending north and south of river Ganga and is roughly delineated in the south by the contour line of 150 meters above the sea level. The alluvial plain in the north of river Ganga is monotonously flat and the diversities seen on the surface are due to action of rivers viz. Ghagra, Gandak, BurhhiGandak, Kamla, Balan, Adhwara, Kosi and Mahananda. Raised riverside upland is known as levee and alternation to depressions between the streams are commonly called 'Chaurs'. Contrary to this, the alluvial plains in the south of river Ganga are interrupted at the places by small isolate and long narrow hills such as Barabarhillsnear Gaya and Kharagpur hill near Munger representing the outliers of the southern hilly tract of Chotanagpur plateau. This alluvial soil has been built by the alluvium brought from the southern hills by the rivers viz. Sone, Punpun, Paimar, Phalgu and Chandan. The most characteristic features of this region are the formation of saucer shaped back swamp landscape along the Ganga levee popularly named as "Tal".
3. The Eastern (Chotanagpur) Plateau : It consists of a series of plateau standing at different level of elevation in the southern part of the state, covering the part of the districts of Bhagalpur, Munger, Nawada, Gaya, Aurangabad, Jehanabad and Arwal.
4. The VindhyanRegion: It comprises the western hilly portion of Bihar state covering the part of Rohtas and Kaimur districts. Hills are mostly

composed of Upper Kaimur sandstone. The region has high level plateau with steep escarpments, valley sand undulating plains.

Irrigation/rainfedareas :

One of the major input requirements of agriculture is the availability of water resources. Rainfall in Bihar is largely due to South West Monsoon, which account for 85 % of the total rainfall in the state. The total irrigated area in the state is 34.62 lakh hectare, which comes from the contribution of the six major sources (Table). The irrigation status of the state (district wise), reveal that altogether there are 27 districts which are having net irrigated area more than 50 per cent, while remaining only eleven districts have net irrigated area less than this. The area under rainfed condition is about 56 per cent when compared to net cultivated area. The highest rainfed area comes under the district of Kisanganj (84.70 %), followed by Purnea (81.60%) and Nawada (81.20 %) respectively. The area under rainfed cultivation is lowest in the district of Nalanda (24.78 %) in Bihar.

Soils of the state are poor in N and organic carbon content. Calcareous soils of Samastipur and Muzaffarpur contain 10-60 % of free $CaCO_3$ with low to medium organic carbon content. The coarse textured soils of Saharsa and Purnea are poor in P status while rest of the soils is low to medium in P status. The soils are mostly medium in K content except in areas of intensive cropping and coarse textured soils. Soils related problems in different parts of Bihar have been presented in Table.

Table : Identification of area wise soil physical problems in Bihar

Major soil association	**Area (m. ha.)**	**Districts covered by each soil association**	**Major soil physical problems**
Sub-Himalayan forest soil	0.06	North-east corner of Old Champaran	Acidity & High permeability, light textured and gravelly phase
Recent alluvial	0.58	Thin strips in Northern of Champaran, Sitamarhi and portion of Purnea and Saharsa	Acidity, high permeability and places, water logged opener in recent alluvium
Recent alluvium non calcareous and non-saline	1.50	Located in the Alluvium plains of Kosi and Mahananda rivers, Purnea,	At places water logged

soils		Saharsa, northern part of Bhagalpur, Begusarai and Madhubani	
Young alluvium non calcareous, saline alkali	0.14	Western part of East Champaran and patches in the West Champaran	Saline-alkali, low permeability
Recent alluvium calcareous	0.55	A thin strip along the bank of rivers, in the Diara of the Ganga and Gandak rivers	Soil are sandy and Diara land problems
Tal Land soil	0.29	The southern bank of the Ganga river and in the backwaters of Ganges along the southern bank of the rivers	Inundation and heavy textured with associated tillage problems, following soil compactness
Old alluvium gray, grayish yellow, heavy textured soil that cracks	0.58	Bhojpur, Rohtas, Nalanda, Patna, Nawada, Gaya, Aurangabad, Munger, Begusarai	Low to very low permeability and presence of compact clay pan formation
Old alluvium redish yellow, gray catenary soil,	1.30	Bhojpur, Rohtas, Patna, Nalanda, Gaya, Aurangabad, Munger& Bhagalpur alluvial plains	Very low permeability with entire area and clay pans following compaction in some of the area.
Old alluvium yellowish & red soils of foot hills	0.55	Foothills separating the alluvial plains from Plateau regions	Shallow and drought affected soils
Old alluvium, saline and saline-alkali	0.08	Western part of Bhojpur and Rohtas districts	Saline-alkali problems
Red yellow, light gray catenary soils	--	Major portion of South Bhagalpur, South Munger	Very low water holding capacity, light textures and shallow depth
Yellow redish and yellow medium deep light textured catenary soil	--	Hilly part of Rohtas	Low to very permeability and heavy textured soil.

Source : 25 years perspective plan of land use planning of Bihar state (2000-2025), RAU, Pusa, Samastipur, Bihar

Nutrient Use in Crop Production :

Nutrient consumption in Bihar was a mere 22 kg. NPK/ha.in TE 1982 which increased to 63 kg./ ha. in TE 1991 and reached a level of 82 Kg./ha. in TE 1998. Fertilizer consumption increased in all the zones during this period. There was wide variation in the level of its use across zones/districts. It was as high as 104 Kg./ha. in Zone III and 69 kg./ha in Zone I in TE1998. Total consumption of chemical fertilizers in Bihar was 731.6 thousand MT during 2004-05 The level of consumption has increased to 1064.8 thousand MT during 2006-07. But, there is imbalanced use of N, P and K. While the ideal ratio would be 4:2:1, this was14.7: 7:1 in 2004-05 but improved significantly to 6.8: 3: 1 in 2005-06. It is hoped that this ratio may reach the desired level in the coming years. More farm households use fertilizer, improved seeds, and pesticides in the rabi (winter) season than that in the kharif season. This is primarily due to the availability of irrigation in the winter season. For instance,43% of farmer households use improved seeds in the rabi season compared to an all India level of 34%. NPK consumption per hectare in 2004-05 was 282 kg in Khagaria, followed by Begusarai (219 kg), Patna (215 kg) and Bhagalpur (211 kg). Even in the districts like Bhojpur, Samastipur, Muzzaffarpur, West Champaran, Vaishali, Purnea and Jamui, consumptions were quite high ranging between 165 and 176 kg. Very low consumption per hectare was observed in Sheohar (12 kg), Supaul (19 kg), Madhubhani (28 kg), Banka (34 kg), Kishanganj (35kg) and Gopalganj (37 kg). But despite this increase, nutrient consumption per hectare in the state is still lower than the national average. Soil Testing is another area that requires the attention of agricultural scientists and officials, so that farmers use fertilizers judiciously.

Table : Consumption of fertilizers season-wise in Bihar (2003-04 & 2006-07)

Nutrients	**2003-04**			**2006-07**			**% Increase / Decrease**
	Kharif	**Rabi**	**Total**	**Kharif**	**Rabi**	**Total**	
N	302.74	320.84	623.58	339.59	475.12	808.71	+29.70
P2O5	12.34	33.51	45.85	69.56	108.86	178.72	+289.8

K2O	3.45	22.22	25.67	27.76	50.61	77.37	+201.4
Total	318.53	376.57	695.10	430.21	634.59	1064.80	+53.18

Source : Fertilizer Statistics of India (2008)

Table : Fertilizer recommendation for crops

Sl. No	Crops	N : P : K (kg/ha)
1	Rice	80 : 49 : 20
2	Wheat	100 : 60 : 40
3	Maize	100 : 60 : 40
4	Hybrid sorghum	115 : 65 : 35
5	Minor millet	40 : 20 : 20
6	Red gram	20 : 50 : 0
7	Black gram	15 : 40 : 0

Some important recommendations of the SAU on Nutrient Use are :

1. Follow the fertilizer recommendations made for major agricultural/horticultural crops under different agro-climatic zones of Bihar suited to crops and soils of the particular region.
2. Adequate P fertilization in rabi crops in Rice-Wheat, Maize-Wheat, Pearl Millet-Wheat and Sorghum-Wheat system is desirable and a blanket recommendation is application of 30 to 45 kg of P_2O_5/ha to rice and 75 to 90 kg of P_2O_5/ha to wheat found to improve the responses. As kharif crop are grown wet conditions, where P availability is relatively higher due to increased moisture regime.
3. Potassium (K) should invariably be applied in all the crops along with N & P for sustainability. Split application of K in light textured soils improves FUE.
4. In oilseeds and pulse related cropping system respond relatively more to sulphur fertilizers, hence the application of S should be ensured in desired way..
5. In rice-wheat cropping system, Zn should preferentially be applied in proper dose to rice crop and the succeeding wheat or any other succeeding rabi crop will be benefitted with residual Zn, no further fresh application.

6. Use of green manure crops (Dhaincha, Lobia) can be encouraged for those localities where compost or FYM is not added to soil frequently, found to increase organic matter content and improve the soil structure and permeability.
7. The bio-fertilizers should be used in the field carefully as per recommendation, its preparation/formulations should be correct i.e. the microbial load on the carrier material should be sufficient, in no case less than 10^8/gm of carrier matter or colony formed /unit (CFU).
8. Proper use of mulching as it provides suitable condition to enhance fertilizer (nutrient) use efficiency.
9. Naturally occurring minerals like use of rack phosphate in calcareous soil should be used only with organic sources or PSB or bio-fertilizers.
10. Promotion of leguminous shrubs, pulses and oilseeds and green manuring.
11. Selection of suitable crops and adoption of proper reclamation practices for region specific problematic soils of Bihar.

3. Water related issues and management:

Bihar is rich in water resources. The state has adequate rainfall all over, a network of perennial and semi-perennial rivers, and a sufficient supply of ground water at low depth. In terms of the total water supply, it has a distinct advantage as compared to other parts of the country. If this is developed and used properly, Bihar would be in a position to attain the level of 100 per cent irrigated agriculture. The water sector in the state, however, faces severe problems. The most important among these are: (i) In the absence of adequate storage facilities, the occurrence of floods has become a recurrent phenomenon.(ii) South Bihar, with semi-perennial or seasonally flowing rivers and uncertain rainfall, frequently faces drought of moderate to severe intensity. (iii) All over the state, water for irrigation is used inefficiently. An indicator of the water use inefficiency is the low proportion of double or multiple cropping, despite abundant water supplies.(iv) Most of the groundwater is lifted with the help of less efficient diesel motors, thereby raising the cost of well irrigation. The inadequate and inefficient utilization of water resources in Bihar can be ascribed mainly to neglect of the operation and maintenance (O&M) of canals and water bodies. The farmers still prefer to go for flood irrigation. They are still ignorant/unaware about the gains in productivity possible through the adoption of precision irrigation methods such as sprinklers and drip irrigation.

What is needed is to have an integrated, multi-disciplinary approach. An approach that covers not only technological aspects but also social, economic, legal and environmental concerns. Water related issues must be an inseparable aspect of food security but also in its own independent right. There is strategic need of appropriate programmes/projects for the water sector as (i) A comprehensive programme of repairs and maintenance of canals and water bodies in the state. (ii) Management of water resources by the users should be extended to cover at least half of the irrigated area by 2020. (iii) greater coordination between agricultural scientists and irrigation authorities should be promoted and scientific watering of crops should be popularized and (iv) Controlled irrigation through drip irrigation and sprinkler irrigation should be encouraged in the water-scarce regions.

Table : Net area irrigated by source in Bihar

Source (Category)	**Area (000'ha)**
Canals	971.00
Tanks	155.00
Wells / Tube-wells	2264.00
Others	07.00
Other sources	132.00
Total net irrigated area	**3529.00**

Surface water and ground water status :

The State of Bihar is fortunate to have ample surface water as well as balance ground water resources. Private investment is taking place in this sector mainly for exploitation of groundwater through shallow tube well, cavity well, bamboo well and also through dug well and irrigation pond in limited area. All blocks in the State comes under 'safe category'. Nearly 76 per cent of the net irrigated area in Zone-1, 85 per cent of the net irrigated area in Zone-2 and 45 per cent of the net irrigated area in Zone-3 have tube well as the source, while canal irrigation accounts for about 14 per cent in Zone-1, 13 per cent in zone-2 and 48 percent in Zone-3. In the state as a whole, tube well irrigation accounts for 62.5 per cent of the net irrigated area, followed by canal 30 per cent and other sources 7.5 per cent. The availability of ground water in future for irrigation works out to 16.11 lakh ha m which may support approximately 8 lakh new tube wells in the State, out of which approximately 3 lakh units have been installed leaving a balance potential of approximately 5 lakh units.

The study on water management in crop productivity has revealed the fact that uneven bunds in farmers fields is the most serious problem for on farm management under Sone Command Area. The problems of narrow, small and uneven bunds occurs mainly due to small size of plots, objections by neighbouring plot owners and involvement of human labour in the construction of bunds. This problem can be solved by creating large scale awareness about participatory on-farm water management, along with initiatives by Government agencies and its programmes.

Rain water harvesting:

The rainwater harvesting intervention can increase crop productivity, food supply and income, can increase water and fodder for livestock and poultry, can increase rainfall infiltration, thus recharging shallow groundwater sources and base flow in rivers, can regenerate landscapes increasing biomass, food, fodder, fibre and wood for human consumption, improves productive habitats, and increases species diversity in flora and fauna. The regulation of rainwater harvesting in proper way can affect the temporal distribution of water in landscape, reduces fast flows and reduces incidences of flooding, reduces soil erosion, can provide habitat for harmful vector diseases, bridges water supply in droughts and dry spells. Cultural rain water harvesting and storage of water can support spiritual, religious and aesthetic values. It can enhance the primary productivity in landscape and can help support nutrient flows in landscape, including water purification

Strategies for enhancing water-use efficiency in Agriculture:

In order to achieve high crop yields in rice, timely seeding of rice nursery is essential. It is possible only with the help of ground water. Thus installation of large number of shallow tube wells in the canal commands is essential for creating soil moisture regime for rice-wheat and other production system with more water use efficiency. As delayed transplanting in both the cases (rice and wheat) not only causes in reduction in yield, but also require more irrigation (from tube wells).Specific trainings and demonstration through on-farm trials helped the farmers in time application and proper utilization of irrigation sources and methods in enhancing the water use efficiency in agriculture crop production (eg.-A case study in rice-wheat production system in Bihar). Drip irrigation and fertigation has the potential to achieve the crop productivity and simultaneously maintain the irrigation efficiency above 80 %, which comes under micro irrigation system, useful where there is scarcity of water and high value crops (horticultural crops). Its scheduling provides efficient use of water and nutrient and also increases the yield and improve quality of produce.

Hence enhancing water use efficiency in agriculture, the following strategies, techniques and management approaches are required:

1. Selection of suitable varieties of crops/plants
2. The optimum time of sowing/planting
3. The correct method of crop/tree plantation
4. Weed management and use of herbicides
5. Suitable method of irrigation for different situation of land and soil type.
6. System of Micro-irrigation
7. Use of fertigation to have additional advantage of nutrient use efficiency

Watershed Management in the State:-

Developing sustainable Agriculture, treatment of degraded land, enhancing livelihood of the landless, checking migration of rural work force in rainfed sub plateau region and flood affected plains is a big challenge before the State. Treatment of watershed on catchment basis has been implemented in the State since start of VIII plan period. Before that, Soil Conservation Directorate under Agriculture Deptt. Bihar was implementing State and centrally sponsored schemes of land levelling, reclamation of the degraded land, measures to check soil erosion, moisture conservation measures including construction of retention terrace and bench terrace, afforestation etc on farmers field. Most of the watershed Development programme was funded by ministry of Rural Development Department., Govt. of India under Drought Prone Area Programme (DPAP), Integrated Watershed Development Programme (IWDP) schemes and implemented by the state Rural Development Department. Few watershed development programmes have been implemented by directorate of soil conservation, Agriculture Department, Bihar through the funding of Ministry of Agril. & Co-op. GOI.under National Watershed Development Project for Rainfed Area (NWDPRA) and State Plan. Watershed development programme is being implemented by NABARD in the rainfedplatetau. But these schemes are limited only in 8 soil conservation districts of Bihar (sub-plateau region) namely Gaya, Nawada, Aurangabad, Rohtas, Kaimur, Munger, Banka and Jamui. Although a number of Watershed projects have been & being implemented in the state, only a few Watersheds have been saturated and successfully managed. Post project maintenance of the assets created is a big problem, which the state is facing.

Table : Irrigation status of different districts of Bihar (Area '000 ha)

1	2	3	4	5	6	7	
Districts	**Gross cultivated area**	**Net cultivated area**	**Gross irrigated area**	**Net irrigated area**	**Net irrigated (by all sources including seasonal irrigation) (%)**	**Rainfed**	
						Area	% of net cultivated area
Patna	234.377	207.288	164.021	101.730	49.08	124.455	60.00
Nalanda	223.781	182.935	185.491	139.638	76.33	45.340	24.78
Bhojpur	185.032	182.184	146.778	109.942	60.35	82.695	45.40
Buxor	177.082	139.661	146.153	103.102	73.82	43.567	31.20
Rohtas	355.091	254.387	333.551	168.542	66.25	-	48.00
Kaimur	198.841	156.071	169.767	117.481	75.27	53.094	34.01
Gaya	151.904	149.611	122.484	081.856	54.71	211.942	70.00
Jahanabad	083.110	064.722	070.256	050.194	77.55	22.712	35.10
Arwal	048.017	039.889	040.619	031.411	78.75	16.559	41.50
Nawada	099.974	093.392	085.553	058.552	62.69	75.850	81.20
Aurangabad	209.167	200.714	163.537	144.193	71.84	88.030	43.85
Saran	231.627	191.689	108.855	099.248	51.78	101.737	53.10
Siwan	254.966	165.440	124.189	110.472	66.77	63.864	38.60
Gopalganj	225.037	146.439	105.262	096.484	65.89	59.480	40.61
Muzaffarpur	295.250	197.527	126.077	108.251	54.81	121.041	61.27
E.Champaran	353.835	297.095	165.385	147.660	49.70	169.935	57.20
W.Champaran	385.433	280.758	185.342	111.612	39.76	173.651	61.85
Sitamarhi	159.220	121.801	619.650	055.810	45.82	85.991	70.60
Sheohar	044.598	026.243	016.774	013.860	52.81	14.592	55.60

Vaishali	196.394	126.944	091.748	066.405	52.31	63.909	50.34
Darbhanga	189.310	166.448	105.018	074.610	44.83	102.925	61.83
Madhubani	307.392	220.825	138.344	097.000	43.93	146.816	66.48
Samastipur	252.041	184.061	113.715	098.067	53.28	88.825	48.25
Munger	060.250	049.036	037.844	029.507	60.17	36.111	73.64
Begusarai	166.920	117.078	090.075	074.887	63.96	49.497	42.27
Shekhpura	055.491	035.302	036.719	023.864	67.59	25.140	71.21
Lakhisarai	077.599	060.300	052.523	042.995	71.30	43.864	72.74
Jamui	060.338	058.772	023.085	017.326	29.48	102.649	70.50
Khagaria	128.349	082.313	083.822	072.829	88.48	21.575	26.21
Bhagalpur	182.832	140.869	085.528	059.567	42.29	93.521	66.38
Banka	154.218	151.689	112.772	088.793	58.54	80.732	53.22
Saharsa	191.130	108.111	094.914	059.303	54.85	57.005	52.72
Supaul	242.349	145.788	143.214	089.686	61.52	73.095	50.13
Madhepura	196.710	125.938	129.970	080.092	63.59	57.144	45.37
Purnea	280.903	208.032	169.479	072.826	35.05	169.770	81.60
Kisanganj	191.256	128.530	044.696	026.534	20.64	108.775	84.70
Araria	277.177	181.932	106.187	055.291	30.39	137.825	75.75
Katihar	269.491	166.372	142.671	086.732	52.13	107.163	64.41
Bihar	7396492	5556.186	4324.687	3160.619	56.88	3121.018	56.00

Implementation of watershed programme :

On critical review of the on-going Watershed projects, it has been observed that the main thrust i.e. -participatory approach has still not been institutionalized. In the project area, post project sustainability continues to be a serious concern. Delivery mechanism is a critical weak link under the above programme, which includes institutional set up at community level and its co-ordination with PRI's as well as at higher level.

After inception of common Guidelines in April 2008 State Level Nodal Agency (Bihar Watershed Development Society) has been formed under chairmanship of Development Commissioner, Bihar. BWDS and District level line departments are being strengthened to implement and monitor all the activities of Integrated Watershed Management Programme on participatory approach. Emphasis will be given on capacity building of watershed community in order to increase sustainability of interventions done in watershed project area. State is very keen in implementation of the Integrated Watershed Management Programme in order to:-

1. To rejuvenate geo-hydro-logical system of the catchment & to restore fragile geomorphological & ecological system of the catchment.
2. To increase Rural livelihood which will check migration of rural work force.
3. To develop sustainable agricultural practices in rainfed area & flood effected areas.
4. To overcome the natural calamities like drought & flood this is quite frequent in the state.
5. To increase marketability of agricultural produce & rural household finished products.
6. To cheek soil erosion & to increase soil moisture regime.
7. To provide enough storage structures to store surplus run off and make it available for supplemental irrigation, drinking water to cattle, ground water recharge, fishery etc.

Economic gain from improved watershed practices:

Significant improvement in local employment generation. The villages which used to experience off-season migration, now report minimum migration. Even many families who have migrated earlier, returned to the villages. Increased numbers of wells have perennial water and a rise in the water levels of almost all wells in the watershed observed. The increase in agricultural production has been reported due to increase in cropping intensity and increase in rabi and summer crop area, adoption of better varieties of crops, improvement in yield of crops as observed the increased area under irrigation. It also resulted diversification of cropping (e.g. to horticulture) and added additional area, which was so far waste land, brought under cultivation in many important districts of this state. Improvement in the condition of the landless due to continuous wage availability during project implementation in their village itself and through increased agricultural activity in post-project period. Taking up of dairy activity in large scale through adoption of cross bred/ improved cows due to fodder cultivation and availability of higher quantum of grass.
The demand for credit has gone up significantly and dependence on money

lenders reduced due to self help group activity. With strong community involvement, loan repayments have improved. There are secondary effects like visible improvements in housing and jump in school attendance. So major shift in terms of diversification of agriculture into crops, commodities, enterprises, cropping/farming systems is called upon to revert the process of degradation of natural resources, to make agriculture/horticulture a profitable business and to retain rural population in villages.

4. Diversification of agriculture:

Three crops occupied more than 10 % of GCA in 1999-2000. The area share of cereals in the gross cropped area (GCA) has been around 80 % in most years from 1970-71 to 2007-08.

There has been a significant change in cropping pattern in the past few decades. It is being observed that area devoted to food grains (cereals and pulses) was much higher in few decade back, but now the changed scenario in Bihar. The proportionate areas under horticultural crops have become relatively higher in this state. It has been found that developed districts showed greater diversification away from food crops towards non-food crops compared to underdeveloped districts. Diversification of paddy-Wheat cropping system with oilseed crops, adopting late sown mustard in Rice fallows and flood prone areas, oilseed as intercrop in sugarcane, maize, potato, wheat, in limited irrigation by replacing low yielding wheat are new recommendations. Institutional survey and field level survey indicate that small and marginal farmers showed more horizontal diversification within the crop sector towards high value crops, such as oilseeds, sugarcanes, jute and vegetables compared to other categories (i.e. lesser diversification) within the allied sectors (fisheries and livestock). From the factor analysis of value of output in agricultural diversification using district wise time series data, it is seen that there are some constraints to diversification towards horticulture like, unbalanced use of fertilizer, inappropriate water management and lack of other quality input etc. The cropping pattern change studies have been made on the basis of the changes at the district level analysis through diversification indices and the information based on the pattern of different zones in the state.

Zone I: About 79% of the net cultivated area is put under kharif crops. Rice, Wheat, Maize, and Pulses are the prominent crops of the zone followed by sugarcane and oilseeds. Rice occupies 44%, Wheat 19.85% and maize 9.1% of the gross cropped area. Among the oilseeds, rapes and mustard and linseed occupy the major area. The major rice producing districts are east and west Champaran and Madhubani.

In irrigated region, Rice-Wheat rotations are very popular. High yielding varieties of rice are popular but in the low lands and areas having deep water conditions, mainly the traditional varieties predominate. High yielding varieties of Wheat have already become very popular. Both Kharif and Rabi maize are taken by large numbers of progressive farmers. Sugarcane is another crop, which is very popular with farmers having irrigation facilities and this zone is covered with large number of sugar mills. Both October sown and February sown sugarcane is cultivated. Under un-irrigated situations, mixed cropping of maize and arhar in uplands is a common feature. In low lands, rice followed by gram or rice followed by barley plus pea is a popular rotation.

Amongst the cash crops, tobacco and chillies are the most important crops. Fields put under tobacco and chillies are mostly kept fallow during early kharif period and the transplanting of these crops is done in the month of September.

Zone II : Rice is the most important crop of this zone and is grown both under mono-cropping and multiple cropping systems. The multiple cropping involving jute, rice, and wheat sequence is very much popular with large number of progressive cultivators having assured irrigation facilities. This zone alone accounts for more than 90 % of the jute production of the state, maize is another important crop which is grown both during Kharif and Rabi seasons. In traditionally mono-cropped rice areas, medium duration rice varieties followed by high yielding wheat varieties, is the most popular cropping sequences. In un-irrigated low lands, Lythyrusand Lentil are taken as "paira" crops.

Zone III : In this zone rice followed by wheat is the most important crop, occupying 32 % & 22 %, respectively of the gross area cultivated. Since this zone has as much as 60 % area under irrigation, the level of crop production is higher as compared to other zones. The cultivators of this zone have been very progressive. In upland, potato has been very important crops. Two crops of potato in Rabi seasons are taken after Kharif maize or early rice. In low lying paddy fields, Lythyrus, Gram and Lentil are taken as paira crops. In the eastern portion of Patna district and western portion of Munger, vast Tal land exists where no cropping is possible in Kharif due to water logging in the entire monsoon.

In the past decade, important changes being noticed in agriculture at national level are diversification, modernization, market orientation and commercialization, involving introduction of new crops, and varieties, increased share of horticulture, diversion in processing and export oriented production. Growing importance of horticultural produce could be attributed to increasing demand due to the growth of health conscious population and enhanced income. However, in intensively cropped areas, the crop diversification with introduction of horticultural crops have been found beneficial from the point of view of ecology, economics and employment generation opportunities. Horticulture which includes an array of crops eg. Fruits vegetables, spices, medicinal and aromatic plants, flowers, ornamentals and plantation crops have become important means of diversification. The horticultural crops particularly vegetables, spices and tuber crops are grown commercially as they fit well in sequential double or triple cropping on account of wide variation in their maturity period. In Vaihsali and Nawada districts, vegetables are grown extensively one after another. As for example: Brinjal/cauliflower/tomato – Cucurbits/cowpea/okra. In Samastipur, Muzaffarpur and Patna belt spices like turmeric, zinger, chilli, coriander, and dill are grown commercially.

Among fruit crops, mango, guava, litchi, banana, papaya, jackfruit, acid lime, pumello, bael, karonda are grown commercially in different parts of the state. Plantation crops like tea and coconut are also found growing in kosi belt of this state. It is obvious that almost all tropical and subtropical fruits are grown in the state with great ease and success. Some aquatic fruits/crops like gorganut (foxnut-makhana) and water chestnut are being raised commercially in this state.

Quality Litchi is being produced in the districts of Muzaffarpur, east Champaran, Samastipur, Vaishali and west-Champaran etc. A wide range of variability of mango varieties are commercially being grown in the districts of Darbhanga and Madhubani, needs proper intervention for potential production and benefits to the growers. Banana cultivation in the district of Vaishali particularly have gained wide popularity for large scale production with high yield even with minimum care and maintenance. Though, predominant area under pulses has also shown a marginal increase but the proportion of area under oilseeds and sugarcane declined marginally. The farmers, in pursuit of supplementing their needs and income adopted integrated farming systems, majority of them revolve around the crops + livestock components. Livelihood of small and marginal farmers, comprising about more than 90% of total farmers, remained dependent mainly on crops and/or livestock, which are often affected by weather aberrations. Under present scenario, the institutions R&D supports, there is many scientifically designed, economically profitable and socially acceptable, appropriate integrated farming systems models developed to harness the benefits of integration (crops including agricultural and horticultural), livestock, fisheries, poultry, piggery, food processing etc.).

5. Mechanization in agriculture:

The mechanization of agriculture has increased up in Bihar due to the credit facilities and government policy support. The farmers have also realized that mechanization in agriculture is an essential input to modern agriculture. It enhances the productivity, besides reducing human drudgery and cost of cultivation. It is also helping in improving the utilization efficiency of inputs. Some of the new equipment have become popular with farmers. These are (i) Tractor – operated no till drill – for sowing of wheat directly after paddy without preparation of the seedbed and thus it is both time, input and energy saving. (ii) use of seed cum ferti-drill to improve efficiency of sowing and nutrient use by crop plants. (iii) the use of potato transplanter to improve sowing efficiency and to reduce human drudgery. The irrigation system for better water and nutrient use efficiency are being adopted by the farmers. There are also ranges of machinery to improve harvesting operations and to reduce human drudgery. Efforts are needed to intensify the crusade of popularizing machinery and agricultural implements through demonstrations and also through training to village artisans about use and after care of these assets. In order to upgrade the skill of the farmers and applying new techniques, suitable training programmes should be organized. In case of costly farm machineries, custom hiring services should be facilitated, so that small and marginal farmers could avail the benefits of its services (Pande and Gupta, 2012).

6. Gaps in Technology Transfer:

1. Gap between the state average productivity and potential is very high owing to poor technology adoption and use of inputs. Therefore, bridging the existing yield gaps by making adequate availability of quality inputs to farmers would be the first and foremost requirement for improvement of crop productivity. Crop specific and zone specific strategies should be adopted at

farmer level to derive maximum benefit. Bihar needs specific development strategies for North and South.

2. Experiments have been conducted in Bihar under Zero Tillage, Bed Planting, System of Rice Intensification (SRI) and Site Specific Nutrient Management Systems with encouraging results. This needs to be promoted. Besides, efforts should be made to promote contract farming in maize, and certain horticultural crops for which the State has huge potential.
3. Soil surveys helped furnishing comprehensive information about soils and preparing an inventory of soil resources of the state. The agricultural research programme also focussed its efforts on improving resource use efficiency, conserving natural resources, particularly soil and water, and rehabilitating degraded soils of this state. The management of degraded lands posed an important challenge.
4. Research outputs of watershed programmes were found appropriate in solving the problems of about 65 % of the total cultivated area. Watershed programmes have shown benefits in various target domains, documented in the form of higher incomes, crop diversification, and increase in irrigated area and fodder availability, and soil and water conservation. The problem of women migration was also addressed through it. The studies also reported that out-migration was checked to a large extent. Orientation of farmers and their closer association will help in deriving desired benefits.
5. The increase in resource use efficiency of perennial crops is very much needed. Factors like high plant density and under planting of the main crop, lack of irrigation facilities, the capital intensive nature of the technology, lack of skilled labour and the non-availability of capital were the major constraints to its adoption especially for resource poor farmers.
6. Challenge of raising productivity of crops in Bihar can be achieved by developing varieties which require lesser water, adopting agronomic practices which increase water use efficiency and diversifying to crops which require less water.
7. Rainfed areas need to be developed through integrated water management and in situ/ ex situ harvesting of rainwater. Water use efficiency through sprinklers and drips under micro irrigation scheme would ensure more crop per drop of water. Multiple use of limited water for multi enterprise agriculture will provide much needed livelihood security to small farmers. The integrated farming system models will also provide much needed

insurance against climate change related risks. A sizeable area in Bihar is constituted by the Tal areas. There is a need to develop strategies for water management in these areas for aquaculture based systems during *Kharif* and crops in *rabi*.

7. Policy Focus on Soil and Water management:

There are number of factors that diminish the value of land. Intensive farming practices are foremost among these apart from the interaction effects of improper adoption of technologies and imbalances in resource and input use under the era of climate change. The rationale for policy intervention should be focussed on two factors-(i) the significance of off-site costs as a result of land degradation, (ii) the cost of on-site degradation due to faulty adoption of technologies and practices, even when it is not apparent in the immediate context. This requires a foresight and vision for long term sustainable development through policies, action and awareness brought out through education, training and extension programmes. The objective of the policy intervention should be to (i) restore efficiency to meet the growing consumption needs, (ii) suitable mechanism for scientific management, conservation and development of land resource, (iii) expansion of forest cover to restore ecological balance (iv) conjunctive use of surface and ground water (v) preservation of agricultural land.

For integrated approach for effective use of land we need eminently practical plans for land use management. There is need for strict laws for land use, conservation, based on climate, water and soil keeping in view the site specific needs for sustainable development.

Acknowledging the problem of land degradation in Bihar, the Government (both central and state), has formulated policies and programmes to prevent land degradation on one hand and take remedial measures to improve the quality of degraded land on the other. It included institutional support, programmes like (i) Soil conservation in the catchment of river valley Project and Flood prone River (RVPFVP) (ii) Reclamation and development of alkali and acid soils (RADAS). (iii) Watershed Development projects in shifting cultivation area. (iv) World Bank Aided Land Reclamation and Development Project (LRDP) (iv) National Project on management of soil health and fertility (NPMSF), National Food Security Mission (NFSM) and RashtriyaKrishiVikasYojna (RKVY) etc. The National Water Policy (NWP) 2002 states that “Water” is a scarce and precious national resource to be planned, developed, conserved and managed on an integrated and environmentally sound basis, keeping in view the socio-economic aspects and needs of the States. It is one of the most crucial elements in developmental planning. As the country has entered the 21st century, efforts to develop, conserve, utilise and manage this important resource in a sustainable manner, have to be guided by the national perspective.

This can be done through effective watershed management, reduction of regional imbalances and diversification of land use. Preventive measures on adverse effects from industrial waste and effluent and development of agro-based industries are also keys to developing and integrated approach. To monitor the better use of land, Remote sensing satellite technology like Geographical Information System and Global Positioning System can be used.

Reclamations of wasteland is one of the most important aspects of sustainable land use. Agrarian practices can be modified for reclaiming waste land. For example, application of gypsum consequently for three years with reduced application in the second and third year will reduce salinity. Integrated watershed management is preventive method in which soil and water is conserved and cropping pattern is altered to improve land use.

Percolation of water into subsoil, reduction of surface water runoff, elimination of soil erosion and increase water availability are sustainable management practices. For attaining these objectives, check dams along gullies are constructed, bench terracing, contour bunding, land levelling, planting grass along the contours, good vegetal cover on the watershed are deployed.

The soil and water conservation division, Ministry of Agriculture is taking care through its functionaries in the state through Integrated Water Management Projects and also use of shelter belts and strip cropping as conservation measure (TERI Report, 1997). The National Land Use and Waste land Development Council (1985) was set up with the objective of formulating a National policy and Perspective Plan for conservation and management of land strategy. It is time to set right some policies unsuitable for sustainable development. For example, the government policy of heavily subsidizing electricity for tube well irrigation and chemicals led to poor land quality and eventual abandoning of land.

Similarly, the new Economic Policy that encouraged relaxation on land acquired by non-resident Indians, conversion of agricultural land into non-agricultural land, ceiling of agricultural land holdings eventually led to distorted market value due to speculation.

Economic incentives for soil conservation practices, conjunctive use of chemicals with biological inputs, classification of land use statistics and studying the land use agriculture will help the macro level. Use of remote sensing technology to study different dimensions of the problem is mandatory. Legislation is in place for conservation of bio-diversity and forests but not to protect soil relations. Such gaps in the law should be filled in with appropriate legal protection. New technology and crop management practices should emphasize the integrated systems approach. Meaningful farm research practices will address the concept of linking agriculture with environment. The aim of agriculture should be sustainable crop production with enhanced production envisioned for the long term.

Diversification of agriculture should be encouraged. Farming oilseeds and pulses in place of cereals and horticulture wherever applicable demand less water and encourage crop rotation. This permits an understanding of agro-climatic conditions, favourable topographic conditions, efficient land use, conservation of soil and maximum use of land resources.

Integration of farm forestry with agro forestry will reduce the tremendous pressure on land. Growing a combination of species like agri-silviculture, farm and grove system will make management approach complementary, improve biomass production, regeneration of land resources and increased generation of employment and income.

The working groups on Agriculture and allied sectors constituted by the Planning Commission regarding formulation of 12th Plan have highlighted the dwindling natural resources and advised for giving greater emphasis on efficient management of natural resources particularly soil and water resources. The issue of soil health rejuvenation would thus receive a more focussed attention in different centrally sponsored schemes/missions in the years to come and the state will just make efficient efforts for implementation and try to harness the beneficial outcome.

The required assistance, technological gaps in this state need to be bridged up by institutions (ICAR/SAUs) and its network, proper dissemination of technologies, timely availability of inputs to the end users has to be ensured by state functionaries. These collective and concerted efforts would certainly go a long way in maintaining soil health and water use efficiency , leading to enhanced productivity and farm profits.

Thus, integrated and sustainable land use comprises prioritization of critical land sensitivity, understanding land use and forest response, integrated strategy for forest and pest management, diversification of agriculture, crop combination, use of farmer's indigenous knowledge to attain food and nutritional security, increased productivity and address the environment concerns. This is the way forward towards an evergreen revolution.

Water resources planning and development have traditionally been project-oriented. However, as the demand on the water resources increases with increased developmental activities, a number of projects are necessarily to be taken up in the same river basin for supplying water for various purposes which many a time conflict with each other. In such a situation, project specific planning will no longer be conducive to the optimal development and utilization of the water resources. The National Water Policy (2002) lays down that all the developmental projects should be formulated within the framework of an overall plan for a basin/sub-basin. Central Water Commission issued Guidelines for the 'Preparation of River Basin Master Plan' in 1990.

Impact of conservation agriculture technologies on natural resources and its proper management is even at this state is slow process and significant changes will take place over a long period. Hence medium/long term monitoring sites need to be set up to demonstrate the effect of soil health and environment.

8. Expected gain:

The planned study with required quantified information will help to explain how things are changing over time and space for decision making in particular, about the situation or trends in the state with enhanced quantum of quality production and productivity. After the constraint analysis and undertaking the need based strategic R&D activities and efforts for efficient integrated management of natural resources so as to enhance productivity of agricultural production systems in sustained manner. The joint efforts of Central/State Governments and Institutions will proper policy support in PPA mode will increase the area under cultivation creating conditions and facilitating situations to have higher input use efficiency and high yield per unit time per unit area. The developed technologies through strategic and adaptive research in the present context will be more feasible and productive. The newer technologies will increase the cropping intensity, area under cultivation, high yield with quality produce with more economic viability and ultimately the livelihood security. Giving boost to vermin-compost technology and support from State Government will further strengthen this noble mandate and simultaneously help in the economic and soil health security of the state. In this context, natural resource management may act as driving force to boost the economic, social and demographic conditions in a given time frame with resulting changes in production, life styles and consumption under the present situation of population growth with desirable environmental, economic and social impact.

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Jharkhand was carved out of Bihar to create a new state in the year 2000.This was done primarily to focus on the development of Mineral resources, Agriculture and allied sectors,Roads,electricity,education,Forests,Waterresources,for a better living of the predominantly tribal dominated region. One of the richest state in terms of minerals, such as , coal,ironores,copperores,uranium,limestone,bauxite,mica,dolomite,chinaclay,kyanite,quartziteetc.The state is also rich in natural resources with small rivers,ponds,streams,hills, forests and biodiversity. Soils of the region are fertile, especially the lowlands, while the uplands are coarse-textured and eroded due to hilly terrain and high rainfall. Average annual rainfall is fairly high (>1300 mm/annum),but due to poor water resources planning and poor governance at different stages of the implantation process, the region has remained rainfed with poor agricultural scenario. Lacks of perennial rivers have contributed to low agricultural output causing distress among the farming community.But,things must change with time. With rising population, diminishing land resources, poor irrigation facilities, rising poverty and malnutrition, increased rural migration towards cities and inability to attract and retain youth in farming,onecannot think of economic development of the state. Considering the fact that about 70% of the population of the state live in rural areas, agriculture is and will continue to be the central theme in the development arena. The present paper analyses the current state of resources (primarily soil and water) available for agricultural development, their status of utilization, which if revamped and revitalised can bring about a transformation that will lead to prosperity of the people as well as the region.

Agroclimatic setting

Jharkhand state comprises of 24 districts (Fig. 1) which lie between 22* and 25.5*N and 83.5 and 88.5*E.The elevation ranges between 140 and 1200 m above sea level. The region has large number of streams and rivulets, which become dry in winter months. Present land use pattern in the state is given in the Table 1.This shows that the area under Crops is about 30% of the geographical area. About 29% is the Forests. There is a large area under fallows, part of which can be brought under the plough by conservation measures.

The state has three distinct agro climatic subzones under Zone-7 (eastern plateau and hill region).Zone IV comprises the central and north-eastern plateau,ZoneV is the western plateau and Zone VI is the south-eastern plateau.

Some of the important features of the sub-zones are presented through Table-2 and Fig. 2

Table 2: Agricultural & Climatic features of Agro-Climatic sub-zones

Particulars	Sub Zone IV	Sub Zone V	Sub Zone VI
Geographical Area (Lakh Ha)	35.18	30.95	15.57
Irrigation (%)	11.40	12.60	7.80
Land put to non-agricultural use (lakh ha)	3.08	1.80	1.95
Barren and uncultivated land (lakh ha.)	2.60	2.00	1.13
Cultivable waste land (lakh ha)	1.20	1.00	0.55
Net area sown (Lakh ha)	7.12	8.00	2.94
Total Cropped area (lakh ha.)	7.95	8.94	3.79
Cropping intensity (%)	112	112	129

Annual Rainfall (mm)	1270	1246	1400

FIG. 2

Land situation and Farmers

As per 2001 census, 77% of the total population live in rural areas and 71% of the labour force depends on agriculture. Farmers in Jharkhand are primarily small and marginal. Average size of operational holding is 1.18 ha and 81.9 % households have less than 2 hectares of land.

Average size of operation holdings

State	Average size of operational holdings (in hectares)	% of House holds having below 2.0 hectares	% of holdings having 10 hectares an above area.
Jharkhand	1.18	81.9	0.84

The land surface is rugged and undulating ranging from flat land to steep slopes. Agriculturally the upland is known as TANR land and classified as TanrI,Tanr II and Tanr III ,depending on the slope ,nearness from the homestead land and the productivity.Thelowlands,are classified as Don I, Don II and Don III,Don I is the best land form from the point of view of growing crops. Characteristics of a typical upland,medium land and lowland are presented in Table-3

Table 3: General characteristics of upland, medium land and low land

Characteristics	**Upland land**	**Medium Land**	**Low Land**
Colour	Red or Brown red	Yellow or Yellowish	Grey or Greyish
Texture	Light textured (Loam)	Medium texture (Clay loam)	Heavy textured
Drainage	Well Drained	Moderately Drained	Poorly drained
Soil reaction	Low pH	Moderately acidic	Neutral pH
Soil fertility	Poor in organic carbon, Ca, Mg, N, P & S	Poor in Organic carbon N, Ca, Mg	Medium in N & Organic Carbon.

Rainfall pattern

The state receives rainfall from both the streams of monsoon i.e. South-west monsoon and North-east monsoon. In normal years,pre-monsoon rains are received in the month of May, which helps for summer ploughing (Verma etal. 2007).Monsoon usually breaks in middle of June each year. Late arrival and early cessation is also not uncommon. The rainfall distribution is uneven and erratic in some years, causing drought or flood in some parts of the state (Table-4).At times,150 to 200 mm rainfall in 24 hours or a dry spell of 2-3 weeks or more in July or August occurs , which has a harmful impact on standing crops. Failure of Hathia rain (late September to early October) is observed almost once in four years. The climate of Jharkhand is classified as sub-humid mega-thermal with large water deficiency. About 85% of the total rainfall is received during June to September , where potential evapotranspiration is far less than precipitation. This offers opportunity to harvest runoff water and its recycling as per crop needs during dry spell. In the remaining eight months,evapotranspiration is much higher than precipitation, which requires supplemental irrigation for raising crops (Fig. 2 and 3)

Frequent Drought: Jharkhand

2001 : Highest food production in India: In Jharkhand 11 districts & 57

		blocks drought affected
2002	:	Whole Jharkhand drought affected
2003	:	11 districts & 67 blocks affected by drought.
2004	:	Whole Jharkhand affected : 9 dist. Near famine situation.
2005	:	Drought affected
2006	:	Severe drought in Palamau & Bokaro
2007	:	Normal
2008	:	Palamau worst affected
2009	:	Whole Jharkhand affected
2010	:	Whole Jharkhand affected
2011	:	Normal

Fig.2 Fig.3

Verma etal.,(2007) indicated that the quantity,onset,progress and spatial distribution of the South-west monsoon dictates the cropping pattern. A significant quantity of rain water,20-25% of the South-west monsoon (250 mm say)can be harvested through small scale interventions on watersheds. This intercepted water can effectively control intermittent droughts and prevent crop failure.

Soil and Water Conservation Programme

Government and NGOs are active in implementing various land and water conservation measures in the state, but coverage is small and impact, as yet, is uncertain. Guidelines exist, but interpretation of them varies widely. There is a tendency for the implementers to view conservation programmes as short-term sources of wage income generating programmes rather than improvements to the resources of the respective communities conservation measures have thus focused on engineering structures and conservation-farming technologies have received inadequate attention The components included in the land and water conservation programmes include the following activities.

1. Agricultural lands: bunding, terracing, land shaping, levelling, contour cultivation and planting, water storage, and water escapes and outlets for removal of excess water, etc.
2. Non-agricultural lands: closures, afforestation, raising of utility trees, plantations, grassland development, contour trenching, and stone walls, etc.
3. Engineering measures: water harvesting and silt detention structures, treatment of gullies, stream banks, landslides and slips , etc., in agricultural and non-agricultural lands.

The main land and water conservation programmes implemented in the state so far are.

1. National watershed Development Programmes for Rainfed Agriculture (NWDPRA):
2. Rajeev Gandhi Mission watershed Programme (RGM):
3. State watershed development programmes through the District Rural Development Agency(DRDA), involving NGOs and PIAs:
4. Bihar Plateau Development Project (BPDP):

(Integrated Watershed Development Project (IWMP)

The basic objective of all these projects were to upgrade both crop lands and cultivable wastelands on a watershed basis, to stabilize and increase crop yields from rainfed farming, to augment the fruit, fodder and fuel resources through appropriate alternate land use systems and to develop and disseminate technologies for proper soil and moisture conservation. It is implemented in the districts/ watersheds where less than 30% of the cultivated area is irrigated.

Under the Rajiv Gandhi Mission (RGM) watershed programme, some improvements in approach have been adopted including a measure of bottom-up planning by the community. Watersheds have been treated by dividing the area into three reaches (upper, middle and lower) with treatment commencing from the upstream end of the catchment. NGOs and others implement some watersheds by various government officers on deputation to DRDA. The upper limit of total investment has been fixed at Rs 4000/ha but interpretation of the area varies in some cases referring to gross area and in others net area after reduction for land owned by the Forest Department Costs have now increased and there has been a provision to raise average investment to between Rs 6000 – 7000/ha depending upon terrain. Farmers are involved in implementation of the works but as paid labourers and not partners. Implementation still remains target driven with rates of development determined by rate of fund disbursement rather than community need or ability to change. Minimal attention is paid to capacity building and thus long term sustainability may well be lacking.

These flaws were taken care with the coming of Integrated Watershed Management Programme where the cap of investment was raised to Rs 12000/ha and bottom up approach is being followed where money is being transferred to Gram Sabha. Thus the execution and monitoring is done by the stake holders.

The pure engineering approach to land and water conservation is costly and rarely sustainable lack of adequate dialogue between line agencies and beneficiaries to identify the beneficiaries' needs seems to be the major contributory factor to non-sustainability of the structures.

In theory, the aim of the water-harvesting programmes has been to conserve both land and water and thereby increase the moisture status in the watershed. In practice the approach has been more aimed at storing water for a second crop season (Rabi), rather than for supplementing deficiencies in rainfall during and at the and of the Kharif Season.

Two types of tank are found within the catchments depending upon whether they are located in steep or relatively flat terrains. In the former, the traditional designers were aware of the problems of flood flows and created closed tanks the restricted the amount of inflow thereby also limiting the spillway needs. For the latter tanks, both closed off channel and bund type across streams were created. The latter were provided with embankments, spillways and outlet works ad channels to the cultivated area. Almost all of the tanks constructed by the Minor Irrigation Department or under the Watershed programmes fall into the latter category. In such cases, water is supplied to left and right bank main canals and from them onto the on-farm water distribution network. Normally, irrigable areas will cover over 40 ha and include and o more villages.

Under the watershed programmes, embankments have been constructed across minor ephemeral streams/nalasto form small reservoirs that are being used both for irrigation as well as to slow down the movement of water through the catchment. The details of these dams do not seem to have been clearly thought through with many technical omissions being present many of which relate to spillway design and location and elevation of irrigation outlet. These have been planned for the irrigation of up to 20 ha of less with little thought having being given to actual availability of water through the crop season, corps to be grown and the O & M arrangements.

Land forms and soil related constraints for Agriculture

Soils of the state are mostly red and lateritic. The typical Alfisols with well expressedilluvial horizon (Bt) developed mainly in Old Alluvium underlain by granite-gneiss. Profile features of soils under different land situations is presented in Table- .Sarkar (2002) based on detailed studies concluded that four dominantly occurring landforms viz.,hilly terrain,undulatingplain,plateau and valley comprise the different soil types and land use systems. The major features of the land situations in the state have been described below (Sarkar etal. 2009)

*Rainfed gravelly and eroded uplands: Land is situated in high to medium slope. The soil is light textured,red,highly acidic in reaction, with very low water holding capacity, sandy and stony, very low in available N,P,K.Generally no crop is grown. Some farmers grow Niger by broadcast after 1-2 ploughing. Nutrients are seldom applied.

Rainfed gravelly uneroded uplands: Soils are under medium slope, red, light textured, highlyacidic, with low fertility status. Farmers grow fingermillet, gora-rice, maize, blackgram, pigeonpea. Crop yields are very poor and agriculture is non-remunerative.

Partially irrigated uplands: Soils under medium slope, acidic, sandy, poor water and nutrient retention capacity. Such lands are called “Bari lands”. These are near homesteads with small diameter shallow wells. Soils are low to medium in fertility status. Vegetables are grown with FYM in such lands.

Irrigated uplands : Lands are under medium slope, sandy loam texture, acidic, low soil fertility. Vegetable cultivation is done throughout the year with the use of Fertilisers and well decomposed compost. These Lands have big diameter pucca wells or deep borings for irrigating crops.

Rainfed eroded medium lands: Land is situated in medium slope with slight erosion. These soils are low in available P and N with medium K status. Sufficient water is available through rains and farmers grow Rice in Kharif. Pigeonpea or blackgram based intercropping/mixed cropping systems are common. Compost is applied as per availability.

Rainfed medium lands:

Land is situated at a relatively lower slope without erosion. Soils are sandy clay loam in texture with good water holding capacity. Rice and vegetables are grown in such lands with Compost, Urea and DAP application.

Partially irrigated medium lands: Land is situated in lower slopes. Soils are of average fertility with low to medium organic carbon content. Farmers grow Rice followed by vegetables with application of compost, DAP and split application of urea.

Irrigated medium lands: Land is situated at a lower slope. Soils are heavy textured with medium P and K contents.N deficiency is common. Farmers grow vegetables throughout the year with application of Urea, DAP, Compost and often B (particularly in cauliflower).In some areas, farmers grow hybrid rice with adequate NPK fertilisers.

Rainfedlowlands:Land is situated at a lower slope. Soils are fine textured with good water holding capacity and good fertility. Farmers grow good rice crop using HYVs and fertilisers, such as DAP, Urea and compost. Water management in such lands is very crucial in improving crop productivity and for sequence cropping.

Partially irrigated lowlands: Land is situated at a lower slope. Soils are of good fertility status with good water holding capacity. The soils are medium in N and P with high available K status. Crops receive irrigation through rivulets,ponds,wells and ditches. Vegetables and rainfed wheat crop is common.

Irrigated lowlands: Land is situated in a lower slope. Soils are heavy with good fertility status. Crops are irrigated through ponds,wells,rivulets.Farmers use fertilisers,especially in Rice,Vegetables and Wheat crops and get good yields.

Rainfed deep lowlands: Land is situated at a relatively lower slope. The soils are heavy textured. Waterlogged conditions prevail uptoJanuary.Farmers grow summer vegetables/summer rice after recession of waterlogging in February/march. Soils are fertile. Farmers use compost and small quantity of fertilisers to grow crops. Soils are medium in available N and P and high in available K status.

Major soil related constraints for crop production: Soils of the region,ingeneral, are coarse textured with poor water and nutrient retention capacities. Upland soils are acidic in reaction with poor organic carbon content and high Phosphate fixation. Soils in hilly areas are subject to erosion of top soil and loss of soil fertility. Nutrients such as N.P.S, B are most limiting from the point of view of crop production. Crop productivity suffers due to one of the following reasons:

1. Undulating topography with varied slope.
2. High permeability
3. Low pH of upland soils
4. Shallow soil depth with crust formation at places
5. Emerging deficiencies of micro- and secondary nutrients
6. Physical and Chemical deterioration(land degradation) due to waterlogging and erosion.
7. Loss of top soil due to deforestation, grazing and rainfall in hilly terrain.
8. Soil and water pollution in cultivated areas due to As,F and excess Fe.

Nutrient use trends: Deficiency of N,organic matter and P is common in majority of the soils in the state and it is increasing over years. Soils are acidic in many places, especially in the uplands, which need special amelioration measures. Quality of Organic manures used by the farmers is poor and need to be improved by adopting improved methods of composting, such as enriched compost/vermicompost.Biofertiliser use is not common among farmers. Similar is the situation in case of residue incorporation in-situ.Availability of Borax,lime,Phosphogypsum,rockphosphate etc.in the local market needs to be ensured for use by the farmers.In recent years, there has been an increase in the Boron and Sulphur deficiency in the cultivated areas, which need to be addressed for better quality and quantity of production per unit of cultivated land. Farmers have to be advised to use Potassium for crops to withstand climate change, disease& pest incidence and rainfall deficits. Some of such suggestions for increasing and sustaining the crop productivity of crops/cropping systems under different land situations are given in Table-- below.

Table : …..Important Nutrient deficiency problems, identified in crops and cropping system in Jharkhand

System / Area	Nutrient deficiency problem
Intensively vegetable growing areas	Boron, Calcium, Sulphur & Molybdenum
Rice-fallow	Phosphorus, Potassium
Soyabean-Wheat, Groundnut- Wheat, Rice-Pea	Phosphorus, Sulphur, Calcium
Groundnut + Pigeon pea	Phosphorus, Calcium, Boron
Rice-Vegetable	Potassium
Maize – Wheat	Nitrogen, Phosphorus

Our concerns in the Nutrient use in crops are ten-fold.Theseare: i.excess use of Urea and little or no use of Phosphate and potash for crop production in many areas ii.use of fertilisers per unit of cropped land is very low (about 60 to 70 kg NPK/ha)especially in crops such as, uplandrice, Ragi, Blackgram, Pigeonpea, lentil etc. iii. not much use of secondary nutrients(Sulphur) and micronutrients (Zn,B) for crops leading to poor human and animal health, iv. poor soil testing service in the state, v. not much awareness on quality of inputs used for crops, vi.not much use of biofertilisers, as a supplement to inorganic fertilisers, vii.not much awareness about integrated plant nutrient management for iproved plant nutrition, viii. not much use of lime /dolomite/basic slag to amend acidic soils of the state, ix. Poor input supply situation in rural areas.Poor agro-advisory service available to the farmers.

Crops and Cropping Systems: The state of Jharkhand is traditionally monocropped. Uplandrice, Ragi ,Maize, Blackgram, niger, Pigeonpea are common in uplands, while, transplanted rice, wheat, oilseeds are common in lowlands. Vegetable cultivation is common across the state both in kharif and rabi seasons. Zonewise distribution of crops in the state is as follows:

Subzone IV Rice,wheat,maize,greengram,gram,mustard,pea.

Subzone V rice,maize,niger,chickpea,pigeonpea,gram,pea.

Subzone VI Rice,maize,linseed,niger,pea,gram

There is vast scope of introducing improved intercropping systems in crops like upland rice,Ragi,Maize,groundnut,Soyabean,withPigeonpea and Blackgram under rainfedconditions. Thedistribution of crops in Jharkhand shows the predominance of food crops with relatively small area under pulses and oilseeds (Table…..)

Table… Major crops in Jharkhand state

S No.	Crop	Area (Hectares)	% of Cropped Area
1	Foodgrains	1,823,079	87
2	Cereals	1,532,167	80
3	Pulses	290,912	7
4	Vegetables	224,120	7
5	Oilseeds	94,268	3
6	Fruits	32,700	2
7	Sugarcane	400	
8	Others	29000	1
9	Total	2366,000	100

Area of concern is rainfedagriculture, mono cropping, low use of nutrients in crops, risk of crop failure due to low or no rainfall, lack of awareness among farmers. Adoption of rainfed/dry land technologies in crop production can substantially improve the cropping intensity with higher yields and better management of natural resources. Some of the profitable intercropping systems for upland and medium lands are:

1. Redgram+Maize(1:1): alternate rows,60 cm apart with full plant population of both the crops.
2. Redgram+Rice (1:2): 2 rows of rice in between 2 rows of redgram.
3. Redgram+groundnut (2:6): 6 rows of groundnut sown after 2 rows of redgram(paired rows)
4. Redgram+blackgram (1:2): 2 rows of blackgram between 2 rows of redgram.

Such systems not only stabilises productivity by reducing the adverse impact of weather variability, but also reduces the risk of crop failure considerably. Two areas need attention for the success of the intercropping systems-stra cattle grazing and weeds. These are the two greatest bottlenecks in the success of intercropping systems.

Crop productivity trends and Food security concerns

Average productivity of crops in Jharkhand is fairly low. According to the assessment of Mishra and Choudhary (2010), the productivity is about 2t/ha for rice, 1.5t/ha for wheat, 1.3t/ha for maize, 0.74t/ha for Ragi, 0.68t/ha for pulses, 12t/ha for fruits and 15t/ha for vegetables. A comparison of statistics available for India and Jharkhand, indicate low crop productivity of major food crops with poor per capita availability of foodgrains.Poor irrigation facility and very low nutrient use in crops have resulted in low cropping intensity. Literacy rates are also fairly low,which has resulted in poor awareness to improved farm technologies (Table…..)

Table……………………….

The state requires the enhancement of food grain productivity by at least two-fold to achieve self-sufficiency. The demand-supply situation of cereals, millets and pulses analysed over the years reveal an alarming situation (Table……&……).There is an urgent need to address such issues with a planned and focussed approach to have a bearing on food and nutritional security of the population.

Table… Demand-supply situation in Cereals and Pulses in Jharkhand state

Year	Population(Lakh)	Requirement(Lakh Tonnes)		Estimated Production		Deficit(-)	
		Cereals	Pulses	Cereals	Pulses	Cereals	Pulses
2006-07	298	45.68	4.35	24.37	2.50	- 21.31	- 1.85

2011-12	328	50.28	4.79	28.13	3.23	-22.15	-1.50
2016-17	363	55.64	5.30	34.45	4.50	-21.19	- 0.80
2020	391	59.94	5.71	47.16	5.71	-12.78	--

Mishra and Choudhary (2010)

Considering the daily requirement of cereals and pulses for the growing population, it is likely that food shortage will exist at least up to 2020 or beyond?

Table….Estimated availability of Cereals and Pulses over the years in Jharkhand

Year	Daily Min. Requirements		Estimated Availability		Shortage (-)	
	Cereals	Pulses	Cereals	Pulses	Cereals	Pulses
2006-07	420	40	220	19	-220	-21
2011-12	420	40	235	25	-185	-15
2016-17	420	40	260	32	-160	-08
2020	420	40	330	40	-90	--

As per ICMR guidelines. Mishra and Choudhary (2010)

Management Issues for Soil and water resources in the State

I Soil health Maintenance: Soil health is a major issue that needs to be addressed for improving crop productivity,grainquality,nutritional standards and soil quality.At present,in most cases only blanket recommendation for nutrient use in crops is being practised over large areas leading to falling productivity, poor nutrient use efficiency,multinutrient deficiencies, high nutrient mining from soil and low profits from nutrient use. Soil health management needs to be refined to minimize risk for the farmers, and greater inclination on the part of farmers to practice balanced nutrient use for high crop yields.NBSS&LUP (ICAR) and Birsa Agril. University, Ranchi have developed the Soil Resource Inventory for the state of Jharkhand. Based on delineation studies, soil nutrient maps for major, secondary and micronutrients at District level have been developed and these have been made available to State/district level authorities after imparting needed training. What is thus needed is to properly plan, monitor and implement the programme on soil health. Some of the major management issues for the state are given below: I.Managing 10 lakh hectares of acidic uplands(pH < 5.5) with the use of technology of furrow application of lime/dolomite/basic slag @ 2 to 5 q/ha in direct seeded crops (Sarkar,2013). Adoption of this technology alone, will help increase the crop productivity in the state by at least 10 lakh tonnes.ii.Low soil organic matter level has resulted in poor soil quality,poor soil physical and biological conditions.Integrated use of organic manures,biofertilisers and fertilisers need to be promoted based on crops/site/duration/season. iii. Soil tests should be the basis for making fertiliser recommendations in crops.Soil test laboratories need to be equipped with facilities for micronutrient analysis.Soil health cards need to be provided to farmers after soil tests of farmersfields.iv.Information available so far indicates minimal use of Potassic fertilisers in crop production.Similar is the situation with nutrients such as Boron, Sulphur and lime, even if these are deficient in many soils. Farmers often use excess of Nitrogenous fertilisers at the cost of others, which has resulted in imbalance in nutrient use.This needs serious thinking and quick redressal. V.High value crops are of special significance for promoting export oriented agriculture. Crops such as,soybean,groundnut,maize,vegetables,fruits need focus in the balanced nutrient use programme.

For successful implementation of the programme on soil health improvement, the following aspects must be borne in mind:

1. Crop-livestock interactions-Farming system of the farmers and ways and means to intervene for betterment.
2. Crop residue management, such as rice straw, maizestocks, wheatstraw, green leaves,weedsetc.possibility of their incorporation in soil/use as a component of compost making-their characterization,assessment of quantity generated,training of farmers for their optimal use.
3. Options for small and marginal farmers with small holdings and their livelihood security.
4. Preparing composts of good quality in terms of their decomposability, nutrient contents.
5. Input supply system for farmers at Block/Panchayat level-availability at right cost/right time/right quality/right place.
6. Management of water resources by farmers-need for improvements to ensure supply to crops instead of one crop only.
7. Proper weed control measures in crops-as weeds take up nutrients for their growth from soil and keep the crop starved.

8. Control all the limiting plant nutrients for good crop yields and deficiency diseases-knowledge empowerment of farmers on the essential plant nutrients, particularly secondary and micronutrients.
9. Extension personnel's must approach the farmers with correct message for effective dissemination of knowledge/information on agro technologies to farmers.

II. Improving Crop productivity per unit area of farmers fields

The state Agricultural university and ICAR institutions (HARP, Palandu, Ranchi, CRURRS, Hazaribagh, KVKs) have contributed immensely in developing farmer friendly technologies, goodvarieties, which has the potential to increase the productivity of agriculture by atleast two fold in the next five years. Some such technologies are:rain water conservation, water harvesting, mulching, acid soil management, integrated plant nutrient management, residue recycling, conservation agriculture, hybrid rice technology, inter cropping systems, rice-fish-poultry/pig farming, system of rice intensification, micro-irrigation etc. These have been adopted by farmers in many areas, but still there is a long way to go. One has to look into the resources that the farmers have in their command and their assessment of the benefits of such technologies in the current situation. There is a big gap that exists between state average yield and yield in experimental plots, which has to be minimised through intensive farmer's trainings, demonstrations, and other means of technology transfer mechanisms. Farmers have to be convinced by participatory approaches that adoption of such improved technologies will bring prosperity in the farm family.

Crop	Yield(Kg./ha)		Yield Difference (Kg./ha)	Gap of State average over Exp. Trial average (in%)
	State Average (2006-06)	Experimental Trial Average (1996-97 to 2004-06)		
Rice	1490	3200	1710	115
Maize	1345	4000	2655	197
Wheat	1492	4000	2508	168
Ragi (Marua)	658	3000	2342	356
Arhar	658	1750	1092	166
Kulthi	412	1100	688	163
Gram	873	1750	877	100

Urad	553	1200	647	117
Masoor	556	1750	1194	215
Rape Mustard	537	750	213	40
Linseed	367	750	383	104
Ground Nut	896	2500	1604	179

Primarily, it is the level of management that brings about such vast differences in crop yields with similar inputs (seed, fertiliser, pesticide, irrigation etc.).To make it more meaningful, farmers should not be treated as beneficiary, but a co-research worker and the crop variety developed or improved technology released should be tested under farmer's management conditions.

Current initiatives of the Govt. of India, through the "National food security Mission" is a welcome step in this regard.This"Mission"envisages to increase the productivity of rice, wheat and pulses by bridging the yield gaps as discussed above. Some of the important interventions that seems essential for increasing productivity of crops are as follows: I. Higher pulses productivity through better varieties,weedmanagement,lime use in acidic soils, use of Rhizobium culture and Phosphaticfertilisers.ii.Improving productivity of transplanted rice by selecting proper varieties,maintaining proper plant population,INM,disease and pest management.SRI technique is especially suited under irrigated mediumland/lowland situations.iii.Maize/Wheat productivity can be improved by selecting proper varieties,weedmanagement,balanced use of plant nutrients,disease and pest management,maintaining optimum plant population. iv.Vegetables, Groundnut, Soybean, Pigeonpea and Fruit crops need to be promoted in rainfed uplands/medium lands for improving farm profits with nutritional security of farm families.

Crop diversification and Integrated farming systems

Diversifying the existing system of cropping is essential for improving productivity, profitability, risk bearing capacity, andreduce migration and ensuring food security for rural households. To make this possible, timely sowing/transplanting of crops,plantprotection,balanced nutrition with marketing of farm produce must be in place.

Crops/cropping systems must be selected keeping in view the rainfall pattern, land situation and rooting behaviour of crops. Some of the promising crops, which can replace rainfed rice (not profitable) are maize, ragi, pigeonpea, blackgram, cowpea, soybean, niger, sesamum etc. Pulses have inherent ability to trap moisture from lower strata of soil and thus can tolerate moisture stress. Vegetable cultivation in areas of available irrigation (pond, ditch, water harvest structures) is very successful.Dryland horticulture and agroforestry systems in slopy uplands are suitable.In crop-livestock systems,forage crops are well suited.Thus, approach should be to replace non-remunerative upland rice by maize,pigeonpes or blackgram based intercropping systems. In farmers fields, HYVs of both principal and companion crops, proper crop geometry and plant population need to be ensured foe better results.

The strategy to manage soil and water should be based on watershed approach-rain water conservation, productive use of water ensuring high returns.IFSmodels,such as rice-fish-duck/pig, which has been successful in many places need to be expanded in as many farmers fields as possible.Integration of agriculture,horticulture,livestock,fodder,tree species with soil and water resources available with the farmers is extremely important to break the yield barrier.Farming community need to be brought closer to the process of development and their voices and concerns should never be neglected.

Better approaches for soil and water conservation

Development of Irrigation resources:

Although irrigation offers considerable income increases, there are few sites where the conventional small and medium to large-scale gravity irrigation schemes can be developed. Most of these have already been taken up or are on the drawing board. In the tribal programme areas there are a number of perennial streams and innumerable small streams but in few sites does the combination of land and water resources balance. In addition, the topography of rolling hills is not very suitable for conventional irrigation systems. Raising the water from the streams and rivers requires pumping in most cases and the widespread use of irrigation requires storage. In addition, many of the rivers although having either small perennial flows or flows that are available at the end of the rainy season and the beginning of the dry season, have limited potential for development.

The present gravity irrigation development in the tribal areas is limited to small schemes many of that are fed by gravity from existing tanks. This combined, with area irrigated from wells, represents the greatest area under irrigation in the hilly medium and upland areas although the former do not figure widely in statistics that relate primarily to full technical irrigation (at least 125% cropping intensity). In Jharkhand , irrigation represents a small proportion of the total land sown (11% in Ranchi down to 5% in East Singhbhum). Traditional irrigation methods account for 42% of the area under irrigation illustrating that the resources are small are best tapped by this means.

Lift irrigation schemes are also located within part of the state They fall into two categories: (i) large-scale lift irrigation schemes, constructed and maintained by the Minor Irrigation Department with irrigable command areas averaging 40 ha or more; and (ii) small-scale lift irrigation schemes have not been successful due to the lack of electricity supply or limited diesel supplies in rural areas. Many schemes have not been operational for some time an intake wells have become silted, parts stolen, other parts inoperable due to lack of maintenance. The geology of the programme area varied considerably with groundwater being generally less available in Jharkhand. In the hard rock terrain, groundwater is available in the weathered zone, fissures and joints much of the programme area is suitable for dug wells and low-yielding tube wells. Water mostly occurs under water table conditions and, in some favourable pockets, under confined and artesian conditions. Groundwater fluctuates greatly in the hard rock area, due to the steep gradient; fast draw down caused by quick diffused discharge down slope and in the valleys, and low porosity. The average specific yield of weathered granitic aquifers is 3.4%, as compared to sandy alluvium that ranges from 12 to 18%.Only limited developments tap the groundwater potential and this is primarily due to the relatively high running costs and poor availability of electrical supplies in the rural areas. Some areas are using diesel driven pumps, but this is not widespread.

Dug wells and pump sets

Under the million wells programme (juldhara').hand dug wells for irrigation have been popular in the lowland and medium lands of Jharkhand mainly due to the high level of subsidy The advantage of this system is that they are built on and individual basis and operated by farmers with small land holdings and limited resources. Water is abstracted from the wells using the traditional laathaKudi to irrigate areas from 0.35 ha to 0.5 ha. for the cultivation of a vegetable crop during the second crop season (Rabi) and in some few cases also during the summer. The latter cropping period has not been popular due to much lower depth of water at that time of year. With the planned ending of this support to open hand dug wells, there has been an increase in the number of wells. It was observed , however, that there has been a tendency to overso the capacity for the wells in a particular area with potential problems of interference between the wells and draw down in the water table.

Recently there has been a tendency to replace the LaathaKudi with low capacity kerosene driven small centrifugal pumps. These are not really suitable for many of the wells where static water levels range between 5 and 6 metres at the end of the rainy season up to 7.5 metres and beyond in the summer months. This is outside the safe operating range of the pumps and although they are functioning at the moment. The life can be expected to be considerable reduced to about 3 years.

Conservation Structures

Engineering structures are used for the control of gully and sheet erosion. In most cases these comprise dry stone structures and earthen embankments. Many of the designs are poor and do no comprehend either the wider technical knowledge for such structures that is available in the communities or in India nor indeed the performance of other works in the same small catchment area. Few check dams in gullies are provided with a central low overflow section and little attention is paid in practice to the size of the upstream catchment area. This has had the result that the structures are either by-passed due to side cutting or fail due to overtopping at the parts of the structure without downstream protection.

Many structures that start out as erosion and gully control structures end up being part storage structures. They are thus not very cost effective and in many cases are inappropriate. Earth dams constructed on-stream do not have adequate provision for the passage of floods, have poorly constructed embankments that are too steep and inadequately compacted and have outlets for irrigation that lake little advantage of the stored water volumes.

Constraints in Soil and water conservation Programme

Major constraints that are affecting the sustainability of the ongoing land and water conservation programmes include.

1. Rigid approach to programme implementation and cost ceiling;
2. Top down approach by both GOI staff and NGOs without adequate consideration of field situations and communities real needs;
3. Limited practical scope for community management and participation;
4. Inadequate staff and logistics support and shortage of experienced technical man-power, that forces the executing agencies to use a design which is often inappropriate;

5. The definition of micro and milli watersheds used nationally and in the execution of watershed programmes has caused problems as land and village boundaries are not catchment boundaries except in those very steep catchments;
6. Flexibility is needed in programme design to extend the size of the target area beyond watershed boundaries to include all persons utilizing the resources of a particular catchment;
7. There is a strong tendency to treat the range and scope of village interventions provided in project design and preparation documents as a shopping list of activities rather than indicative activities for budgetary planning;
8. Irrigation developments are aimed at full irrigation to cover both Kharif and Rabi seasonsand in some cases a third crop rather than meeting the water deficiencies in the current farmers cropping schedules;
9. Technical aspects of water harvesting and water spreading techniques are not well understood of appreciated:

Development Strategy for Soil and Water Conservation:

The initial aim has to be to improve the moisture statue during the main crop (Kharif) season. This will be followed by improvements during the second crop (Rabi) and perhaps some additional summer season improvements can also be considered Full irrigation should not be the primary objective as the aim of this sub component will be to slow down the movement of water through the catchment and also to make use of seasonal flows in nalas to supplement the vagaries in rainfall. This will be achieved using the Milli and micro watersheds as the basic building block but there will be no predefined limit to activities to undertaken or areas for treatment. The key will be to use traditional villages and their communities to identify interventions and to link these together to provide a holistic and mutually dependent approach.

Potential for the expansion of irrigation in the state is limited and therefore development programmes must concentrate on measures that will improve conditions for rainfed agriculture. The Kharif crops the most important crop for the area and measures need to be put in place to ensure where possible the security of this crop. This leads to both improved agronomic and technical support measures that rest on conserving as much water as possible during the monsoon. Runoff management is thus the key to improved rainfed farming. Once the water resource is augmented through rainwater conservation and runoff management, the usefulness of building soil resource quality and improving traditional cultivation systems and devising new ones becomes more apparent. Plans must therefore aim at maximizing rainfall through conservation techniques and water harvesting structures, the use of protective irrigation using traditional irrigation from tanks, wills and streams and agronomic improvements for conserving moisture for longer periods.

Approach

It is now widely recognized that the engineering approach to soil conservation is immensely costly and rarely sustainable. Technologies concerning soil and water conservation has not been able to encourage the farmers to the extent that is commensurate with the benefits obtained in scientist managed studies. If performance is measured over long periods. The results have been extraordinarily poor for the amount of effort and money expended, technologies have neither persisted not spread . Past experience also indicates that financial assistance to force certain land treatments that encourage rainwater conservation is not enough to attract adoption. Since a wealth of experience exists with the farmers on site specific opportunities and constraints, interaction with the farmers should make use of their indigenous knowledge on farming techniques to construct new innovations.

Currently there are three migration from the watershed – water, people and soil. Any measures taken must identify the causes and treat them rather than the effects. The assumption is that if problems of soil erosion are solved, then the stake holders will directly benefit. There must therefore be a move away from the current engineering approach towards improved dialogue between the promoters and the beneficiaries. This will permit the needs and perception of the latter to be identified and measures to be introduced that fulfil these criteria. These must be planned and implemented using an interactive approach that brings the professionals and farmers closer together.

Farmers have been reluctant to accept conservation measures such as improved or new contour bunds that disregard ownership boundaries and disrupt the shape of land holdings. Measures such as the "5% Pond Model" would thus seem to have relatively limited application, certainly initially. The scope for improved water conservation related more to common land and inter –property initially. The scope for improved water conservation relates more to common land and inter-property (inter bund) treatment. Acceptance of vegetative barriers can, however, be enhanced if the species selected , apart from assisting in rainwater conservation, yield some visible economic benefit (e.g. cash yielding products like broom grass), or help in improving soil fertility when used as green manure (e.g. gliricidia).

Improved land husbandry, rather than structural and mechanical solutions, appears to be the key element in land and water conservation strategy under the programme. The broad strategies to be pursued will therefore be: i) utilizing the land according to its capability, ii) putting adequate vegetative cover on the soil during the rainy season: iii) conserving as much rain water as much rain water as possible at the place where it falls: iv) draining out excess water with a safe velocity and diverting it to storage ponds for future use , and v) avoiding gully formation and putting checks at suitable intervals to control erosion and recharge groundwater.

Engineering must be treated as a support function to assist service providers in fulfilling the wishes of the communities. Any interventions will be in response to problems identified by them and although it will be necessary to cost components to obtain and idea of community budgets, a high degree of flexibility must be used in the selection of type of works to be undertaken.

The strategy to be followed is as follows:

1. Prepare the actors (farmers and staff providers) through training and capacity building.
2. Examine in detail the existing social arrangements associated with tanks.
3. Identify with the communities their problems and aspirations.
4. Examine these problems and aspirations in relational to the tank and the traditional technical and social options for overcoming them.
5. Relate the various problems to the known quantity i.e. the tank) and the impact that they have on its well being.
6. Identify local knowledge and experience and persons with it (to be used as master framers) for overcoming the identified problems and aspiration.
7. Identify and select additional external experience and resources needed to support traditional experience.

Interventions:

Land and water conservation

1. Repair and improvements to existing tanks:
2. New tanks and fish ponds:
3. Gully control structures and measures:
4. Check dams and small storage dams:

5. Field contour bund improvement and erosion control:
6. Nala protection and flood flow control through paddy field:
7. Small Diversion weirs across Nalas:
8. Channels for spreading of monsoon stream flow for supplementing Kharif and Rabirainfall:
9. New hand dug wells for irrigation:
10. Establishment of maintenance procedures:

Repair and improvements to existing tank. Every village had at least one tank developed by the Community and which served as the water source for the community. These locally designed and built water harvesting tanks and small storage structures were constructed both across a stream or nala and also on sloping land. The type and location depended upon the land slope and position in the catchment and reflected the level of runoff and risks associated with such runoff. The area supported by a tank would very considerably, between 290 ha and 200 ha depending on the size and location and if the water was used for irrigation, it as supplementary for the Kharif crop.

In the upper reaches of the watershed, smaller tanks have been assumed and the size would increase through the medium lands to the low lands. The works involved would be the reintroduction of the social management system and hence operation and maintenance, the repair and improvement of any damaged sections and the raising of the embankment by about 1.0 metres were land holdings permit. Inlet and outlet works would be rehabilitated and adapted for multipurpose use (screens and monks will be provided if pisciculture is to be developed). Spillways will be adjusted to meet the current estimates of runoff and if appropriate, upstream riprap and downstream toe drain would be provide depending upon the hydraulics of the site and the wishes of the communities.

New tanks and fishponds. These would comprise either closed tank with surface inflow and outflow arrangements according to the traditional village designs (to reduce the flood inflows and need for a large spillway) or of the conventional Line Department design of a bund and spillway. The former is preferred as it s within the skills and knowledge of the local population. Some sites may preclude this option in which case the latter would be used. They will be located on minor catchments and placed either across a stream or nala or off-stream with a feeder channel and small diversion weir. It is essential that on-stream stream structures are equipped with adequate spillway capacity whose design is supported with substantiated estimates of catchment runoff. The structures would impound part of the seasonal run off from upper catchment. The site conditions and the proposed storage capacity would dictate the height and length of the structure. The embankment would have an impervious core to prevent seepage through the structure and for the larger structures would be provided with upstream riprap and toe drain on the downstream side depending upon the hydraulics of the site. Fill materials required for the structure would be obtained from the reservoir area and local vicinity and it is expected that this will be the limiting factor on tank size. The fill materials would be placed in compacted layers of about 150mm. Inlet and outlet works will be provided and the details will depend on the use to which the tank will be put. Outlet canals would be provided to the farmers' fields and tanks are summarized below:

Gully control structures and measures. Both biological/vegetative and engineering measures should be utilized with the aim of slowing down the speed of water running inside the gully during heavy rains and to maintain the flow in the centre of the gully (to reduce gully bank erosion). And overall plan will be prepared for the area to be assisted and, although it is theoretically desirable to treat gullies and other problem areas from top to bottom with check dams, this is rarely economical. A system of prioritization will be developed with vegetative measures being included with brushwood, dry stone and crate wire check dams. Where material is deposited on the bottom of the gully, cuttings and seedlings will be planted to further reduce the water speed and to encourage further deposition.

The check dam will be adapted to the size of the gully with small gullies and the upper portions of gully systems being suitable for vegetative checks and brushwood check dams made from decaying or sprouting posts, branches and brushwood. For gullies whose depth is greater than about one metre and in those gullies where runoff is artificially concentrated by runoff from roads and buildings dry stone and crate wire check dams will be used. Banks and slips within the gullies will be controlled through vegetative measures and the planning of shrubs and trees Sustainability will rest on selection of species seen as useful by farmers.

Check dams and small storage dams. As with the gully control, engineering measures will be utilised with the aim of reducing the aim of reducing the velocity of runoff water and where possible, to control the runoff to harnessing the water for water harvesting purposes. Check dams will be requited on larger gullies. These will comprise dry stone check dams, made of relatively small and medium size angular stones or rocks piled up without cement or netting and limited to 2 metres height, crate wire or in some cases masonry check where deeper gullies are encountered. Such structures must be built to the required engineering standards and supervised by sufficiently experienced Engineers.

Field contour bund Improvement and erosion control. The current farmers system of store checks in farm bunds will be developed and introduced in all areas to reduce the damage caused when water drops from one farm pot to another. Where stones are not readily available, vegetative barriers such as vertiver will be used. Assistance and advice would be given to the improvement of vulnerable parts of the farm bunds and for the control of flood flows through the narrower valleys that have been fully developed as Paddy fields. Farmers would be encouraged to develop their current system of emergency channels by lowering the land in one part of the field , the vulnerable part, and bunding it separately from the main field, Vertiver or other similar vegetative measures would be provided at the limits of this bund. Where considerable drops are encountered, engineering measures such as brushwood checks and boulder checks would be built.

Nala Protection and flood flow control through paddy field. Both vegetative and engineering measures (brushwood: dry stone: crate wire retaining walls) will be utilized to control bank erosion and slips within the nalas. The aim would be t reduce the loss of land due to stream bank erosion. This will be achieved by reducing the velocity of flow at the nala bank during heavy rains and deflecting the flow towards the centre of the gully. Banks and slips within the gullies will be controlled through vegetative measures and the planting of shrubs and trees. Sustainability will rest on the selection of species that are seen as useful by farmers to ensure their maintenance.

Channels for spreading of monsoon stream flow for supplementing Kharif and Rabi rainfall. Although there is good total annual rainfall within the programme areas, the high variability means that significant periods of no rain occur within the rainy season. At these times the nalas are still flowing and by means of nala diversion weirs (see below) and unlined gravity canals, this excess nala flow can be diverted onto the cropped land. The channels would be trapezoidal in section and would connect to the upper fields within a given village area. Not all fields can be commanded care would be taken to select the most suitable alignments to benefit the greatest number of landholders. These measures should be constructed so as not to increase soil erosion and, although designed to provide protective and life saving irrigation to crops in Kharif, may well permit some cultivation in second (Rabi) season where nalas have a perennial or longer period of flow.

Small diversion weirs across nalas.Diversion weirs/check dams. These would comprise a concrete weir or small overflow dam, constructed across a perennial stream and having sufficient water to irrigate the fields downstream by gravity. The height of the diversion weir would be 1 – 15 m. depending on need. It would have on outlet on one or more banks with gated control structure built from masonry or other suitably available local materials. The head regulator will connected to and earthen canal for conveyance and distribution of water to the field channels.

Rehabilitations of existing hand dug wells for irrigation and the construction of new wells. These would comprise open, dug wells (6 m diameter and 10-12 m depth), constructed at suitable sites to tap shallow groundwater. The design would be based on those developed locally under the "million wells" programme and would be stone lined and fitted with the traditional laathakudi for raising the water. These wells are seasonal and have high fluctuations in water levels between dry and rainy seasons, low permeability and limited well yields. They would be either individually owned or shared between 4 or 5 farmers and would typically irrigate an area of about 2 ha during Kharif season and 1 ha in Rabi .

Watershed Management

Transfer of Technology concerns

Dr.M.S.Swaminathan,the eminent Agricultural scientist,in his recent book "Remember Your Humanity:Pathway to Sustainable Food Security" in 2012 has said that "conferring the economy and power of scale to farm families with small holdings is the most serious challenge facing our agriculture".He has emphasized the need to establish "community managed food and water security systems" at local levels especially in disadvantaged areas.

Transfer of improved technology to farmers calls for retrospection on our part. there is complete absence of a mission to improve the farmers lot. Scientists and extension personnels are aware of the fact that the scenario of the rainfed areas of the country will move from bad to worse with climate change. Drought induced food and water scarcity will become more acute. We have to take urgent steps to arrest such a situation.But,on most cases,the attitude is poor. What is needed is a concerted effort on the following direction:

1. Bridge the yield gap between farmers field and research plots. Work on a participatory mode with farmers, as co-workers and not beneficiaries.
2. Demonstration of improved agricultural technologies should be conducted in farmers fields for improving knowledge base of farmers and facilitating adoption.
3. Input supply situation in rural areas need considerable improvement.Atpresent,quality seeds of improved crop varieties,pesticides,fertilisers,agricultural implements are not available to farmers in proper cost at times of need.
4. Training component for farmers continue to be weak. Many a times, even trainers are not very convinced with the appropriateness of technology and the way, it can benefit the farmers.
5. Farmers complain about inadequacies in the soil testing service provided to them. This should be addressed to ensure conservation of natural resources, so vital for our sustenance.
6. Marketing of food items (surplus after domestic consumption) is big problems in villages. Farmers do not get proper price of their produce, which harms their confidence. Access to assured and remunerative markets must be available to the farmers.
7. Information and communication technologies must be utilised to help farmers.Kiasn Call Centres need to address farmer’s problems in a more efficient and integrated way than that at present.
8. Human resource engaged in technology transfer activities in rural areas need to be oriented towards the site specific issues for redressal.This needs to be monitored for effectiveness,regularity,integrity,andapproach.Corrective measures need to be taken for bringing radical changes in the delivery system.
9. Government and non-government organisations working in a region should form consortia(NAIP,ICAR experience) and address the farmer related issues.There should be a road map for development. Regular and meaningful interactions with farmers and making them partners in the system of work will ensure success.

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AGRICULTURE IN ODISHA

The state of Odisha is located in the subtropical belt in Eastern Region of India between 17°47′ N to 20°33′ N latitude and 81°21′E to 87°30′E longitude, covers an area of 15.57 mha and representing 4.7 per cent of the total geographical area of the country. The state is surrounded by West Bengal in the north east, Jharkhand in the north, Andhra Pradesh in south west, Chattisgarh in the west and Bay of Bengal in the east. The coast line in the state stretches 482 kms in the east. The state has 30 administrative districts, 58 subdivisions, 314 blocks and 51,048 villages. The state capital is at Bhubaneswar (Fig. 1).

The entire state is divided into two broad regions: (1) The Plateau region, comprising of 77 per cent of total geographical area (TGA) and (ii) The coastal region, comprising of 23 per cent of TGA.

General Climate

The state is endowed with wide variations in climate, geology, land forms and vegetation, which are reflected by the large variety of soils. The climate is hot dry, sub-humid to hot moist sub-humid, monsoon type and is characterized by high temperature, high humidity and medium to high rainfall ranging from 1394.6-1750 mm with average of 1482 mm, of which more than 85 per cent is received between the months of July to October. The mean annual temperature ranges from 26.0 to 28.0°C with mean summer temperature ranging from 31 to 35°C and mean winter temperature from 21 to 23°C. The soil temperature is hyperthermic and *iso hyperthermic* and the soil moisture regime is *ustic*. In low lying areas where water stagnates during rainy season qualify for *aquic* moisture regime.

Physiography

Based on stratigraphy, tectonic history and relief features along with erosional processes, the state presents four broad and well defined physical regions viz., (i) Northern plateau, (ii) Central table land, (iii) Eastern ghat and (iv) Coastal plains

These four physiographic regions are further sub-divided into seven physiographic regions, namely the *Eastern Ghat, Gadjat hills,* *Dandakaranyaregion, Mahanadi basin, Bengal basin, Utkal plain* and *Mahanadi delta* (Fig.2).

The Eastern Ghat Region

It consists of hill ranges covering 36 per cent of the total area of the state. The hill ranges lying to the east and south west of the central table land is expressed by dissected steep sided, broken, elongated mountain ranges with deep garges and intermountain valleys. The eastern faces of the hills are rocky and precipitous and often throughout spurs and promontories towards the east while the western slopes are easier and well covered with jungles. The top of all ranges are flat and few isolated hills are detached from the main range. It is mainly composed of gneisses complex of Precambrian origin. Metamorphosed Archaean formation comprising of Khandalites, *Charmokites* and granite-gneisses from basement to the younger groups like *Gondwanas, laterite* and recent alluvium.

The Garjat hills

It occupies 26.4 per cent of TGA of the state, covering the districts of Mayurbhanj, Keonjhar, Dhenkanal, Angul, Deogarh, Sambalpur and Sundergarh are undulating, frequently intersected by hill range with a general slope from north to south. The Brahamani and the Baitarani dissect it into three blocks. The eastern block consists of the heavily forested hills of Mayurbhanj district. The middle block is again a well forested hilly region which occupies most of Keonjhar district and part of Dhenkanal and Sundargarh. The western block is flat topped and steep-edged with dense forest cover. The average elevation of the upland is 900 m forming the most important watershed of the Baitarani and Brahamani.

The Mahanadi Basin

It lies between the northern uplands and south-western hilly region of the Eastern Ghats. The tract covers area of Sambalpur, Jharsuguda, Baragarh, Kalahandi, Bolangir, Subarnapur, Boudh, Angul and Dhenkanal districts. Isolated hills rising abruptly from the plains are a frequent sight. The middle part of the Mahanadi valley and the lower Tel basin are quite extensive. The carrying capacity of the land is low compared to the coastal plains.

The Dandakaranaya Region

It is an undulating topography with well marked elevation and depressions ranging from 300 to 900 m. It is a hilly dissected plateau mostly formed of gneisses *charnokites* and *khondolites* covering Kalahandi plateau and Koraput upland. The Tel, Jank, Udanti, Hatti and Sandul, the tributaries of the Mahanadi, drain the major portion of the region. The region is characterized by hot and humid climate.

The Bengal basin

It lies in the Ganga delta occupying the part of Balasore and Mayurbhanj districts. Its elevation rises from 4 to 50 metre towards the older alluvium. It is the extension of Rahr plain of West Bengal. Erosion has carved out of this plain broad undulations and long continued weathering has given rise to lateritic soils. The east flowing rivers have cut deep into the tertiary surface and deposited newer sediments on their flood plains, thus giving rise to terrace-like flats on their slopes.

The Utkal Plain

It consists of recent and tertiary alluvium along with the patches of Archaean gneisses and sand stones covering the districts of Balasore, Bhadrak, Jajpur, part of Puri and Ganjam. Pleistocone alluvium also occurs at several places. Parallel sand dunes brought by ocean currents and winds from south west are observed with an elevation of 16 to 27 m and 1 to 4 km long supposed to be originated due to coastal uplift. It covers part of Ganjam and Balasore districts and Bhadrakh and Kendrapada districts.

Mahanadi Delta

It is formed by the deltai sediment of Mahanadi, Brahmani and other rivers in recent times. All along the coast, lagoons are formed in association with coastal uplift. The deltaic plain rises gently west lands to the foot of the Eastern Ghats with wide variations in width. Presence of hills breaks the monotony of the topography. These hillocks are considered to be outer planks of the Eastern Ghats. The growth of the delta is maximum towards the northern part. The river Mahanadi is subjected to heavy flooding and together with the Brahamani and the Baitarini causing immense damage to agriculture.

Agro-ecological regions

Based on the variability in rainfall (P), potential evaporation (PE), actual evapotranspiration (AE), relation between P and PE, AE and PE and PE nd length of growing period (LGP) for normal cropping system, the entire terrain of Odisha state has been divided into three*agro-ecological regions* and 6 *agro ecological sub-regions.* The 3 agro-ecological regions are under 2 ecosystems.

1. Sub-humid ecosystem with Agro-ecological sub-region 11, 12.1, 12.2 and 12.3 and
2. Coastal ecosystem with Agro-ecological sub-regions 18.4 and 18.5.

Table 1. Agro-ecological regions and their characteristics

AER No.	Characteristics of the agro-ecological regions
11	Characteristics of the agro-ecological regions with red and yellow soils and growing period (GP) 150-180 days.
12.	Eastern plateau (Chhotonagpur) and eastern ghats, hot sub-humid eco-region with red and lateritic soils and GP 150-180 days (to 210 days).
18	Eastern coastal plain, hot, sub-humid to semi and eco-region with coastal alluvium derived soils and GP 150-180 plus days.

Agro-climatic zones

Integrating the effects of land form, topography, climate, soil and crop adaptability, the state has been divided into 10 agro-climatic zones (Table 2 and Fig. 3).

Fig. 3 Odisha map showing the agro climatic zones and revenue districts

Table 2. Agro climatic zones, area and broad soil groups of Odisha

Sl. No.	Agro-climatic zones	Area (M.ha.)	Broad soil Group	Main locations
1.	North western plateau	1.20	Mixed and yellow	Sundargarh, Deogarh, Kuchinda, Kerai.
2.	North central plateau	1.72	Red, mixed red and black	Baripada, Keonjhar
3.	North eastern coastal plain	0.95	Coastal alluvial saline	Balasore, Ranital, Bhadrakh, Kendrapara, Jajpur.
4.	East and south eastern coastal plain	2.04	Deltai alluvial, laterite	Puri, Bhubaneswar, Ganjam, Cuttack
5.	North eastern ghat	2.85	Red loam, brown forest soil	Khurda, Gajapati
6.	Eastern Ghat high land	0.96	Red, laterite	Koraput, Nabarangpur
7.	South eastern ghat	0.97	Red, black	Jajpur, Malkangiri
8.	Western undulating land	1.24	Red, black	Bhawanipatna, Nuapada, Padampur
9.	West central table land	2.41	Laterite, mixed red and black	Sambalpur, Bolangir,
10.	Mid central table land	1.23	Red, laterite, alluvial	Dhenkanal, Angul, Athagarh.

Population

The population, its density, decadal growth rate and literacy rate in the state have been presented in Table 3.

Table 3. Total population, population density, population decadal growth rate and literacy rate in the state of Odisha compared to all India (2011)

	Population (000 Nos.)			Population density (sq. km)	Population decadal growth rate	Literacy rate (%)
	Male	Female	Total			
Odisha	21201	20746	41947	269	13.97	73.45
All India	623724	586469	1210193	382	17.64	74.04

The 2.885 per cent population (4.19 crore) of the country is confined to the state of Odisha. The population density per square km. (269/sq. km) decadal growth rate (13.97) are less compared to the country average. The literacy rate is almost at par (73.45 per cent) with all India literacy rates of 74.04 per cent. The SC and ST population constitute 17 and 22 per cent of the total population respectively. The 85 per cent of the population lives in rural areas. Cultivators and agricultural labourers constitute 65 per cent of the work force. The male population dominant over female in the state.

Size of the farm holding

The average size of holding in the state based on 2005-2006 census is 1.15 ha, which range from 0.84 to 1.90 ha, lowest in the coastal districts (having high population density 488-681 /sq.km) and highest in the western part of the state (having low population density).

Irrigated area

The total irrigation potential created till 2011-12 from all sources was 45.05 lakh ha (30.68 lakh ha during kharif, 66.7 % and 15.35 lakh ha during rabi, 33.3 %).

Category of irrigation system in the state include major, medium, minor flow, minor (lift) and other sources (Table 4).

Table 4. Sources of irrigation in the state (lakh ha)

Sl.No.	Type	Kharif	Rabi	Total	(%)Total
1	Major and medium	13.7	6.3	20.0	43.4
2	Minor (Flow)	5.76	0.45	6.51	14.1
3	Minor (Lift)	5.33	3.02	8.35	18.1
4	Other sources	5.89	5.28	11.17	24.3
	Total	30.68 (66.7)*	15.35 (33.3)	46.03	

* Data in the parenthesis indicate per cent of TGA

The major and medium categories of irrigation projects shares 43.4 per cent of the total irrigated areas in the state followed by 18.1 per cent through minor (lift) irrigation facility and 14.1 per cent through follow-minor irrigation facilities. Other sources including ponds, nullas, water shade areas shares 24.3 per cent areas. During kharif season 66.7 per cent areas have the irrigation facilities whereas 33.3 per cent during rabi season.

Problems

1. The canal commands practicing rice-based cropping system, seepage from canal network along with the faulty water distribution system and field-to-field irrigation has resulted in tail-end deprivation, low irrigation efficiency and reduction in net irrigated area.
2. It has also caused water logging in the canal commands and degradation of basic soil and water resources.
3. Under exploitation of ground water and raising of water table in canal commands has reduced the under ground space for water storage.
4. Consequently, there is reduction in ground water recharge.
5. The reduced amount of natural recharge adds to the runoff excess, thereby aggravating floods and flood-related damages.

Water Resources

The annual per capita water availability in Mahanadi, Brahamani, Baitarani and Subarnarekha basins is 2067, 2388 and 1982 m^3, respectively. In these basins the ground water potential is estimated to be 21293, 5879 and 2185 M m^3, respectively. The ground water development in the state is only 23 per cent (less than the neighbouring states WB 38 per cent, Bihar 46 per cent, Jharkhand 33 per cent, all India 42 per cent).

Water-related constraints

A substantial portion of state comprises of hills and valleys. The intense rains during rainy season generate rapid overland flows on the unprotected hills, resulting into sheet, rill and gully erosion. Deforestation and shifting cultivation in these regions further accelerate the problems.

In the plateau and hill region (i) the probability of drought occurrence is very high (>50 %), (ii) ground water exploitation is very low (<10 %) with low irrigation facility, (iii) low crop and water productivity. Large scale migration of the native farming population aggravate the situation further.

In the coastal plane zone; (i) the extent of ground water exploitation is about 30 per cent, (ii) risk of saline water intrusion due to over exploitation of ground water, (iii) water salinity due to nearness to sea, (iv) poor water fall conditions resulting in water logging and water congestion, and (v) very low water use efficiency.

The ground water reserve in the state is 20 lakh ha-m, out of which 3 lakh ha-m is used for drinking, industry and other committed uses, while 17 lakh ha-m is available for irrigation. However, only 23 per cent ground water is used for agriculture.

The ground water development has been constrained due to following reasons:

1. Fragmented and marginal land holdings associated with low risk bearing capacity of the farmers.
2. Large area are under rock zones, which have low water discharge rates in the state.
3. Power supply system is very poor to utilize vast ground water potential.
4. At some places groundwater is contaminated with iron (> 1mg L^{-1}) in Keonjhar, Mayurbhanj, Sundargarh). In coastal Odisha, fluoride concentrations > 1.5 mgL^{-1} in isolated patches of Khurda, Nuapada, Angul and Bolangir. The nitrate

concentrations > 45 mg L^{-1} have been ^{observed} in same pockets of Ganjam, Kalahandi and Bolangir districts.

5. Lack of sound ground water utilization policy of the government.

Scope

A substantial scope exists to enhance ground water utilization in the region for both *kharif* and *rabi* crops for providing supplemental irrigation. The productivity of ground water can be increased by delivering the well water to fish ponds before utilizing for irrigation which increases water productivity. Open well or tube well will be designed in such a way that their annual yield equal to recharge.

Management of rain water

Construction of on-farm reservoirs (OFRs/ponds) in series at different top sequences is the bare-need for harvesting rain water coming out as excess runoff. These OFRs recharges the ditches, wells and ponds located in the recharge zone. These systems help managing drought in kharif and growing of second crop in *rabi*.

The in situ water harvesting include contour farming, compartmental bunding, mulching and different types of tillage practices.

Water harvesting structures include (i) rain water or direct surface runoff harvesting (roof top collection, dug out ponds/storage tanks), (ii) stream flow or runoff harvesting structures (*nala* bunding, gully control structures/check dams/ weirs, water harvesting dams/stop dams, water diversions, percolation tanks; and (iii) sub-surface flow water harvesting, subsurface weirs, micro-catchment/ micro-water shed.

At Kalahandi, Publbani (undivided) and other hilly districts even though polythene-lines small rain water harvesting structures (*dola* 4.5 m^3 capacity) were constructed in the past , these structures are no more in use due to poor maintenance by the beneficiaries. The follow up action by the Government/Departments who constructed the structures have not been taken up to maintain/re-use of these structures, even though at the initial stages the benefits were realized. Time to time educating, the farmers/users is very much essential. Lot many things need to be done under this aspect in the state of Odisha.

Looking at the per cent area under different crops grown in the state having irrigation facility, it is seen that 100 per cent of sugarcane, 89 per cent of vegetables, 61 per cent of spices, 48 per cent of rice , 21 per cent of oil seeds, 7 per cent of pulses and 4 per cent of fibre crops (Table 5). The pulses and oilseed crops are neglected crops in the state.

Table 5. Per cent of total irrigated area covered under different crops in the state

Sl.No.	Crops	% of total area covered
1	Paddy	48
2	Other cereals (maize, wheat, ragi)	20
3	Pulses	7
4	Oilseeds	21
5	Fibres	4
6	Sugarcane	100
7	Vegetables	89
8	Spices	61
	Total	37

Rainfed areas

The rainfed areas in the state dominant over irrigated area of the total cultivated land (61.80 lakh hectare), 29.14 lakh ha (47 %) is high land, 17.55 lakh ha (28 %) medium land and 15.11 lakh ha (25 %) low land. The 35 % of the cultivated land is irrigated, rest 65 % are rainfed, 70 % during *kharif* and 60 per cent during *rabi* (39.55 lakh ha).

In the rained belts cultivation of rice, coarse cereal, pulses, oil seeds, fibres, spices and vegetables predominates.

The area under uplands in the state is very high in interior districts. Kandhamal (81 %), Rayagada (68 %), Gajapati (63 %), Boudh (63 %), Kalahandi (63 %), Nawarangpur (67 %), Dhenkanal (57 %), Angul (57 %), Bolangir (57 %), Sundargarh (56 %), Malkangiri (55 %), Koraput (55 %), Keonjhar (54 %), Jharsuguda (54 %) and Deogarh (53 %).

Problems of rainfed agriculture in the state of Odisha

1. The climatic constraints include

1. High variability in terms of commencement and cessation of south west monsoon.
2. Frequent and prolonged dry spells leading to drought situation.
3. Erratic distribution of rainfall in the season both spatially and temporarily.
4. Monsoon depressions and cyclones some times cause high intensity rainfall and floods.

2. Edaphological constraints

This include

1. Poor crop stand due to
1. Failure of germination and seedling emergence as a result of soil crusting.
2. Quick surface drying affecting poor crop establishment.
3. High temperature cause heat injury to emerging seedlings and germinating seeds.

2. Poor crop growth due to :
1. Low moisture holding capacity and low profile storage (10 cm/m).
2. Poor soil fertility due to low organic carbon content, with low plant nutrients, low cation exchange capacity, coarse texture soils favouring leaching losses.
3. Soil became very hard when dry restricting intercultural operations for weed control.
4. Compact argillic horizon restricts root depth.

3. Decline in land productivity due to
1. Sloping topography
2. High runoff loss (26 %)
3. Soil erosion loss with formation of gullies and ravines (10 + soil loss/ha of bare land).
4. Associated with this there is loss of nutrients causing poor fertility.

All these proves that the dry lands are not only thirsty but also hungry.

4. Social problem: Allowing cattle population for grazing soon after the harvest of *kharif* crop restrict crop production in post *kharif* season.
5. Collection of cow dung is not a practice, which limit the use of FYM in agriculture.
6. Poor marketing facility: Even though communication system has developed, the middle man system, no post-harvest storage facility compel the farmers for distress sale of the produce.

Steps taken in the state

The technology for dry land rainfed farming in the state has been generated through the AICRP on dry land agriculture operating at Phulbani in the district of Kandhamal. The salient findings and recommendations are given below:

1. Different crops have been selected/breeded for matching the length of growing season (LGS).

Sl. No.	Crop	Varieties	Remarks
1	Rice	ZHU-11-26, Vandana, Pathara, RR 166-645, Saria (Local)	80-100 days duration
2	Black gram	OBG-23, OBG-15, Pant-U-30, T-9, Sarala	60-70 days duration all yielding seed yield of 9.5 to 11.4 q ha^{-1}
3	Arhar	ICPL-87051, ICPL-85063 (Laxmi), ICPL-87119 (Asha), UPAS-120	Yielding 12-18 q seed ha^{-1} within 150-230 days
4	Horsegram	Urmi (DS 2-2)	Yielding seed yield of 9.3 q ha-1 within 90 days
5	Groundnut	Smruti,	
6	Caster	DCH-177, DCH-30, Aruna	
7	Greengram	K-851, PDM-54	
8	Cowpea	BEJ-2, SGL-1	
9	Maize	Navjot, DHM-103	
10	Turmeric	Sudarsan, Suguna, Subarna, Roma	
11	Ginger	Vardhan, China, Nadia, Suprava	
12	Yam	Orissa Elite, Gajanan	
13	Cassava	Sree Jaya	
14	Colcasia	Telia	
15	Sweet potato	Gouri	
16	Yam bean	Rajendra, Mishri, Kenda-1	

2. Promising intercropping systems have been tested and proposed for the rainfed areas.

These are (i) Rice + arhar :: 5:2 yielding

Sl. No.	Intercropping system	Yield (t ha^{-1})	Rupee return per rupee investment	Remarks
1	Rice + arhar (5:2)	1.8 (grain) + 1.0 (seed)	1.34	Rainfed upland
2	Maize + cowpea (2:2)	3.9 (grain) + (1.5 pod)	2.68	Rainfed interior districts
3	Maize + arhar (1:1)	3.2 (grain) + 0.6 (seed)	1.32	Rainfed interior districts
4	Groundnut + arhar (6:2)	1.0 (pod) + 0.6 (seed)	1.69	Rainfed interior districts
5	Yam + maize (1:2)	12.0	5.8	Slopy red calenite

		(tuber) + 3.0 (cob)		soil
6	Rice + radish (4:2)	1.8 (grain) + 9.0 (tuber)	2.44	High altitude
7	Rice + okra (4:2)	1.6 (grain) + 4.1 (fruit)	4.7	Interior districts

3. Integrated nutrient management comprising of FYM, green leaf manure glaricidia, subabul, cassia (N_2 fixing plants) added with half of P_2O_5 and K_2O ha^{-1} not only produced higher sustainable yields for principal crops but maintained better soil health in the rainfed system.
4. Green leaf plants not only supplement N for crop, fodder for animals, conserve soil but also fuel for domestic purpose which save deforestation .

5. Water harvesting and seepage control

Soil-cement lined tank (soil cement mortar (6:1) of 6 cm thickness) has been proposed for storing runoff water for use covering $1/10^{th}$ of the cropped area.

Through National Agricultural Innovative programme (ICAR/OUAT) (NAIP) it has been demonstrated that crop diversification with high value crops like potato, garden pea, cabbage, cauliflower, capsicum and Raikia bean (local improved bean) can substitute local paddy (< 1.0 t ha^{-1}) during late kharif to early rabi with very high return (B:C ratio 3.5 to 6.0). During kharif maize + cowpea (2:2), maize + greengram (2:3), maize + yam sweet potato, Turmeric, zinger crops are much more remunerative (B:C ratio >1:2.0) than traditionally followed local paddy.

Table Performance of high value crops under crop diversification in sunflowers

Sl. No.	Crop	Yield (t ha^{-1})		Response (%)	B:C ratio
		FP	INM		
1	Potato (local)	9.9	13.8	39	
2	Potato (High yielding)	18.8	22.5	20	
3	Garden pea (green pod)	8.7	12.6	44	
4	Cabbage (early)				
5	Cauliflower (early)	7.4	9.5	28	
6	Capsicum				
7	Raikia bean	9.1	10.9	20	
8	Onion				
9	Cotton (seed cotton)	1.6	2.2	38	
10	Turmeric	13.9	18.0	29	

11	Ginger	18.2	21.2	16	

Odisha watershed Development Mission (OWDM)

It is a registered society came into existence on 30th June, 2000 under the administrative control of Department of Agriculture by the Government of Odisha for poverty alleviation ina "Strategic Mission" mode, which focuses coordinates, operationalize soil, crop environment related issues with people's participation in watershed approach. Watershed is a geo-hydrological unit where all the excess rain water emptics through a common point in a given area having no physical dimension. It could be as small as 4-10 ha to as high as 25,000 ha.

Even though, the state have been delineated into 20,079 micro-watersheds by Orissa Space Application Centre (ORSAC), till date 5949 micro-water sheds have been implemented covering treatable area of 36.53 lakh ha under various schemes.

Integrated Wasteland Development Programme (IWDP), Drought Prone Area Programme (DPAP), Additional Central Assistance (ACA) in KBK districts, coffee Development Programme (CDP), National Watershed Development Project for Rainfed Areas (NWDPARA), River Valley Projects (RVP), Rashitrya Krishi Vikash Yojana (RKVY), Western Orissa Rural Livelihoods Projects (WORDP), Orissa Rural Livelihoods programme (JEEBIKA). Integrated Watershed management Programme (IWMP). These projects operates for 4 to 7 years.

Programmes and their achievements

Sl. No.	**Programme**	**Operational site**		**Treatment area (lakh ha)**		
		district	**Micro watershed**	**Target**	**Achievement**	**(%)**
1	IWDP	23	1046	5.44	3.58	66
2	DPAP	08(47 blocks)	1319	6.68	4.15	62
3	ACA	08(kbk)	314	1.67	1.67	100
4	RLTAP	08(kbk)	150	0.75	0.22	29
5	CDP	0.2 (kbk)	-	0.02	0.067	-
6	NWDPRA	-	221			Continuing
7	RVP	-	25	0.43		Continuing
8	RKVY	07	100	0.50		Continuing
9	WORLP	04	Completed since 2011			
10	JEEBIKA (ORLP)	06	Continuing			
11	IWMP	26	1235	6.859		Continuing

Crops grown

A number of crops grown in the state, which include cereals, pulses, oilseeds, vegetables, spices, sugarcane, fibres, spices and condiments, fruit crops. The area and its per cent of total area, production and productivity (kg ha^{-1}) under each crop have been presented in Table 6. The cereals particularly rice occupies more area among the crops. It is the predominant crop in the state. The productivity of all most all crops is below the national average.

Table 6. Crops grown in the state with area and productivity (2011-12)

Crop	Total			Productivity (kg/ha)	
	Area (lakh ha)	% of total area	Production (lakh MT/ bale)	Odisha	India
Rice	40.04	48.4	58.95	1472	
Maize	2.62	3.2	6.05	2321	
Total cereal	44.79	54.2	66.95	1495	
Pulses	20.83	24.2	9.20	460	
Oilseeds	7.65	9.2	6.63	867	
Vegetables	6.98	8.4	9.52	13789	15,200
Sugarcane	0.39	0.47	27.88	72000	
Fibres	1.08	1.30	4.77	3081	
Spices	1.54	1.86			
Fruits	5.33	6.1	32.51	6100	11,300
Floriculture	0.08	0.1	-		

Agriculture Growth rate

The growth of Agriculture and Animal Husbandry (AH) sector either alone or together with forestry and fishery sector is 8.58 and 11.27 per cent, respectively at current price (2011-12). The quick estimate of contribution of agriculture, AH, Forest and Fishery sectors to GSDP in the state and the country are 16.44 and 14.10 per cent respectively based on 2004-2005 prices.

Food security concerns

Considering the requirement of rice, cereals, pulses and oilseeds of 400 g, 500g, 50 g and 45 g per adult per day, respectively, the state was self sufficient with respect to rice and cereals only by the year 2010-11. However, by the year 2011-12, the state is having deficit under all the commodities except in vegetables (Table 7). The projected population of the state by 2020 will be appear to 4.83 crore. To feed such population the projected quantity of food commodities, requirement will be very high (Table 7).

By the year2020 the state will remain self sufficient in vegetable production. Only compound to the production level of 2011-12. For rest of the commodity attempts should be made for increasing the production, 20.6 per cent for rice, 32.4 per cent for cereals, 37.9 per cent for pulses , 261.0 per cent for oilseed and 71 per cent for fruits (Table 7).

Table 7. Estimate of marketable surplus of rice, cereals, pulses, oilseeds and vegetables in Odisha (2011-2012) and projected requirement (2020)

Item	Population (lakh)	Adult equivalent (88 %)	Total consumption requirement (tonnes)	Total consumption including wastage (tonnes)	Production	Surplus(+)/ deficit (-)	Production	Adult equiv. (88 %)	Total requirement (tonnes)
	2011-12						Projected 2020		
Rice	422.24	371.57	54.25	62.20	58.95	-3.25	483.00	425.00	71.14
Cereals	422.24	371.57	67.81	77.50	66.95	-10.55	483.00	425.00	88.70
Pulses	422.24	371.57	9.63	11.01	9.21	-1.80	483.00	425.00	12.70
Oilseeds	422.24	371.57	18.43	21.06	6.64	-14.42	483.00	425.00	24.10
Vegetable	422.24	371.57	40.16	49.12	79.2	+30.00	483.00	425.00	56.40
Fruits	422.24	371.57	38.14	48.51	32.51	-16.00	483.00	425.00	55.60

Land utilization

The state has the geographical area of 155.71 lakh hectare of which 37.3 per cent is under the forest. The 34 per cent area is under cultivation of different crops of economic importance. Even though vertical expansion is essential, there is scope in the state for horizontal expansion covering cultivable waste, barren and uncultivable low land under current fallow (Table 8).

Table 8. Land utilization statistics in the state of Odisha (2011-12)

Sl.No.	Particulars	Area (lakh ha)	Total (%)
1	Geographical area	155.71	-
2	Forest area	58.13	37.3
3	Misc. tree and grobes	3.42	2.2
4	Permanent pasture	4.94	3.2
5	Cultivable waste	3.75	2.4
6	Land put to non-agriculture	12.98	8.3
7	Barren and uncultivable land	8.40	5.4
8	Current Fallow	8.88	5.7
9	Other fallow	2.29	1.5

10	Net area sown	52.92	34.0
11	Gross cropped area	88.01	-

The gross cross cropped area of the state is 88.01 lakh hectare with the cropping intensity of 166 per cent. The 10 coastal districts in the state have the cropping intensity ranging from 154 to 231 with an average of 189. For rest of the interior districts the average cropping intensity is 164 per cent ranging from 130 to 219 (Table 9). Water availability for cropping in the interior districts had restricted the intensity of cropping.

Table 9 Cropping intensity in different districts of Odisha.

Sl. No.	Coastal District	Cropping intensity	Sl. No.	Districts	Cropping intensity	Sl. No.	Interior Districts	Cropping intensity
1	Balasore	160	1	Bolangir	134	11	Nawarangpur	157
2	Bhadrak	154	2	Sonepur	191	12	Rayagada	166
3	Cuttack	231	3	Dhenkanal	187	13	Mayurbhanj	143
4	Jagatsinghpur	204	4	Angul	181	14	Phulbani	176
5	Jajpur	196	5	Gajapati	219	15	Boudh	176
6	Kendrapada	190	6	Kalahandi	168	16	Sambalpur	152
7	Ganjam	184	7	Nuapara	172	17	Baragarh	153
8	Puri	216	8	Keonjhar	152	18	Deogarh	172
9	Khorda	180	9	Koraput	151	19	Jharsuguda	134
10	Nayagarh	176	10	Malkangiri	164	20	Sundargarh	130
	Average	189					Average	164

Crops, intercrops and cropping systems

The crops, inter crops and cropping systems suggested for individual macroclimatic zones of the state to mitigate ill effects of aberrant weather problems arising due to monoculture, increase the income of small land holdings, employment generation, ensuring constant flow of income, conservation of natural resources, effective recycling of farm by-products and to alleviate hunger and malnutrition. The time tested intercropping and cropping sequences suggested by the university is given in Table 10.

Table 10. Suggested intercropping and cropping sequences for different agro climatic zones.

Sl.No.	Agro climatic zones	Intercropping	Cropping sequences
1	North western plateau zone, RRTTSS-Kerei	1. Arhar + groundnut (2:5)	Rice - mustard
		ii) Arhar + greengram (2:5)	Rice-Horsegram
		iii) Arhar+ rice (2:5)	Rice-Bengalgram/ field pea

Sl.No.	Agro climatic zones	Intercropping	Cropping sequences
		iv) Arhar + cowpea (2:5)	Rice-Vegetable/greengram
			Rice-potato-sesame
2.	North Central Plateau Zone, RRTTS, Keonjhar	Arhar + groundnut (2:8)	Rice-Mustard
		Arhar + Rice (2:10)	Rice-Bengalgram
		Arhar + Runner bean (2:1)	Rice-wheat
		Maize + Arhar (2:1)	Rice-vegetable+vegetable
		Maize+Groundnut(2:3)	Rice – potato-sesame
			Maize-mustard
			Rainfed arhar 60 % area + 40 % rice in upland mixed crops
3.	Western central table land (RRTTS-Chiplima)	Arhar + groundnut (2:6)	Rice-Groundnut
		Arhar+Greengram (2:3)	Rice-wheat
		Arhar + rice (2:5)	Rice-vegetable
		Groundnut + Greengram	Rice-Maize
		Sugarcane+Mustard (1;2)	Rice-Rice
		Cotton+greengram (1;2)	Rice-mustard-groundnut
		Rice+field pea (Paira)	Rice-mustard-rice
			Rice – Veg. – Veg.
			Rice-maize-okra
			Rice + potato+sesame
			Rice + wheat+greengram
			Rice –Sunflower-greengram
			Rice-Groundnut-Greengram
4.	Mid Central Table Land zone (RRTTS-Mahisapat)	Arhar+groundnut (2:6)	Rice – Caster
		Arhar + Sesame (2:4)	Rice-Groundnut
		Arhar+Greengram/Blackgram (2:3)	Rice-Mustard
			Rice –greengram/ blackgram/ Coriander
		Arhar+rice (2:5)	Gram/Coriander
		Arhar + rice (2:5)	Rice – wheat
			Rice-mustard
			Rice-Veg.-Veg.
			Rice+potato+sesame
5.	Eastern Ghat High Land Zone (RRTTS-Semiliguda)	Arhar + Ragi (2:4)	Rice-wheat
		Arhar + niger (2;4)	Rice-mustard/bengalgram/ linseed
		Maize + cowpea (2:2)	Rice – vegetable
		Ragi + Soybean (5:2)	Rice – rice
			Rice-mustard-vegetable
			Rice-Veg.-Veg.
			Monsoon potato-mustard/wheat
			Maize-vegetable
			Cowpea-Niger
6.	South Eastern Ghat Zone (RRTTSS Kalimela)	Arhar + blackgram (2:3)	Rice-sesame
		Arhar + sesame (2:4)	Rice-field pea
		Arhar + Rice (2:4)	Rice –vegetable
		Arhar + groundnut (2:3)	Rice-wheat

Sl.No.	Agro climatic zones	Intercropping	Cropping sequences
		Maize + cowpea (2:2)	Rice-mustard
7.	Western Undulating zone (RRTTS-Bhawanipatna)	Arhar + groundnut (2:5)	Rice – field pe/bengalgram
		Arhar + Jawar (1:1)	Rice-Onion
		Arhar + rice (1:1)	Maize – mkustard
8.	North Eastern Coastal Plain zone (RRTTS-Ranital)	Arhar + groundnut (2:6)	Rice – horsegram
		Arhar + rice (2:5)	Rice-mustard
			Rice-potato-sesame
			Rice-Potato-Pumpkin
			Rice-mustard-rice
			Rice-Veg.-Veg.
			Jute-greengram/groundnut
9.	East and South Eastern Plane Zone (RRTTS, Bhubaneswar)	Arhar + Groundnut (2:6)	Rice-potato/Veg.-Sesame
		Arhar + greengram (2:6)	Rice-Veg.-Veg.
		Arhar + Blackgram (2:3)	Rice-groundnut (Rainfed)
		Arhar + rice (2:5)	Jute-rice-rice
		Arhar + ragi (2:4)	Rice-rice
		Maize+cowpea(fodder)(2:2)	
10.	North Eastern Ghat Zone (RRTTS, G. Udaigiri)	Arhar + ragi (2:4)	Maize-Toria
		Arhar+ Niger (2:4)	Rice-groundnut-cowpea
		Mustard + runner bean (2:2)	

Specifications for effective intercropping

Growing of two or more crops simultaneously in the same piece of land is known as intercropping. It is recommended for the uplands constituting 75 per cent of the cultivated land of the state. It is proposed because it acts as insurance against crop failure due to drought. Inclusion of legume component in the system fixes atmospheric N_2 and supplies N- to non-legume crops. Based on the research and demonstrations conducted by the university the recommended intercropping systems for the rainfed uplands of the state are given below (Table 11).

Table 11. Intercropping systems recommended for rainfed uplands of Odisha

Intercropping systems	Row ratio	Set specifications (cm)	Intercrop row distance (cm)
Rice based			
Rice + green gram	4:1	Every 5th row	
Rice + black gram	4:1	For intercrop	
Rice + groundnut	4:1		
Rice + okra	4:2	30-75-30	30
Rice + cluster bean	4:2	30-75-30	30

Maize based			
Maize + cowpea	2:2	30-90-30	30
Maize + cowpea (fodder)	2:1	30-30-30	-
Maize + runner bean	2:2	30-120-30	60
Arhar based			
Arhar + groundnut	2:6	30-210-30	30
Arhar + sesamum/niger	2:4	30-150-30	30
Arhar + greengram/Blackgram	2:3	30-120-30	30
Arhar + ragi	2:4	30-100-30	20
Arhar + rice	2:5	30-120-30	20
Arhar + rice (mixed broad cast)	40:60	40 % arhar seed rate + 60 % rice seed rate	- -

Climate and rainfall

The climate of the state is tropical, which is characterized by high temperature, high humidity, and medium to high rainfall, short and mild winter. The average normal rainfall is 1451.2 mm , however it ranges from 1394 to 1759 mm. Most of the rainfall received in the state concentrated in the period of 3 months of monsoon season. During 2011, the pre-monsoon rainfall (April 11 and May, 2011) was excess by 38 per cent, Monsoon rainfall was excess by 2 per cent. The post monsoon (October, 2011 to December, 2011) and summer (January 2011 to March, 2011) rainfall were deficit by 87 and 2 per cent, respectively (Table 12). The number of rainy days varied between 59.6 and 83.9 with overall of 69.3 . In the month of July and August, 2011, there were 15 number of days were rainy days.

Table 12. Rainfall pattern in the state (2011)

Period	Rainfall (mm)		Deviation (%)
	Normal	Actual	
Summer (Jan 11 to May, 11)	59.8	22.4	(-) 62.54
Pre monsoon (April , 11 to May, 11	96.4	133.1	38.07
Monsoon (June, 11 to Sept. 11	1144.3	1163.1	1.64
Post monsoon (Oct. 11 to Dec. 11)	150.7	19.5	(-) 87.06
Grand total	1451.2	1381.1	(-)7.8

Consequences

The effect of erratic distribution of rainfall negatively influenced agriculture in the state (Table 7). The kharif crops were effected by (i) heavy weed infestation, (ii) late transplanting of paddy with aged seedlings effecting yield, (iii) drying of medium and late paddy with poor crop stand, poor tillering etc.

Temperature

The state experiences maximum temperature of the maximum summer temperature of 42ºC during the month of May and minimum of 6.9ºC during January (ranges from 34.1 to 42ºC) and minimum temperature in winter ranging from 6.9 to 15ºC (Table 13). The maximum relative humidity (RH) of 95 % during September and minimum of 24 % during March.

Table 13 Maximum , minimum temperature and relative humidity realized and recorded in the state (2011)

		Jan.	Feb.	Mar.	Ap.	May	June	July	Aug.	Sept.	Oct	Nov.	Dec.
Temperature ºC	Max.	29.2	32.3	37.6	38.1	42.0	36.9	33.6	32.5	32.4	33.9	32.3	30.3
	Min	6.9	10.7	15.9	19.5	21.3	22.9	22.5	21.9	21.5	17.9	11.8	8.4
RH (%)	Max.	88	89	80	83	80	86.0	88.0	94	95.0	91.0	90.0	89
	Min	36	33	24	29	38	61.0	72.0	78	78.0	59.0	48.0	47

Climate change in the state

Odisha is getting hotter

The mean annual temperature in the state has increased by 1.0ºC in the last 40 years from 1951-1990. The magnitude of increase was maximum in the coastal areas. Heat waves have become more intense and for an extended period.

Rainfall pattern is changing

The annual rainfall decreased between 1950-1990 by 19-225 mm. During last 14 years from now, the annual rainfall in coastal districts increased and interior districts decreased. Low pressure over the Bay of Bengal is increasing. The total number of low pressure including both depressions and the upper atmospheric cyclonic circulation has more than doubled with 12 low pressures in 2007 (Odisha Agriculture Statistics-2007).

Extreme weather events are increasing

Last decade Bhubaneswar recorded the maximum rainfall of 400.3 mm in one day as against the preceding record of 256.4 mm between 1969-1978. Inter-annual variation within the decade also has increased. The number of days with very heavy rainfall (>125 mm) has also increased. Record daily maximum temperature is gradually increasing with 46.3ºC at Bhubaneswar in 2005. Number of hot days with > 45ºC is also increasing with such 3 days in 2005, while it was absent in 1970s and 1980s except for 1972 (Pasupalak, 2009).

Land and soil degradation in the state

Because of wide variation in temperature, rainfall, relative humidity etc. with long sea coast (482 kms) the state experiences wide range of climatic conditions and seasons. Increasing demographic pressure on the limited soil resources, in appropriate practices including over-exploitation and unscientific management for short term gains with extreme disregard for long term sustainability of soil health have led to soil and land degradation. The natural, human induced and administrative and policy factors are responsible for land degradation in the state.

Extent of land degradation in the state

The degraded and fallow land are confined to 62.364 lakh ha (40 % of total geographical area) in the state. The loss in crop productivity due to land degradation ranging from 4 to 7 per cent and total out put equivalent to 210-330 crores (Soil erosion, Odisha-2005). The soil resource suffer from diverse ailments due to land degradation. The soil degradation status in the state of Odisha is presented in Table 14.

Table 14 Soil degradation status

Type of soil degradation		Degree of degradation				Total area
		Slight	Moderate	High	Extreme	
A.	Water erosion (loss of top productive soil)	14.981	17.853	20.14	0.685	53.659(3.0)*
B.	Physical deterioration					
	Water logging	2.28	2.165	-	-	4.445(2.8)
	Flooding	0.505	1.67*	0.13	0.06	2.365(1.5)
	Mine spoil soil					0.50(0.32)
	Shifting sand					0.24(0.15)
	Strip land (both sides of roads, railways etc)					1.15(0.72)
C.	Chemical degradation					
	Salinisation	0.09	0.42	0.235	-	0.745(0.47)
	Total	17.856	22.108	20.505	0.745	63.104(40)
D.	Stable terrain					
	Under natural condition					6.8 (4.5)
	Land with no degradation problem					79.629(50.5)
	Misc. area (road, river, habitation)					2.906
	Total Geographical area					152.400

*Data in the parenthesis indicate per cent of total geographical area

The degradation of soil is manifested in following forms: (a) wind erosion, (b) water erosion (c) physical degradation, (c) Chemical deterioration (soil salinization, sodication, acidification, excessive nutrient mining, organic matter depletion etc.

The land degradation in the state is mostly due to water erosion (30 per cent area) resulting in to the loss of top soil. Especially high rainfall, slopy, light texture of soil, lack of surface cover due to deforestation and improper cropping, wrong tillage practices, contribute to soil loss, ultimately leading to productivity loss. The information for soil loss in the state has been categorized as (Table 15).

Table 15 Extent of soil loss in the state

Sl.No.	Category	Loss (t/ha/ year)	Area (%)
1	Very slight	<5	49.6
2	Slight	5-10	18.6
3	Moderate	10-15	10.3
4	Moderately severe	15-20	6.7
5	Severe	20-40	9.5
6	Very severe	40-80	4.2
7	Extremely severe	>80	1.1

Attempt taken controlling soil loss

Various attempts have been taken by the state Department of Agriculture through soil conservation and water shed mission (discussed in forth coming chapter).

Land fragmentation

Several factors attribute to lower agricultural productivity in the state, many consider skewed distribution of agricultural land, small size operational holding high incidence of share tenancy and rural poverty are major impedance to agricultural growth

Table 16 Category of farmers

Sl.No.	Category of farmers	Land holdings	Total (%)
1	Marginal	<1.0ha	59.7
2	Small	1-2 ha	26.6
3	Semi-medium	2-4ha	10.8
4	Medium	4-10ha	2.5
5	Large	>10ha	0.4
	Total		100.0

Out of 43,56,392 number of farmers in the state having 50,19,476 ha of operational area (based on 2005 census) the small and marginal category together account for 86.3 per cent of the total population possessing land holding constituting 58.4 per cent of total (Table 16) of the small and marginal category 55 per cent farmers are below poverty line.

The demographic increase has been reflected in increase in number of operational holdings by 30.3 per cent during 1991 to 36 per cent by 2001 and 45.2 per cent by 2005 compared to 1961. Keeping pace with the increase in number of operational holdings, the operational area has not increased number (ranging from 15.8 to 18.2 per cent) on the contrary the average size of the holding, which was 1.44 ha during 1961 had decreased consistently by 11.1 per cent during 1991, 13.2 per cent during 2001 and 20.2 per cent during 2005, restricting modernization of agriculture in the state (Table 17).

Table 17 Number and operational holdings in the state based on 2005 census

Year	Number (lakhs)	Holdings (lakh ha)	Average size of holding (ha)
1961	30.0	43.0	1.44
1991	39.1(30.3)*	40.8(15.8)	1.28(-11.1)
2001	40.67(36.0	50.81(18.2)	1.25(-13.2)
2005	43.56(45.2)	50.20(16.7)	1.15(-20.2)

* Date in the parenthesis indicate per cent increase/degrease of base year 1961.

The land consolidation has to make complete. It is urgently needed for implementation of moderate technology, their causes and remediation.

Water logging

The 4.5 lakh hectare of fertile lands in the state constituting 2.8 per cent of the total geographical area is having water logging problem.

Causes

Alluvial plains irrigated by major irrigation canals for rice cultivation have become water logged due to disturbance in hydrological equilibrium with recharge component exceeding the discharge component with poor drainage. For every 40 hectares of land under irrigation has created 3.2 hectares of water logged area. The pinnet type drainage pattern in valley bottom lands (*Bahal lands*) under Hirakud Command have been water logged. Growing of rice in deltaic back swamps (*Pata land*) or abandoned silted up "*Oxbows" Joroland*, abandoned river beds are typical situations, where natural geomorphic processes are responsible for the micro-depression resulting in water logging.

It is also the out come of, (i) defective infrastructure planning, (ii) indiscipline in water use, (iii) construction of canals and roads without proper cross drainage provision, (iv) disruption of natural land drainage to congestion of natural runoff.

The topography of water logged areas is about 1m below the mean sea level and is saucer type which hold water instead of draining. Deterioration of soil structure with rice-rice cropping systems in canal irrigated tracts lead to hard pan formation in the subsurface horizons and reduce drainage efficiency causing water logging. In coastal districts of Odisha it is the acute problem.

Flooding

The 482 kms long coastal line of Odisha exposes the state to vagaries of monsoon namely flood, cyclone and storm surges. These events cause maximum damage to agriculture. Out of 53 years (1961 to 2013) 34 years were abnormal having occurrence of natural calamities like drought, flood and cyclone and 24 years flood alone. The relief of lithosphere of the state slopes downwards from West to East as such the rivers like Subarnarekha, Budhabalanga, Salandi, Baitarani, Brahamani, Mahanadi and Rushikulya and their branches and rivulets find their way from West to Bay of Bengal in the East. Generally the state receives 79 per cent of total rainfall from June to September which causes flood in many rivers. Heavy rainfall in the catchment areas of the larger river system leads to overflow the banks and embankments, causing submergence and inundation of large areas. Due to sand and silt deposits in water courses of rivers, making them shallow, causing less water to discharge, creating flood. The flood causes damage to about 2.365 lakh ha constituting 1.5 per cent of total area.

Mine spoil land

The state of Odisha is rich in minerals. Mostly open cast mining is adopted, generating huge over burden mine sub soils causing in situ physical land degradation associated with chemical degradation adjacent soil with heavy metals (Table 14).

Strip lands

The land along public roads (5m, both the sides), railways, high tension electric transmission line, and some canal areas, constitute 1.15 lakh ha of the total state geographical area which are generally not only cultivated but also remain fallow through out the year. During rainy season due to water logging encourage water hyacinth and other weeds growth creating unhealthy environment (Table 14).

Shifting sand dunes

It is a menace to six coastal districts of the state which are subjected to aeolian action . The infertile sands make the agricultural land unsuitable for cultivation.

Soil resource of the state

Eight types of soils are found in the state. These are (i) red loam and red sandy soils, (ii) red and yellow soils, (iii) black soils, (iv) laterite and lateritic soils, (v) deltaic alluvial soils, (vi) coastal alluvial soils, (vii) brown forest soils and (viii) mixed and black soils. Their extent and dominance has been given in Table 18 and Fig. __.

Table Soils of Odisha , their extent

Sl.No.	Soil	Area (Mha)	Per cent of total area
1	Red loam and red sandy soil	7.4	45.9
2	Red and yellow soil	5.50	35.2
3	Black soil	0.96	6.2
4	Laterite and lateritic soil	0.70	4.5
5	Deltai alluvial soil	0.67	4.2
6	Coastal alluvial	0.26	1.7
7	Brown forest soil	0.17	1.2
8	Mixed red and black soil	0.16	1.1
	Total	15.82	100

The red loam, red sandy red and yellow soils dominant in the state constituting 81 per cent of the total geographical area. As per the comprehensive system of classification (soil taxonomy, USDA) the soils of the state come under 4 orders (Table 19), where maximum, soils come under *Inceptisols*, followed by *Alfisols, Entisols* and *Vertisols*. The *Inceptisols* represent older alluvial soils, mixed red and yellow soils. The *Alfisols* represent red soils, laterite and lateritic soils, brown forest soils. The alluvial soils, coastal saline and sand dunes, colluvial soils are represented by *Entisols*. The black soils came under *Vertisols.*

Table 19 Soil taxonomic orders and area under each order

Orders	Area under each order (lakh ha)	% of total geographical area
Inceptisols	74.9	48
Alsifols	56.2	36
Entisols	15.3	10
Vertisols	9.3	6

Acid soils

Acid soils are coarse textured, usually compact at the surface, very low in organic matter content (except brown forest soil), high infiltration rate, lower water holding capacity, high permeability, high bulk density and soil crusting are the physical constraints. Seed germination is badly affected by crust formation resulting in poor plant density. Chemically these soils have (i) low pH, (ii) low CEC (iii) low base saturation (16-67 %), (v) a high Al, Fe and Mn saturation per cent. Nutritionally acid soils are deficient in N, P, Ca, Mg, S, B, Zn, Mo and Si. Biologically acid soils are inactive. The ill effects of acidity is dependent upon land situation and season (Table 20).

Table 20. Severity of soil Acidity problem

Sl. No.	Land type	Season	
		Kharif	Rabi/summer
1.	Upland (47.2 %)	Maximum	Maximum
2.	Medium land (28.4 %)	Moderate	Maximum
3.	Lowland (24.4 %)	No	Minimum

* Data in the parenthesis indicate % of total cultivable area

Saline soil:

Because of salt influence, there is decline in productivity in saline soils, ranging from 10-50 per cent. The direct effect of salts on plant growth are physiological, while the indirect effects are manifested through adverse changes in chemical, physical and microbiological status of soil. The soluble salts lower the soil water potential, restrict water entry, into the plant (reverse osmosis i.e., plasmolysis occur leading to wilting of crop plant). Presence of Na and B in saline soil compete for uptake at root site replacing other essential nutrients causing their deficiency) and exhibiting toxic symptoms for Na and B. High exchangeable Na disperse soil aggregates, dispersed clay clogs, the soil pores, adversely alter the air and water relations of the soil, leading to difficulty in land preparation.

Strip lands:

Land along public roads (5 m, both side) railways, High tensionHT electric transmission lines and canal areas constitute strip land and accounts for 1.15 lakh ha which are not generally cultivated and remain fallow through out the year. During rainy season water hyacinth or their water weeds grow in these areas creating unhealthy environment.

SOLUTIONS (Management of problem soils)

Acid soil

A. Agro-Techniques for acid soil management.

1. **Use of organic and inorganic ameliorant:** Soil application of organic (FYM/VC/Compost) and inorganic ameliorants (PMS @ 0.2 LR) not only neutralize the acidity, but also improve microbial activity, availability of essential nutrients for crop uptake leading towards higher yields (15-85 %).
2. **Use of soil test based fertilizers** : Soil Test based fertilizer application as per the crop requirement integrated with both organic and inorganic sources of ameliorants can influence the yield significantly compared to no fertilizer application.

   The resource poor farmers may go for fertilizer application @ 50 % of soil test dose, integrated with organic (FYM) and inorganic soil ameliorant (PMS) in order to get at par yield with sole inorganic nutrients sources.
3. **Integration of bioinoculation with chemical fertilization:** Rhizobium inoculation of legume seeds is very much essential with seed treatment with Mo @ 4 g Na-Molybdate per 10 kg seed for harnessing atmospheric N_2 of 35-45 kg ha^{-1} and reducing the inorganic N dose (20 kg ha^{-1}) and yield improvement (78 %). Non symbiotic biofertilizers (*Azotobacter, Azospirillum*) and PSM should be applied to soil for non-legume crops after amelioration soil with lime and FYM.
4. **Agro technique for increasing phosphatic fertilizer use efficiency**

   (a) Under strongly acidic soil condition (pH < 5.5) the insoluble P sources be selected for direct use as ground rock phosphate for cost effectiveness and higher use efficiency (35 %).

   (b) Under moderately acidic soil condition (pH 5.6-6.0) the 1:1 mixture of water soluble and insoluble P (RPs) sources be used for better P availability , cost effectiveness and higher crop yield.

   (c) The insoluble low grade (low cost)phosphate rocks should be applied to green manure crop to benefit subsequent rice crop growing without phosphorus application.

   (d) Low cost low grade indigenous rock phosphate be recommended after partial acidulation (25-50 %) with H_2SO_4 for better efficiency under moderately acidic soil condition. Rural youth can be employed to prepare such product or regional basis.

(e) The AM fungi may be inoculated to the crops (@ 6 kg ha^{-1}) fertilized with ground low cost low grade rock phosphate for better efficiency and higher crop yields (16-20 %).

f) Modified or compacted products of P can be prepared out of RP, SSP, MAP and S for cost effectiveness and better efficiency of the products under acid soil condition. **Such practice will generate employment for rural youth**.

f) Use of compost enriched with P-through RP, phosphorus, solubilizing micro-organisms (PSM) and OM decomposing micro-organisms will meet the P requirement of crops with greater P availability under acid soil condition. **Such system will generate employment.**

h) The insoluble P sources should be applied with above techniques to rabi season crop to derive maximum residual benefit by rice crop grown during kharif season in the same field.

5. Agro-techniques for K fertilizer use efficiency.

i) There is negative K balance in soils of Odisha with fertilizer application rate of 62 kg of $N+P_2O_5 + K_2O$ ha^{-1} , which is nearly 30 kg $ha^{-1}year^{-1}$.

ii) Among major nutrients, uptake of K by crops is either same or more than N. Under optimal soil conditions the uptake of N, P, K are 2.0, 0.4 and 2.4 kg per quintal of rice grain.

iii) Blanket recommendation of K (which is still in practice) should be avoided. It should be based on input-output mechanism considering soil variability, fertilizer efficiency, season and crop specificity.

6. Agro-techniques for supplementing S to pulses and oil seed crops grown in acid soils.

The pulses and oil seed crops grown in acid soil deficient in S should be fertilized with 30-45 kg S as gypsum ha^{-1}. For better efficiency half of it should be applied during sowing, another at 15-20 days after sowing but before flowering.

7. Micronutrient management in acid soils

The micro-nutrient requirement of crops mostly for B and Zn be decided after testing of soil.

1. The boron (B) supplementation can be done by applying B as Borax @ 10 kg ha^{-1} applied as basal or twice spray @ 0.25 % as borax at 15 days intervals takes care of boron deficiency.

2. For fruit crops (coconut) mango 50 g borax/tree up to 5 years during June-July, there after 100 g/tree will benefit the crop.

3. Supplementing Zn for rice crop one time application of Zn @ 25 kg $ZnSO_4$ $7H_2O$ ha^{-1} applied to heavy textured soil as basal on in two equal splits in light textured soil increases the crop yield (17 to 28 %)

4. Zinc can also be applied @ 2.5 kg Zn ha^{-1} integrated with green manuring or 100 kg FYM for increased efficiency.

8. Agro-technique for amelioration of physical constraints under acid soil condition with tillage operation.

1. **Operation for reducing crust formation**: Integrated application of FYM @ 5 t ha^{-1} and gypsum @ 1 t ha^{-1} to direct seeded rice, reduces crust formation (27 % increase in seed germination) and 40 per cent increased grain yield compared to conveniently yield of 1.23 t ha^{-1}

2. **Reducing compaction:** Integrating secondary tillage with disc harrow and application of FYM @ 5 t ha^{-1} in upland paddy increased the grain yield by 18 per cent compared to the conventional yield of 1.28 t ha^{-1}.

3. Use of puddler-99 for rainfed transplanted rice increases puddling index, reduces energy requirement, with drogery reduction and increased grain yields, significantly compared to conventional tillage practice.

4. The land management practice like contour bunding or bunding with land levelling increases the seed, yield of mustard (10 and 28 per cent respectively compared to FP yield of 551 kg ha^{-1}).

B. Agro-technique for management of iron toxic soils

The iron toxic soil (0.75 lakh ha) can be managed for profitable crop production with following practices.

5. Growing of iron toxic tolerant rice varieties like Kalinga-III, Lalat, Nabin, Pratikshya. Udayagiri, Panidhan, Tulasi, Konark, Birupa and Mahalaxmi etc.
6. Alternate wetting and drying improves the soil condition.
7. Application of lime to soil @ 0.5 LR as basal.
8. Application of fly ash @ 10 t ha^{-1} as basal.
9. Application of ground rock phosphate @ 80 kg P_2O_5 ha^{-1} as basal.
10. Application of potassium @ 80 kg ha^{-1}in split (1:2:1)
11. Application of Zn @ 10 kg ha^{-1} as basal.
12. Application of calcium silicate @ 2 t ha^{-1} can reduce Fe toxicity problem.
13. Subsurface and surface drainage

All such practices increase the yield of rice by 34 to 103 %

C. Management of saline soils

Some physical, chemical and biological remedial measures have been suggested.

1. Physical: Entry of saline water should be checked in the field by creation of embankment, check dams and providing sluice gates.
2. Scrapping of crystalysed salts by mechanical means from soil surface during summer, then flooding with good quality irrigation water reduces salt concentration for subsequent crop.
3. Summer ploughing to check translocation of ground water salt to surface by evaporation by breaking of capillarity movement..
4. Acid forming inorganic amendments like gypsum/pyrite, and organic sources like tamarind waste, mango leaves and green manure crops like dhanicha and floating fern Azolla, BGA (absorbs sodium) after incorporation produce organic acid and improves the soil condition to sustain higher yield.
5. In saline acidic soil lime/ paper mill sludge (PMS) can be used to neutralise the acidity.
6. Saline soil resistant rice varieties (SR 26-B, Getu, Lunishree) and other crops (sweet potato, cabbage, beat etc.) tolerant to salinity should be grown.
7. Plantation crops like coconut should be grown in salt affected areas.

D) Water logged soils.

For management of water logged soils following measures can be adopted.

1. Improving the knowledge of farmers regarding crop water use.
2. Improving drainage facility of the land.
3. Checking the leakage by cementing the inner lyning of canals for checking water loss, restricting fertile lands converting into water logged areas..
4. Growing of crops suitable for water logging condition, like water chestnut, paragrass as fodder/Kalami (*Ipomea* spp.) as green/ Azolla for cattle feed, composting and manuring
5. Integrated farming like rice-fish etc should be adopted looking at the condition.
6. Shunken and raised bed system of cultivation should be adopted for growing of paddy in shunken beds and vegetable and other commercial crops in the raised beds..

E) Mine spoil/waste soil

Three remedial measures suggested for the purpose.

1. Nitrogen fixing quick growing legume tree species suitable to local situation is generally recommended for plantation(*Casuarina equisetifolia* and *Leucaena lucocephala*, *Acacia nilotica*).
2. Mycorrhizae inoculation of crops helps in establishment of the tree species by facilitating water, nutrients, where the roots can not reach.
3. Ameliorative measures (chemical) can also be taken up based on nature of the mine spoils (particularly lime/gypsum are used).

Sand dune soil

14. Sand dune soils can be stabilized by planting with plantation crops like casuarina , cashewnut and coconut etc with application of mycorrhizae and other biofertilizers.
15. Caoder can also be grown under sand dune condition having industrial value for preparationof perfumes, scents etc.
16. Beetlevine crop can also taken up as commercial crop.

Strip lands

17. Social forestry can be practised with the help of unemployed youth or local inhabitants.
18. Under water logged condition pisciculture, prawn culture/water chestnut/sunsunia/ Kalami green, Azolla can be taken up successfully as multipurpose crop (food, greens, fodder and manure purpose).

Increasing soil organic reserve for better soil health

1. Application of FYM/Compsost/ Vermicompost/Enriched compost should be done after each crop to supplement the mineralization loss incurred during growing of previous crop and to create better growing environment for inoculated microbes and to improve soil physico-chemical condition.
2. Organic sources be incorporated into thesoil on the day of application insteadof broadcasting long before sowing with proper moisture.
3. Attempt should be made to recycle the crop residues as far as possible.
4. Instead of burning the crop residues these are to be incorporated in to the soil in order to increase organic reserve, stimulating microbial activity, returning.

5. Government need to encourage for the preparation of manures/ compost in rural areas involving unemployed youth.
    1. Marketing facility need to be created for sale of the products.
    1. Government of India spending huge amount of money on fertilizer subsidy, a portion of it can be used for production of manures utilising wastes generated locally which will keep the rural environment clean.
6. Green manuring or partial green manuring (after harvest of fruits) should be practised sincerely wherever applicable.

INM approach for enhanced crop yield, better soil health and increasing nutrient recovery.

1. Integration of organic source of nutrients to supplement 25 per cent inorganic N, with 75 per cent inorganic N has been observed to be the best combination for most of the crops grown in the state
2. The organic sources need to be applied as basal and the inorganic source in split doses as per the crop requirement to increase the use efficiency, nutrient recovery and crop yield with positive soil balance.
3. Integration of bioinoculation (Azot. Azs., PSM and AM) with recommended dose of fertilizers not only influence the yield of crops (ranging from 10 to 50 %) but also the crop quality (lycopene in tomato, ascorbic acid in chilli, β-carotine in watermelon total soluble solids, sweetness and latex content in papaya.
4. The bioinoculants available, in liquid or solid form need to be inoculated to well decomposed FYM/VC (treated with 5-10 % lime) in 1:25 ratio, incubated at 30 per cent moisture for 7 days increases the population of inoculated microbs by 10-18 times and help them to establish in the field conditions and influence the crop yield significantly.
5. Use of bioinoculants (*Azot, Azs, PSB*) under fertile soil condition (medium to high organic matter , good supply of P, Ca, K, S , Mo etc.) performs better than unfertile condition, hence should be included in package of practice of individual crop.
6. However, *Rhizobium* inoculation of crop performs better under N-stress condition with good supply of P, K, Ca, S and Mo, hence inorganic source of N need to be reduced for leguminous crops to derive benefit of rhizobium inoculation..

Increasing efficiency of chemical fertilizers

1. Application of right type of fertilizers, with right dose at right time and right method increases the efficiency of synthetic fertilizers, hence due attention be given for individual crops.
2. Multinutrient complex fertilizers should be preferred over straight fertilizer particularly for basal application for increased efficiency.
3. Fertilizer application be made, based on soil test and crop requirement.
4. Combined application of FYM or any other organics and chemical fertilizers increases the fertilizer use efficiency by the target crop.
5. Need based fertilizer application should be given more emphasis.
6. Under ameliorated soil condition (lime in acid soil) the use efficiency of chemical fertilizers increases (15-27 %).

Soil fertility status in the state

Nitrogen

Generally soils of Odisha are low in total N (520-2360 kg ha^{-1}). The N deficiency is severe in soils with coarse texture and low in organic matter content. It is more in virgin soil then cultivated soil (Table 20). There was indication that the status of organic carbon (organic matter) in laterite soil with rice-rice cropping system, increased significantly after 18 years of cultivation with 36 rice crops compared to control (without external source of nutrients), irrespective of the inorganic or integrated treatments. It was more reflected in organic (FYM @ 10 t ha^{-1}) and inorganic (100 % NPK) integrated treatment, where both quantity and quality of OM (active carbon and carbon of microbial origin) were high (Pattanayak, 1992, Table 21) emphasizing the need of INM for soil health maintenance in building up of carbon in soil.

Table 20 Organic carbon and soil total N contents of some of the soils of Odisha.

Soil order	Organic carbon (g kg^{-1} soil)		Total N (mg kg^{-1} soil)	
	Virgin	Cultivated	Virgin	Cultivated
Alfisols	2.5-13.9	3.5-10.7	260-1180	350-930
Vertisols	3.7-16.2	3.8-6.3	410-1120	420-630
Inceptisols	3.7-8.2	3.6-5.5	420-600	300-550
Entisols	2.7-8.5	2.8-6.5	290-1020	310-740

Table 21 Quantity and quality of organic carbon in soils with rice-rice cropping system in laterite soil after 36 rice crops

Treatments	Carbon (mg/100g)		
	Organic	Active	Microbial

Fallow	1260	320	13.0
Control	760	170	15.0
100 % N	710	130	13.3
100 % NP	880	200	14.6
100 % NPK	810	170	23.7
100 % NPK + FYM	1170	325	27.0
Initial	730	160	14.3

Recent report of STCR project (2011-12), OUAT with GPS based sampling in 9 agriculturally important districts of Odisha for soil fertility maping indicated that there is build up of organic carbon index values from a level of 1.43-low (Mitra *et al.*, 2002) to 2.28-medium (Table 22) in the soils of nine districts (Puri, Khurda, Cuttack, Nayagarh, Dhenkanal, Bhadrak, Baleswar, Sambalpur and Angul). In spite of increasing trend in organic carbon content in the soils of nine districts, the available N in the soils were categorized under low category. For better management of N in these soils and for fertilizer N prescription they grouped the available N in these soils to four categories : namely : (i) < 100 kg N ha^{-1}, (ii) 100-150 kg ha^{-1}, (iii) 150-250 kg ha^{-1} and (iv) > 250 kg ha^{-1} and 5.2, 37.0, 36.2 and 10.2 per cent samples were in these category respectively and obtained positive significant responses for different crops grown in these soils.

Table 22. Organic carbon status in soil in 09 districts in the state of Odisha

Sl. No.	Content in soil (g kg^{-1} soil)	Average per cent of soils in 9 districts under different category	Index value	
			2011-12	2002
1	<2.5	7.2		
2	2.5-5.0	23.5	2.28	1.43
3	5.0-7.5	31.8	Medium	(low)
4	>7.5	26.2		

Phosphorus

Soils of Odisha are generally low (27 per cent) to medium (73 per cent) in status. Most of the red and laterite soils of the state covering 50 % area are low in available P (Bray's-1P: 1.3-5.9 mg kg^{-1} soil), although their total P_2O_5 content is adequate (0.08-0.35 %).The inorganic P fractions generally dominant over the organic fractions and are mostly *variscite* and *strengite*. The 53 to 90 per cent of added P is recovered as inorganic phosphate, a large percentage as Al-and Fe-phosphate. As the majority of soils (70 per cent) in the state is acidic, there is tendency of fixing 80-90 per cent of the added P, hence the crop use efficiency is <25 per cent (Pattanayak and Misra, 1989).

Application of P continuously for 18 years to 36 rice crops indicated that there was build up of P in soil, more with balanced and integrated practices, then unbalanced and unintegrated one, emphasizing the importance of soil testing before cropping for judicious and efficient P management (Pattanayak, 1992). However, recent P management practice in the state as determined in nine agriculturally important districts indicated that the P index value decreased from a level of 1.75 (Mitra *et al.*, 2002) to 1.38 (Mishra and Das,2012), may be due to less use of P fertilizers due to P price hike in recent past years.

Potassium

The majority of soils in the state (86 per cent) are medium in status, only 7 per cent is categorized as high (Agronica). The *orthoclase feldspar* and *micas* dominant in sand and silt fractions and *illite* in the clay fraction which release K for crop availability. The dominant crop in the state is rice. It is a heavy feeder of K, sometimes equals or higher than that of N. Results of long term experiment (18 years) with rice-rice cropping system indicated that irrespective of its application, there was depletion of K status in soil (Pattanayak, 1992). Due to recharge of K from sub-soils layer during summer season, there was supplementation of K for crop removal (Sahu, 1997). The unbalanced K management in the soil for crop production accounted for an annual negative balance of 29.2 kg ha^{-1} $annum^{-1}$ (Misra and Mitra, 2001).

The decreasing trend in K availability in soils has also been reported from nine agriculturally important districts, where the K index value of 1.90 (Mitra *et al.*, 2001) had decreased to a lower index value of 1.63 (Mishra and Das, 2011-12) indicating imbalanced K use in Odisha agriculture.

Calcium and magnesium

Even though Ca is the dominant cation in soil. Its deficiency is observed in strongly acidic coarse textured soils in the state. Generally the soils of Khurda, Mayurbhanj, Sundargarh, Koraput and Dhenkanal districts exhibit Ca, deficiency in soil containing < 1.5 cmol ca^{2+} kg^{-1} soil. Crop removal of Ca leaching loss due to high precipitation without supplementation, addition of acid forming fertilizers accelerate its depletion in soil.

The ground nut crop grown in the state is more affected by the Ca deficiency, causing chaffiness in pods, reducing pod yield. Its supplementation has been made through liming of acid soils with paper mill sludge (PMS). The availability of PMS has been made subsidized by the Government.

The deficiency of Mg is sporadic and confined to coarse textured acid soils in the state measuring < 1 cmol mg^{2+} kg^{-1} soil. Its supplementation has been made successfully through liming programme (dolomitic lime stone). Recently use of double salt source K_2SO_4 and $MgSO_4$ (*Patent Kali*) for oilseed crops sunflower and groundnut has been made. The coconut crop in the state also respond better to Mg application..

Sulphur

The sulphur is the 4th major essential nutrient to be deficient in Odisha soils next to the N, P and K. Its deficiency range from 7 to 98 per cent in soils of different districts. The average is near to 30 per cent. Out of 30 districts, 16 districts are having more than 50 per cent S deficient soils. Intensive cropping with the use of S free fertilizer (diammonium phosphate-DAP), insufficient use of organics have led to S deficiency in soil. The Government of Odisha, Department of Agriculture has made gypsum application mandatory for oil seed cultivation (mostly for groundnut) in the state and subsidized the price of gypsum to Rs.25/- for 50 kg bag. The oil seed growers use it and get benefit out of it. Further, awareness has to be created for use of other sources of sulphur particularly complex and fertilizer to other crops also.

The recent research result of AINP on Biodiversity Biofertilizers , OUAT, Bhubaneswar indicate that sulphur nutrition of pulse crop horsegram a potential residual residual pulse crop of the state is very much essential (15 kg S as gypsum mixed with FYM), since it limits biological N_2 fixation activity in terms of nodule number, nodule weight, nodule N concentration and ultimately the seed yield. Supplementing sulphur through gypsum @ 15 kg ha^{-1} added with FYM 3 t ha^{-1}yielded 1280 kg ha^{-1}, 3.3 times higher seed yield of 385 kg ha^{-1} (state average, Pattanayak, 2012-13).

Boron

Among the micronutrients boron deficiency in soil is wide spread. The hot water extractable B in more than 12000 sample collected all over 30 districts ranged from 0.18 to 5.1 mg kg soil, where 0.5 mg kg^{-1} soil is critical (Jena *et al.*, 2008) . Out of 30 districts, 13 districts had B deficiency ranging from 50 to 89 per cent samples collected, in 14 districts the deficiency ranged from 11 to 48 per cent samples. Only in three districts the extent of B deficiency ranged from 4.4 to 9.0 per cent. The coarse textured red, laterite, mixed red and yellow soils are prone to B deficiency in the state. The saline soils are generally sufficient in B. Intensively cultivated soils (acid *Inceptisols*) with two crops of rice per annum continuously for 18 years without boron nutrition exhibited its deficiency irrespective of balanced or unbalanced application of inorganic fertilizers (Pattanayak, 1992). Wide deficiency of B is exhibited in rice-groundnut, rice-vegetable cropping systems in the state. Nut drop and cracking of nuts of coconut at early stage, cracking of fruits, vegetables, hollow pith in cauliflower and raddish are common symptoms of B deficiency in the state which warrants its judicious application.

Zinc

The irrigated command areas of the state with rice-rice cropping systems mostly exhibit the Zn deficiency. Analysis of over 18,000 samples covering 30 districts in the state, the DTPA extractable Zn in soil ranged from 0.24 to 2.08 mg kg^{-1} Zn where 0.6 mg kg^{-1} soil is considered as critical (Jena *et al.*, 2008, Pal and Jena, 2011-12). The extent of deficiency range from 0-76 per cent, with a mean of 19 per cent. The Sambalpur and Bolangir district soils were more deficient in Zn, where 65 and 75 per cent soils were deficient respectively. Besides these two districts, in 7 districts the extent of Zn deficiency range from 32 to 43 per cent (Angul, Jajpur, Balasore, Keonjhar, Deogarh, Kalahandi, Bhadrak), in 10 districts the deficiency range from 10 to 22 per cent (Kendrapada, Jharsuguda, Khurda, Gajapati, Mayurbhanj, Nuwpada, Boudh, Subarnapur, Jagatsinghpur, and Rayagada) and in rest of the districts <10 per cent soils are Zn deficient.

In long term experiments with rice-rice cropping system, for 18 years (36 rice crops) the Zn status in soil decreased (Pattanayak, 1992) from initial level of 0.86 mg kg^{-1} soil to 0.34 to 0.59 mg kg ha^{-1}, where it was not applied from external source, but there was build up of the status in the soil receiving FYM @ 10 t ha^{-1} $annum^{-1}$ (1.37 mg kg^{-1}) and Zn fertilization @ 25 kg ha^{-1} as $ZnSO_4$ $7H_2O$ (3.90 mg kg^{-1} soil).

The Zn deficiency is not only affecting the rice productivity but also the vegetables, fruits, oilseed and pulse crops productivity in the state. Its application @ 25 kg ha^{-1} or half the dose as basal and one or two sprayings of Zn-EDTA @ 0.2 per cent for vegetables have been recommended.

Copper

Considering 0.2 mg kg^{-1} soil DTPA extractable Cu to be critical limit, it is not deficient in the soils of Odisha. It ranged from 0.15 to 11.1 mg kg^{-1} soil. The deficiency range from 1 to 12 per cent, minimum in the soils of Mayurbhanj and maximum in Kendrapada. Out of 30 districts only deficiency to the extent of 2 to 8 per cent confined to 10 districts, and in rest of the districts no deficiency.

Iron and Manganese

The DTPA extractable Fe and Mn content in the soils of the state ranged from 1.5 to 415 and from 2.3 to 295 mg kg^{-1} soil respectively. The criticalconcentrations in both the cases are 4.5 and 2.0 mg kg^{-1} soil respectively. In non of the districts the deficiency of Fe and Mn exceeded 10 per cent soils tested. The soil availability of both the micronutrients were adequate.

Cultivation continuously for 18 years with two crops of rice crops without external addition of Fe and Mn resulted in increase in Fe content in soil, whereas Mn content in soil decreased compared to initial status (Pattanayak, 1992).

Molybdenum

Its content in soil range from 0.01 to 0.22 mg kg^{-1} in the state. The response to Mo application has been realized in acid soils which are generally deficient in Mo. Response of Mo application to legume crops as seed treatment @ 10 g sodium molybdate per 25 kg seed has been recommended for better N_2 fixation (higher N with higher leg-hemoglobin) and yield increase (Pattanayak *et al.*, 2000). Similarly Mo application to cole crops have been recommended at the time of nursery raising or to the main field @ 500 g ammonium molybdate ha^{-1}mixed with single sulphur phosphate or spraying the crop with 0.01 per cent ammonium molybdate as foliar spray to supplement Mo requirement of the crop for quality produce (Sahu, 1999).

Iron toxicity

In Odisha, 0.75 lakh hectare wet land rice suffers iron toxicity. Such toxicity occurs in hill bottom red and laterite soils located adjacent to up lands under undulating topography due to lateral flow of soluble ferrous iron. This also occurs under impeded drainage condition. These are base unsaturated soils deficient in K, Ca, P, Mg, Zn and Cu. Iron toxic symptoms are seen in rice leaves which turn orange red/bronze colour when the concentration of Fe^{2+} ion in soil solution reaches a level of 250-500 mg kg^{-1} soil during submergence. Upon oxidation of Fe^{2+} to Fe^{3+} ion, it get deposited on the root surface imparting deep red colouration, stunted root growth with restricted uptake of other essential nutrients. Ultimately reduce the rice yield to the extent of 50-80 per cent (Mitra *et al.*, 1990).

Fertilizer consumption

The agriculture in the state (2011-12) utilized N-P_2O_5-K_2O of 323404, 135483 and 55800 Mt with a total of 514687 MT (Table 23). The per hectare consumption was 62.25 kg below the national average. The *kharif* season average consumption was 2.17 times more than *rabi* season consumption. The major nutrients were used in the ratio of 5.8:2.4:1 slightly deviated from the balance ratio of 4:2:1. This indicate that utilization of K was not proportionate.

Compared to earlier year (2010) the total fertilizer consumption during 2011 was less (Table 23). During 2010 fertilizer consumption was higher by 4.5 per cent than 2011. As the gross cropped area was higher during 2010 than 2011, the per hectare fertilizers consumption almost remained same, without decrease.

The per hectare fertilizers consumption in the state varied widely between 7.3 and 175.48 kg ha^{-1}, lowest in Phulbani and highest in Nabarangapur. The fertilizers consumption in five districts (Nabarangapur, Sambalpur, Baragarh, Bhadrak and Baleswar) were more ranging from 175.48 to 117.4 kg ha^{-1}. Fertilizer consumption in 9 districts were more than 50 kg but < 100 kg ha^{-1}. In rest of the districts it varied between 7.3 and 49.45 kg ha^{-1}.

Table 13 Comparative fertilizer consumption figures , 2010-2011

Year	Total nutrient (MT)						Total cropped area (000 ha)	Per hectare consumption (kg ha^{-1})
	Kharif	Rabi	Kharif + rabi					
			N	P_2O_5	K_2O	Total		
2010	384285	153565	294722 (3.3)	153970 (1.7)	89158 (1)	737850	8557.66	62.85
2011	352565	162122	323404 (5.7)	135483 (2.4)	55800 (1)	514687	5267.75	62.25

Data in the parenthesis indicate consumption ratios

Table 24 Comparison of per hectare average nutrient consumption in the state

Nutrient kg ha^{-1}	Nutrients kg ha^{-1}		Consumption ratio	
	2010	2011	2010	2011
N	34.4	39.1	3.3	5.7
P_2O_5	18.0	16.4	1.7	2.4
K_2O	10.4	6.8	1.0	1.0
Total	62.8	62.3		

Due to price hike of potassic and phosphatic fertilizers, these fertilizers were not available to the farmers during 2011 as a result there was deviation in the consumption ratio compared to the year 2010. (Table 24). This has been reflected in food grains production also (Table 25).

Table 25 Comparative figures for the production of different commodities

Crop	Production (000, MT)		
	2010-11	**2011-12**	**Balance**
Total cereal	7770.49	6695.24	(-) 1075.25
Total pulse	999.38	920.89	(-)78.49
Total food grain	8769.87	7616.13	(-)1157.74
Total oilseed	638.01	663.69	(-)25.68
Total Vegetable	9027.74	9515.15	(+) 487.41
Total Spices	456.80	477.31	(+)20.51
Other crops	2909.34	2790.00	(-)119.34

Nutrient removal by crops and the balance sheet

Table 26 Fertilizer consumption, nutrient removal and balance (2011-12)

Nutrients	Consumption		Removal		Balance	
	(000,t)	**kg ha^{-1}**	**(000,t)**	**kg ha^{-1}**	**(000,t)**	**kg ha^{-1}**
N	323.4	39.1	290.0	35.0	(+)33.4	(+)4.1
P_2O_5	135.4	16.3	133.0	16.4	(+)1.6	(-) 0.1
K_2O	55.8	6.8	365.0	44.2	(-)309.2	(-)37.4
Total	514.2	62.2	788.0	95.3	(-)274.2	(-)33.1

For the production of varieties of crops (Table 25) in the state altogether 514.1, 000 tonnes of chemical fertilizers have been used (Table 26). For unit (ha) cultivated area 39.1, 16.3 and 6.8 kg of N-P_2O_5-K_2O with a total of 62.2 kg ha^{-1} have been used. In order to produce different crops, 788,000 tonnes of N + P_2O_5 + K_2O have been removed (Table 26). The per hectare removal N-P_2O_5-K_2O ha^{-1} comes to 35.0, 16.4 and 44.2 kg with a total of 95.3 kg ha^{-1}. The balance sheet of fertilizers, consumption is positive for N (+33.4,000 t) and P (+1.6, 000t) but seriously negative for K (-309.2,000t). The extent of nutrient mining was huge for K. The state is using 274.2, 000 tonnes of less chemical fertilizers for present level of production. The balance sheet for individual nutrient per hectare basis was positive for N (+4.1 kg ha^{-1}) slightly negative for P (-0.1 kg ha^{-1}) and seriously negative for K (-37.4 kg ha^{-1}). This indicate that with present level of crop production and nutrient management practices every year we are mining 37.4 kg of K from each hectare of cultivable land, which was 29.2 kg ha^{-1} during 2011 (Misra and Mitra, 2001). This warrants judicious and balanced management of nutrients based on crop need and soil testing.

Farming system

Farming system is the scientific integration of different inter-department and interacting farm enterprises for the efficient use of land, labour and other resources of a farm family which provides year round income to the farmers.

The 86.3 per cent of farmers in the state are small and marginal category. The income from cropping alone is hardly sufficient to sustain the farmers family. For a decent living, the assured and regular income source for the farmers of the state is farming system approach, which has been experimented by the university and demonstrated across the state. A pond based farming system model has been accepted as profitable one (Table __) where the rupee return per rupee investment range from 1.11 to 7.94 with average of 2.18.

Table A pond based farming system model on 1.25 ha farm land.

Components	Employment generation (man days)	Return/ rupee invested (Rs.)
Field crops	98	2.70
Multistoried cropping	88	3.37
Pomology	18	2.63
Olericulture	96	3.18
Floriculture	4	1.80
Pisciculture	31	5.46
Poultry	23	1.11
Duckery	23	1.13
Mushroom	180	1.70
Apiary	1	7.94
Biogas	11	3.38
Total	573	2.18

Organic farming

Even though traditional agriculture was predominately organic in nature, increasing food demand compailed to use the modern organic inputs. The result was positive with respect to use the food production but negative for its ill influences on the environment (due to injudicious improper and excessive use of agro-inputs). The Atlanta conference of 1981 on organic farming have acted as catalysts on triggering interest of organic farming.

Organic agriculture movement is based on 4 principle (i) Principle of health, (ii) Ecology, (ii) Ecology, (iv) Fairness and (v) Cares. Organic agriculture sustain and enhance the health of soil, plant, animal, human and plant as one and individual. It deals with living ecological system and cycles, with them, emulate them and help them to sustain. It ensures fairness with regard to common environment and life opportunities. It is managed in a precautionary and responsible manner to protect the health and wellbeing of current and future generations and the environment.

Considering all these boundaries of the organic system, there are some pockets in the state of Odisha which are organic by default. These areas are confined to tribal community, tribal districts, under exploited areas and disadvantaged areas. However, consciousness has been developed in the last decade in favour of the movement. As a result of this few private sector farms have come up with Bivekananda Mission, Badachana, Biswanahakani, Jajpur for organic vegetable, Keonjhar for organic mango, Kandhamal turmeric, Ginger, Koraput for Kusumi oil. Many of such practices have come up with the use of vermicompost vz. Leaf litter manuring, green manuring and green leaf manuring, biofertilizers etc. There is limitation for use as basic __ no RP deposits are available. It has limitations on use of S and K seen weed will be in alternate sample to came outside. For the scope of organic farming in the state is not open for all crops. It is restricted to few fruits, (pineapple, mango, custard apple, Bel, banana) spices (turmeric, ginger) scented rice, ragi, millets, kusumi, safflower and floriculture crops.

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RESOURCE MANAGEMENT FOR IMPROVING AGRICULTURE IN WEST BENGAL

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Introduction:

The state West Bengal is between 21°31'-27°14'N latitude and 85°53'-85°53'E longitude. The total geographical area of West Bengal is about 8.87 million hectares. There are 19 districts in the state including Kolkata. About 75% of the present population of the total populations lives in the villages. The state has to support about 8 percent of India's population with only 2.7 percent of the area. Because of tremendous population pressure on the land resources and about 65 percent of geographical area has been brought under cultivation running the risk of ecological imbalances due to excessive loss of land resources. Agriculturally, West Bengal is a highly potential state as it is blessed numerous water sources and a large area of alluvial region. The land use pattern in West Bengal may be broadly grouped into four categories , namely i) net sown area for agriculture purposes, ii) non-agricultural use, iii) forest lands and iv) fallow lands. The percentage of net-cropped area to cultivable area is 73.35%. Only 16.53 % of the net-cropped area is under multi crop cultivation. 90% of the net-cropped area is under Aman paddy cultivation Cropping Intensity is 117%. About 60 % of the total cultivated land is upland. On the other hand out of the total operational holding 72.68 % belongs to small and marginal farmers (92 % of the total no. of holding) having scattered and fragmented small holdings.

The state of West Bengal comprises of two natural divisions. They are the Himalayan north comprising the districts of Darjeeling, Jalpaiguri and Cooch Behar and the alluvial plain that lies south of and the southern part is a thickly populated level expanse of rice fields dotted with mango, coconut and banana gardens. This vast alluvial plain is the handiwork of many big rivers the chief among them are the Bhagirathi and its tributaries the Mayuraskshi, the Damodar, the Kangsabati, and the Rupnarayan. The Bhagirathi, called Hooghly in its lower reaches is itself a branch of the Ganga and provides Calcutta its link with the sea.

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Agro-Climatic Conditions:

On the basis of agro-climatic conditions, the state has been broadly divided into 6 regions such as (1). Hill regions, (2). Tarai & Teesta alluvial regions, (3). Red, laterite and gravelly undulating regions (4). Gangetic alluvial regions, (5) Vindhya alluvial regions (6). Coastal regions

1. Hill region

This region which is lying in the northern part of the state comprises of the district of Darjeeling excluding Siliguri sub'-division and northern fringe of Jalpaiguri district. The altitude varies from 60 m in the foot hill region to 3700 m above sea level. The rivers namely Teesta, Torsha, Jaldhaka, Mahananda etc. originating from the Himalayas flow through this region towards south-east.

2. Tarai and Teesta alluvial region

This region consists of alluvial plain of Jalpaiguri, Cooch Behar, Siliguri sub-division of Darjeeling district and Islampur sub-division of West Dinajpur. These plains are formed by rivers Teesta, Torsha, Jaldhaka, Mahananda and others. This region is chronically flood prone areas, where about 20% of the lands are subjected to inundation annually. Coarse sands are deposited on the cultivated lands making it almost barren for the next few years. These floods cause loss of crores of rupees annually.

3. Red, laterite and gravelly undulating region

This region which lies in the southern part of the state comprises of western part of Birbhum, Burdwan, Bankura and Midnapur districts and entire Purlllia district. The area is undulated with ridges and valleys which represent the eastern fringe of the Vindhyan ranges and are characterized by the presence of low hills like Ajodhya, Susunia and others. The altitude varies from 6 to 600 m above mean sea level. Seasonal rivers namely Kangsabati, Ajoy, Damodar, Silabati, Mayurakshi flow through this region towards south. east and ultimately discharge into the river Ganges.

4. **Gangetic alluvial regions**

This is non -saline recent alluvial region mostly in the north and eastern part of the river Ganges comprising of Nadia, part of Malda, Uttar and Dakshin Dinajpur, Murshidabad, Burdwan, Hooghly, and 24-Paraganas districts. Topography is flat with number of basins where drainage is extremely difficult causing perpetual problem. A considerable area is subjected to inundation due to river overflow and poor drainage condition.

5. Vindhya alluvial regions

This region is centrally located, composing of western part of Murshidabad, eastern part of Birbhum and Bankura, western part of Hooghly, central part of Bardhaman, Midnapur and northern part of Howarh. The soils are formed from deposits brought down mostly by river Mayurakshi, Ajoy, Damodar, Kangsabati and other river originating from eastern fringe of the Vindhyan ranges. A considerable area is subjected to flood annually, caused by impeded drainage and river overflow during rainy season.

6. Coastal region

The Southern portion of 24-paraganas; Howmah and Midnapur constitutes the coastal region of the state which includes numerous islands. Deposits from tidal currents in the estuary region results into formation of a cluster of islands.The area is criss-crossed by numerous rivers, the rivulets and natural creeks which are highly active due to tidal action. The vast mangrove forest known as the "Sundarbans" lie in this region covering an area of 4300 square kilometers.

WEST BENGAL : AN OVERVIEW

Population (2001 census)	:	8.78 Crore (1st October, 2010) expected
Population Density	:	903 / Sq. Km
No. of Agriculture Districts	:	18
Nos. of Mouza / Village	:	40782
Geographical Area	:	88752 Sq. Km
Agro-Climatic Zones	:	6 Nos.
Cultivable Area	:	8686639 ha
Net Area Sown	:	52.94 lakh ha.
Gross Cropped Area	:	98.015 lakh ha
Area under non-agriculture used	:	17.92 lakh ha
Forest Area	:	11.73 lakh ha
Current fallows	:	2.87 lakh ha
Cultivable Waste land	:	0.316 lakh ha
Barren and un-culturable land	:	0.211 lakh ha
Permanent posture and other grazing land	:	0.0719 lakh ha
Irrigated area	:	62 % of Net cropped Area
Total Nos. of Agricultural Holdings	:	6953922 Nos.
Size of average land holding	:	0.82 ha/ holding
Cropping Intensity	:	185 %

Climate:

June to September are the rainy months in the state. The average annual rainfall varies from 2500 -3500 mm in hill region of north, 2000 -3500 mm in Tarai and Teesta alluvial, 1100 -1300 mm in red, laterite and gravelly region, 1300 - 1600 mm in Gangetic alluvial, 1200 -1500 mm in Vindhya alluvial and 1500 -1700 mm in coastal alluvial regions. The minimum temperature goes even below O^{o}C in winter in hill region of north and is as high as 46^{o}C summer in red laterite and gravelly undulating region. Maximum temperature during summer is 24°, 38°, and 37°C in north hill, Gangetic alluvial and Vindhya alluvial regions respectively. The temperature during winter is as low as 7.9°C in red, laterite and gravelly undulating region. In Gangetic region temperature during winter varies between 40 to 26° Centigrades.The climatic conditions of Purulia, Bankura, West Midnapore, Western part of Bardhamnan and Birbhum districts in particular are drought prone area. These districts has sub-tropical climate and are characterized by high evaporation and low precipitation. Temperature is very high in summer and low in winter and it varies from 3.8^{o}C in winter to 52^{o}C in summer, causing dryness in moisture. Average annual rainfall varies between 1100 and 1500 mm. But uneven, scanty and erratic rainfall results agricultural drought in the *Kharif* season.

Progress of Agriculture Production in West Bengal (1975-76 to 2009-10)

Crop	1975-76		2009-10		Percentage increase
	Production (lakh ton)	Production growth index	Production (lakh ton)	Production growth index	
Rice	68.66	100	148.65	216	116
Food Grain	85.91	100	168.26	190	90
Oilseeds	0.78	100	7.13	914	81.4
Potato	16.15	100	95.00	588	488
Jute	26.86	100	93.26	347	247

Annual Growth rate of rice, food grain and populations in West Bengal (1970-71 to 2008-09)

Year	Population Growth	Production of growth rate (%)

	rate (%)	Rice	Food grains
1970-71 to 1980-81	2.11	1.33	0.97
1980-81 to 1990-91	2.23	6.39	5.80
1990-91 to 2000-01	1.71	1.93	2.07
2000-01 to 2008-09	1.78	1.16	1.04

Adverse effects of modern high- input agriculture on NRM

1. Overuse of natural resources, causing depletion of groundwater, and loss of forests, wild habitats, and of their capacity to absorb water, causing water logging and increased salinity
2. Contamination of the atmosphere by ammonia, nitrous oxide, methane and the products of burning, which play a role in ozone depletion, global warming and atmospheric pollution
3. Contamination of food and fodder by residues of pesticides, nitrates and antibiotics.

4. Contamination of water by pesticides, nitrates, soil and livestock water, causing harm to wildlife, disruption of ecosystems and possible health problems in drinking water
5. Build up of resistance to pesticides in pests and diseases including herbicide resistance in weeds
6. Damage of farm and natural resources by pesticides, causing harm to farm workers and public, disruption of ecosystems and harm to wildlife.
7. Erosion of genetic diversity – the tendency in agriculture to standardize and specialize by focusing on modern varieties, causing the displacement of traditional varieties and breeds
8. New health hazards for workers in the agrochemical and food processing industries.

Added to the above adverse effects, the increasing human as well as cattle population is imposing intense pressure on available natural resources. Accordingly, a challenge has emerged that required a new vision, holistic approaches for ecosystem management and renewed partnership between science and society.

Soil and water are most important and principal natural resources for sustaining living beings and their environment. Soil resource is essential for the production of food, fodder, fuel and feed to meet the requirement of human beings and animals. Water resource in West Bengal is a great concern due to increased demand from agricultural, domestic and industrial sectors in recent past.

The state of West Bengal is located in the east region of India and it is very rich in natural and mineral resources. Apart from natural resources West Bengal also has appropriate agro-climatic conditions apt for agriculture, fisheries and horticulture. West Bengal also has backwoods of certain Indian states that are rich minerals such as Bihar, Odisha and Jharkhand. The forest region in this state has a lot of medicinal plants and herbs. This Indian state has plentiful mineral resources as well and it stands on third position when it comes to mineral production of India and it extends one-fifth out of the entire mineral production of India.

The Ganges is the only perennial river in West Bengal that divides in to two – one branch enters Bangladesh in the name of Padma and the other branch flows in the state in the name of river Bhagirathi and river Hooghly. The northern hilly region has rivers like Teesta, Torsa, Jaldhaka, Mahananda, while the western plateau region has rivers like Damodar, Ajay, and Kansai etc. The Ganges delta including the Sundarbans area is full ofrivers; creeks cover the region like a web. The mineral that is extracted in the highest quantity happens to be coal and it constitutes around 99 percent of the entire lot of minerals extracted from West Bengal. Some of the other minerals that are drew out but only in little quantities are limestone, china clay, iron, copper, wolfram, road metal, quartz, dolomite, rock phosphate, manganese and granite. There are optimum chances of getting natural gas plus mineral oil in the portions near to the Bay of Bengal specifically in Sundarbans, East Midnapore, South 24 Paraganas and the North Bengal plains.

Soil resources

The soils of West Bengal is divided into different categories. They are as follows, (1). Brown forest & Hill soils, (2).Tarai and Teesta alluvial soils, (3).Red and Laterite (4). Gravelly soils, (5). Gangetic alluvial soils, (6).Vindhyan alluvial soils and (7).Coastal soils.

Soil of the eastern part of the Bardhaman district of the area is extremely fertile. Climate and rainfall of the area is favorable for cultivation. The land in the Western Part in general is known to be acid-red laterite uplands and same parts are exposed as story-wastes’ dotted with hills and mounds of low height. Net cropped area of the district is 4.57 lakh hectares and the cropping intensity is 165.

The district of Bankura is included in the Bardhaman division of West Bengal. It is bounded on the north and a part of north-east by the district of Bardhaman from which it is separated by the natural barrier of the Damodar river. The south-east of the district is bounded, over a small distance, by the district of Hooghly, while along the entire southern and western boundaries of Bankura lie respectively the districts of Medinipur and Purulia. High Hilly Region / Hard rock area :- The region consists of the areas like Saltora, Mejia, Khatra, Ranibandh, Gangajalghati etc. covering 176915 hec. Most of these parts don't have the irrigation facility and full of grits. Uneven Lands / Hard rock ring area :- These lands are also grity but irrigated covering 150611 hec..This region consists of the areas like Bankura, Barjora, Chatna, Onda, Simlapal, Taldangra, Raipur, Sarenga etc. Alluvial Lands / Alluvial area :- This type of land includes the areas like Bishnupur, Sonamukhi, Patrasayer, Indus, Joypur, Kotolpur etc. covering 56970 ha. The drought prone area shares the area of 118370 hec., the hilly area stretches over a part of 21432 hec. and 12676 hec. suffers as flood prone. According to soil texture, 60207 ha. is Clay area, 81944 hec. is Loamy-Clay area and the rest part is described as Sandy-Clay area. Problem soils including acid and salt affected soils are covered to about 3 million ha out of total cultivable area of about 7 million ha. Acid soils are found in the districts of Birbhum, Bankura, Western parts of Bardhaman, Purulia, West Midnapur, Cooch behar, Darjeeling ,Jalpaiguri and parts of Dakshin and North Dinajpur and Malda districts. salt affected soils are found in the southern parts of East Midnapur and Howrah districts, South 24 parganas and parts of North 24 parganas districts. However, old and new alluvial soils are found in the districts of Uttar and Dakshin Dinajpur , Malda, Murshidabad and parts of Birbhum ; and Nadia, Bardhaman Hooghly, North and South 24 parganas districts respectively. Besides, forest and hill soils are found in Dargeeling districts. Teesta and Terai alluvial soils are found in Cooch behar, Jalpaiguri and siliguri sub-divisions of Darjeeling districts.

Water resources:

Ground-water in the district occurs both under water-table condition and confined condition. Ground-water in the near surface aquifers occur under water-table condition and in deep aquifers, under confined or sub-artesian condition in favorable terrain. The primary source of ground-water is rainfall, a part of which is lost as evaporation and transpiration and another part moves as surface run-off and remaining part percolates into the ground from direct rainfall or by lateral infiltration from surface water-bodies to form saturated ground-water zone.

Total ultimate irrigation potential of the State is 67.43 lakh hectares. The State Water Investigation Directorate (SWID) has assessed the ultimate gross irrigation potential that can be created through minor irrigation development in the State at 44.33 lakh hectares. Of this, 13 lakh hectares are from surface water sources and 31.33 lakh hectares are from ground water sources. The gross irrigation potential created through major, medium and minor irrigation in the State till the end of March 2009 was 55.01 lakh hectares. The percentage of utilisation of potential created is 81.73 percent in major and medium irrigation structures, while it is 81.64 percent in minor irrigation. Out of the ultimate gross minor irrigation potential of 44.33 lakh hectare, 39.30 lakh hectares has been created up to 2008-09.

Forest resources

As per Satellite Imagery data 52.47 % of total Geo area is used for agriculture. 29.69 % are under forest coverage (including social forestry) and

10.15 % are identified as Wasteland (14.11 % as per Landsat Thematic Mapper/IRS LISS II/III data). The natural forests of the district are mostly of mixed nature. The forest areas of West Bengal are not uniformly distributed. Forests are particularly concentrated in three districts regions namely i) the hills and foot hills of Darjeeling (18 %) ii) the mangrove forests of Sundarban in the deltaic tracts of South East (37 %) and iii) hills and Plateau of the West(38 %). The remaining 7 % forest areas are distributed throughout the rest of districts of West Bengal. The total recorded forest area in the State is 11,879 sq.km. of which 7054 sq.km. is Reserved Forest, 3772 sq.km. is protected forest and 1053 sq.km. , being Unclassified State Forest thus constituting 13.38% of the geographical area of the State. By legal status, Reserved Forests constitute 59.38%, Protected Forests 31.75%, Unclassified Forest 8.87%. The forest cover including the forests created outside the recorded forest area is 15.52% of the geographical area as assessed in the year 2005. There is potential for jatropha and bamboo cultivation and for development of farm forestry and nurseries.

Mineral resources

The important mineral resources of the state are Coal, Rock phosphate, Granite Apatite, Fire Clay, Kainite, Limestone, Manganese, Base metals, Glass sand, Road metal and Building material. The other minerals includes Bauxite, Chromites, Gold, Silver, Fluorite, Ilmenite, Silica, Quartz, Feldspar, Dolomite, Mica, Gypsum, Copper and Graphite etc. are found spreading over different districts of the state.

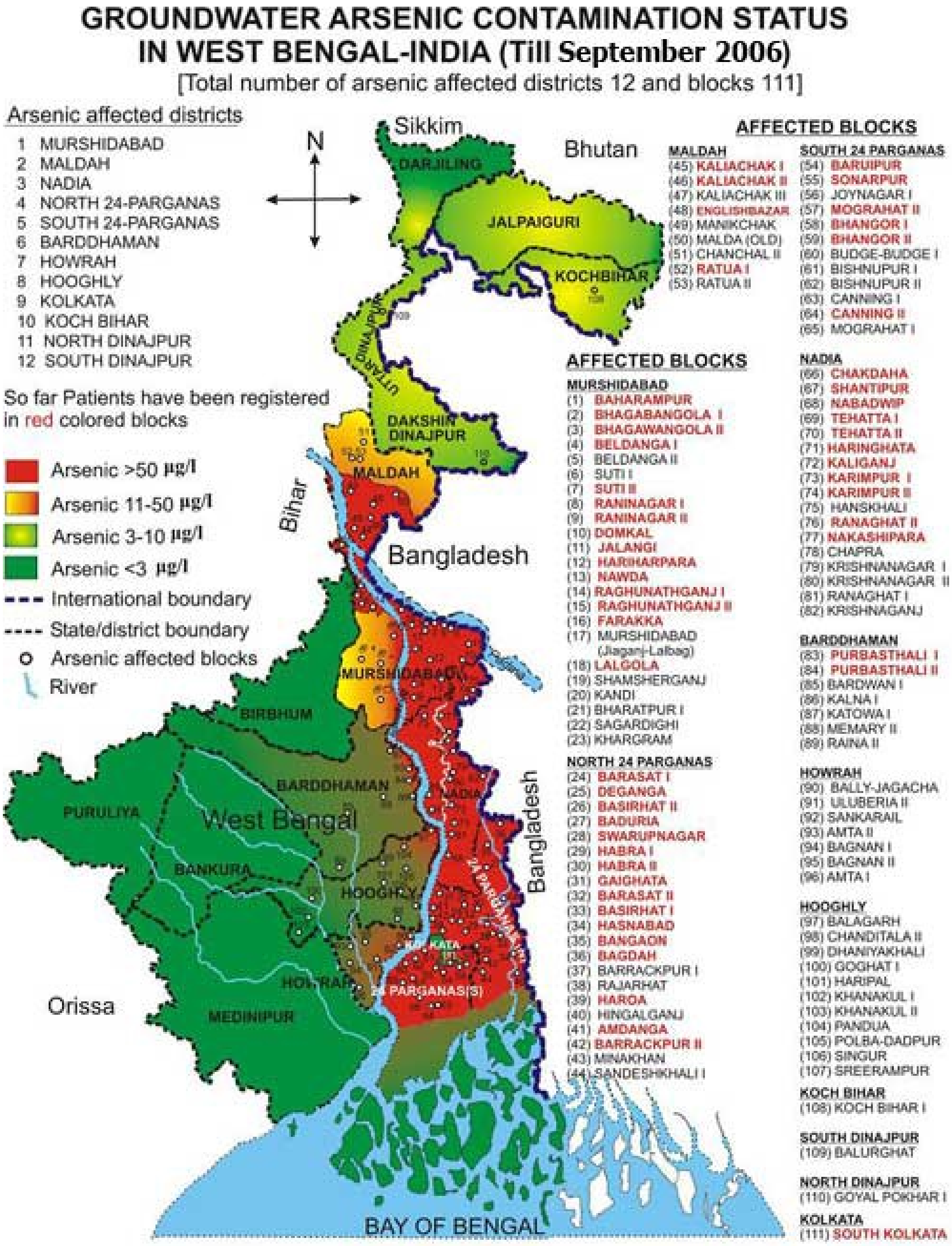
Water resources

The state of West Bengal receives rainfall in heavy showers followed by dry spells. When it rains heavily the soil is not able to absorb water at the rate of rainfall. As a result most of the rain drains away, leaving very little for storage & the recharge of groundwater. This makes most parts of West Bengal experience lack of water even for domestic usage. Thus it does not matter how much rain the state receives, if the rain water is not harvested.

The water resource management in water-scarce region in West Bengal, an eastern region state of India where the majority of rural population depends on agriculture for their livelihood. Thus lack of adequate water resource has inducted high level of uncertainty and insecurity in the mind of the local inhabitant. The Jol Dharo – Jol Bharo (Preserve Water, Reserve Water) initiative of Government of West Bengal tries to provide a replicable framework as a solution to this ecological inequality in the face of looming impacts of climate change.

The world is fast running out of fresh water, our demand for this blue gold is increasing at a faster pace. With passing time and thousand more people are compelled to survive in a water-stressed condition. One-half and two thirds of the global population will be put to sever fresh water crisis within next quarter century. The corporate sector treats water as a commodity. It is human need, not right-they proclaim, the idea of selling water to the highest bidder denies the basic fact that water constitutes the fundamental commodity. It is an integral component of all ecological and social processes.

Our planet is apparently rich in water but about 97.5 per cent of its water resource is saline as such unsuitable for drinking or irrigation. The volume of fresh water is only 2.5 percent of the total and that too is not readily accessible. About 68.7 per cent is remaining as ground water and soil moisture. The global hydrological cycle operates successive stages involving the evaporation-condensation-precipitation of 568000 km^3 of water annually. The continents of the Eastern receive 42750 km3 of water (0.70 percent of the global or 9.36 percent of the Asian precipitation) annually as precipitation but our country renders home to about 16 percent of the world's population on 2.45 percent of the terrestrial surface (National Commission on Integrated Water Resource Development, NCIWRD, 1999). However, in every district of West Bengal, there is a Agricultural contingency plan which includes district profile, rainfall, land use, soil types, agricultural land use, irrigation, crop cafeteria including field and horticultural crops, animal resources, crop sowing window, fisheries etc,. Such contingent plan helps not only to address various problems relating to NRM but also helps to identify the future technology to be adopted for agricultural progress of the state.



The above figure(1) shows the arsenic contaminated blocks of West Bengal till September, 2006. It indicates that if the demand of water in agriculture cannot be met through surface water and if the laws on groundwater use can not be enforced, the possibilities of groundwater contamination will be more. More groundwater contamination means more health hazard and consequently more spending by the state for public health.

Table: 1. Availability of water in West Bengal

Surface and Ground water (Mham)	Availability	Utilisable
Surface water	13.29	5.31
Ground water	1.46	1.46
Total available water by creation of more storage. Additional 1.20 Mham of water will be available for our use. The irrigation sector is the largest consumer of water will be available for our use. The irrigation sector is the largest consumer of water followed by the inland navigation sector. The official projection evinces that demand of water for agriculture would shoot up to 7.71 and 10.98 Mham in the years 2011 and 2025 respectively and those are more than available water for use by all sectors. So creation of additional storage and demand side management are dual challenges of present water management.	14.75	6.77

Source: State Irrigation Department(unpublished)

The utilizable surface water (5.31 Mham) in this State is less than 40 percent of the available surface water (13.29 Mham). One major challenges of water management is to reduce this crucial gap. If utilizable water can be enhanced to 60 percent of the

Table: 2. Requirement of water in West Bengal

Sector	2000	2010	2025
Agriculture	5.38	7.71	10.98
Domestic	0.26	0.28	0.38
Industry	0.26	0.38	0.59
Power (Thermal)	0.31	-	-
Inland Navigation	3.63	3.63	3.63
Forestry	0.01	0.01	0.01
Ecology, Environment and others	1.00	1.00	1.00
Total (Mham)	10.85	13.02	16.60

Source: State Irrigation Department (Unpublished)

The state can distinctly be divided into three geographical units viz.- North Bengal, Western Rarh and Plains to the east of Bramhaputra. About 63 percent of the water resources of the entire State is carried by eight basins of North Bengal while the Rarh and eastern plains are endowed each with 22 percent and 15 percent of water respectively.

The 8 river basins of North Bengal drain the southern slopes of the Himalaya and carry about 98679 MCM of surface and 9130 MCM of ground water annually. Monsoon rain is the source of most of the water in the rivers, which is concentrated within three months. The conservation or storage of water in this tract is difficult because the upper catchment of most

Ground Water Status:

Hydrogeology

The state can be divided into two hydro geological unit namely fissured hard rocks & porous alluvial formations. Fissured formation includes crystalline, meta sedimentary and volcanic rocks. The yield of wells tapping fractured zones varies from 10-20 m3/hr. Two third of the State is underlain by alluvial sediments mainly deposited by Ganga & Brahmaputra rivers. Based on the yield of wells tapping these alluvial sediments, aquifers of the alluvial area can be divided into three zones. 1. Yielding about 150m^3/hr, occurs from Jalpaiguri to Coochbehar in north to Midnapur & 24 Parganas in South. 2. Yielding about 50-150 m^3/hr, occurs in parts of Malda, Dinanjpur South & North and Western part of Murshidabad districts. 3. Yielding less than 50m^3/hr, occurs as Marginal alluvial tract in parts of Birbhum, Bardhaman, Bankura and Murshidabad districts. Ground water resources in the state is shown in table 3.

Table:3. Ground water resources in West Bengal

Dynamic Ground Water Resources in West Bengal	
Annual Replenishable Ground water Resource	30.36 Billion Cubic Meter (BCM)
Net Annual Ground Water Availability	27.46 BCM
Annual Ground Water Draft	11.65 BCM
Stage of Ground Water Development	42 %
Ground Water Development & Management	
Over Exploited	NIL
Critical	1 Block
Semi- critical	37 Blocks
Artificial Recharge to Ground Water (AR)	Area identified for AR: 7500 sq km Quantity of Surface Water to be Recharged: 2664 MCM Feasible AR structures: 11200 percolation tanks with shafts, 3606 gabion structures, 1054 nala bund/ cement plug, 1680 re excavation of tanks, 500 desiltation of village pond, 1000 spring development, 70 sub surface dykes, 1500 RTRWH for Kolkata & Darjeeling.
Ground Water Quality Problems	
Contaminants	**Districts affected (in part)**
Salinity (EC > 3000 µS/cm at 25 °C)	Howrah, East Midnapur, S- 24 Parganas,
Fluoride (>1.5 mg/l)	Bankura, Bardhaman, Birbhum, Dakshindinajpur, Malda, Nadia, Purulia, Uttardinajpur
Chloride (> 1000 mg/l)	S-24 Parganas, Haora
Iron (>1.0 mg/l)	Bankura, Bardhaman, Birbhum,

	Dakshindinajpur, E. Midnapur, Howrah, Hoogly, Jalpaiguri, Kolkatta, Murshidabad, N-24 parganna, Nadia, S-24 pargannas, Uttardinajpur, West Midnapur
Nitrate (>45 mg/l)	Bankura, Bardhaman
Arsenic (>0.05 mg/l)	Bardhaman, Hooghly, Howrah, Malda, Murshidabad, Nadia, North 24 Praganas, South 24 Pragannas

Source: State Irrigation Department (Unpublished)

Opportunities in the state:

Scope for increasing cropping intensity with water harvesting measures and crop diversification. ii) Organic matter rich fertile old and new alluvium soil offer good prospect for increasing productivity and cultivation of all types of crops. iii) Soil amelioration measures through adoption of organic farming, vermin composting offer a good scope for shaping of agricultural scenario of the State. v) Scope for increasing pulses and oilseeds production with sub soil moisture under maximum tillage and increasing jute seed production in the western part of the State. v) Scope for engagement of progressive farmers into contract farming and establishment of agro-based industries. vi) Wide production base with availability of raw material during a major part of the year offering good scope for multi product based fruit and vegetable processing units.

Technology followed for the management of natural resources

It is well known to all agricultural Scientists / experts that soil and water are the vital natural resources for human survival and this is also applicable to the state of West Bengal. Growing population in the state with the simultaneous increasing standard of living are placing the state to tremendous pressure on these two important natural resources . Soil resources in West Bengal is facing severe problems namely, declining fertility status due to constant nutrient mining in intensive agriculture with the adoption of modern agro-techniques , problems of soil salinity and acidity , soil drainage, soil erosion , soil degradation due to heavy metal and arsenic pollution etc. Some other constraints of soil and water resources namely, soil related constraints- excessive nutrient mining, soil fertility deterioration, nutrient imbalances including deficiencies and toxicities , availability of good quality surface and ground water for irrigation, crop related constraints like lack of availability of improved seeds and cultivars etc., other socio-economic constraints very frequently affect crop production.

Further, the water resources of the state are not only consistently declining but also its quality deterioration due to over exploitation both surface and groundwater in particular for agricultural production purposes. The best means of improving the sustainability of agricultural production systems is to control the negative factors causing degradation and at the same time to encourage positive factors improving soil productivity, input use efficiency and sustainability of the system. Therefore, it is pre-requisite to recommend suitable management strategies for maintaining soil fertility and quality as well as conserving water resource for sustaining crop production.

Soil resources

Understanding of land resource systems of the state holistically including the functioning and interactions of each of the components is *sine qua non* to sustainable land management system and for reducing land degradation. For an efficient management of soils in West Bengal existing in different agro-climatic regions, soil related site specific constraints have been identified and accordingly appropriate measures have been recommended.

Loss of soil fertility and soil organic matter have to be minimized through regular monitoring of soil nutrient status and use of sufficient amount of organic resource materials. All these can be made possible by the adoption of Integrated Nutrient Management (INM) practices. Apart from this, suitable agronomic management practices like suitable cropping systems , incorporation of legume crops in the crop rotation, conservation tillage , other resource conservation technology (RCT) , green manuring both *in situ* and *ex-situ* , use of bio fertilizers etc. are recommended for maintaining soil ecology and hence crop production. However, some of the experimental evidences on INM system for the management of soil resource are depicted in table 4.

Table 4. Effect of Integrated boron management on the yield (q ha^{-1}) of rape(*Brassica campestris*)

Treatments	Seed yield		
	2006-07	2007-08	Pooled
T_1: control (only NPK recommended	5.60^{e}	5.58^{e}	5.59^{E}
T_2: NPK as recommended + organic manure @5 t ha^{-1}	6.80^{d}	6.87^{d}	6.84^{D}
T_3: NPK as recommended + B as calbor (1 kg B ha^{-1})	8.10^{b}	8.15^{b}	8.12^{B}
T_4: NPK as recommended + B as calbor (0.5 kg B ha^{-1})+ organic manure @5 t ha^{-1}	8.90^{a}	8.99^{a}	8.95^{A}
T_5: NPK as recommended + B as borax (1 kg B ha^{-1})	7.20^{c}	7.31^{c}	7.26^{C}
T_6: NPK as recommended + B as borax (0.5 kg B ha^{-1})+ organic manure @5 t ha^{-1}	7.80^{b}	7.83^{b}	7.82^{B}
LSD(P=0.05)	0.330	0.333	0.330

Source: Mandal and Das (2011)

It appears from the above table that if boron is applied in appropriate amounts along with recommended NPK (80:40:40) coupled with organic matter in an integrated approach , then the yield of rape will be optimum without deteriorating soil fertile and quality. The farmers of the state are trying to use **organic manures** at least once or twice in a year for sustaining soil fertility and quality depending upon the availability of organic manures for crop production.

Table 5 : Combined application of NPK and Zn fertilizers on the yield of rice (cv.IET 4094) (pooled data of two years, 2005-2007)

Treatments	Grain yield(t ha^{-1})	Benefit: Cost ratio
Control (NPK 100:50:50 + no zinc)	4.0	
NPK(100:50:50) + zinc sulphate at basal@ 10kg ha^{-1}	4.3	0.37
NPK(100:50:50)+ zinc sulphate at 10 kg ha^{-1}in two splits	4.6	1.32
NPK(100:50:50)+ zinc sulphate at 20 kg ha^{-1} at basal	4.8	0.74
NPK(100:50:50)+ zinc sulphate at 20 kg ha^{-1}in two splits	5.1	1.21
NPK(100:50:50)+ Zn- EDTA at 0.5 kg ha^{-1} at basal	4.7	1.71
NPK(100:50:50)+ Zn-EDTA at 1.0 kg ha^{-1} basal	5.5	1.69
NPK(100:50:50)+ Zn-EDTA at 1.0 kg ha^{-1}in two splits	5.3	1.31

Source: Naik and Das (2008)

Naik and Das (2008) reported that the application of Zn-EDTA at 1.0 kg ha^{-1} along with recommended NPK (N was applied as three split; basal, grand tillering and panicle initiation stage, entire amount of P and K as basal) either as basal or splits performed better than any levels of zinc sulphate. The higher levels of Zn was maintained with two splits application of Zn-EDTA than that of zinc sulphate. The highest yield of rice (5.5 t ha^{-1})was recorded in the basal application of Zn as Zn-EDTA at1.0 kgha^{-1} with benefit : cost ratio of 1.69.

Appropriate measures for the minimisation of loss of fertile top soil through erosion has been taken. Purulia, Bankura , West Midnapur, Birbhum and Darjeeling districts are badly affected by soil erosion. Apart from the construction of some engineering devices like channels, underground drainage systems etc.

large scale aforestation , plantation of different herbs and shrubs, vegetative cover , wind breaks, terraces in the hill region etc. are adopted for the reduction of soil erosion through water and wind.

Soil acidity and salinity are also a major problems in West Bengal as it covers togetherly about 3 mha out of total cultivable areas of about 7.0 mha. Acid tolerant and Al- resistant crops may be effective for cultivation in such problematic soils (Das, 2011). Besides, low cost chemical amendments like waste products of steel industry, Basic slag and natural deposits , dolomite may successfully used for the amelioration of acid soils apart from costly liming materials like calcite.

Amelioration of soil salinity in West Bengal is not possible through leaching because of prevailing high water table in the coastal regions. Underground drainage system may be useful but it is not cost effective by an individual farmer. It can be done only by Govt. intervention. Besides, salt tolerant crops , agronomic practices like ridge- furrow method of cultivation may be useful. Planting is useful in the furrow or side of the furrow in order to avoid salt injury. Raised bed technique for crop cultivation is also useful in the coastal saline tract of West Bengal. These techniques are followed by the farmers of coastal area. However, the following conceptual model (Table-6) considering different issues , strategies and objectives for sustainable agricultural production of the state may be useful in future.

Table 6: Possible conceptual model relating to soil quality based on issues, strategies and objectives of West Bengal

Issues Strategies Objectives

Soil degradation → **Diversification of Agriculture** → **Agricultural Sustainability**

Physical : Compaction Integrated farming systems Eco-friendly and

Crustation Paddy cum fish culture system economically viable

Structure Resource conservation technology techniques for
Perenial waterlogging Soil and water conservation conserving natural
Drainage Conservation tillage resources like
Others Integrated Nutrient Management soil, water ,
Chemical : Integrated Water managementorganic resourceNutrient mining Integrated Pest Management materials, seeds etc.
Nutrient imbalances Integrated Agro-input Management Establishment of
Loss of soil fertility including quality seeds, fertilizers, watersheds and
Soil acidity agrochemicals, organic manures their managements
Soil salinity bio-fertilizers,vermicomposts,composts & developments
Soil pollution Residue management, green manuring To derive maximum
Deforestation Low cost locally available chemical use efficiency
Amendments like basic slags, dolomite, of applied fertilizers
Press mud , paper mill sludge,
gypsum etc.
Energy Management
Strategies for removal
of heavy metals and other toxicants
from soils e.g phyto remediation
Development of phyto excluder and Al
resistant plants by improved
breeding technique

Biological:
Minimisation ofactivity To improve the activity To derive maximum
of beneficial soil Macro& of soil micro-organisms benefit out of

Micro-organisms under stressed soil conditions resulted from physical & chemical degradations etc,.	to facilitate different beneficial processes undergoing in soils	applied agro-inputs like, fertilizers, organic resource materials and other inputs
Reduction in Organic matter		Maintenance of Soil health

Water resources

Out of total water resources available in West Bengal, more than 70% are polluted, of which more than 65% water are coming from groundwater sources and the rest from other surface water bodies namely, tanks, canals, wells, lakes etc. However, the quality of groundwater mostly adversely affected by existence of higher concentrations of arsenic, fluoride and to some extent presence of nitrate nitrogen, chloride and sulphate etc. Recently arsenic concentration is of great concern in Bengal Delta plains of West Bengal covering 9 districts out of 19 , while that of fluoride contamination reportedly found in the district of Birbhum. All these contaminants in groundwater severely affect agricultural crop production. However, surface water does not contain arsenic rather free of toxin suggesting soils receiving arsenic/ fluoride loaded water acts as a sink for those contaminants.

Water Balance

It is very important to harvest excess rain water as runoff during medium to heavy rainfall period for its utilization in crop production during rainless period and development of rainfed agriculture through scientific management of rain water, particularly in the East African countries. The gains of water would come from total rainfall over period of application of water as irrigation. The losses constitute a total runoff (R), downward draining (D), Evaporation (E) and Transpiration (T). Thus the balance sheet shows as Surplus and Deficit over a particular period and it uses to give a changed situation of stored moisture in the soil profiles as well as in the plants.

Equationally, Gains = P (rainfall) + I (Irrigation); Losses = Runoff (R)+ Down ward Drain (D) + Evaporation (E) + Transpiration (T); Gains-Losses = S + V where, S and V are changed moisture status in soil profiles and plants, respectively.

Water use for crop production

To get proper understanding on water use, it needs experimentation and observation on the basis of scientific information on these aspects mentioned above. Only the research findings on water requirement of crops and irrigation water use for crop production would lead to formulate a guide lines on effective utilization of irrigation potential whatsoever it has it has been created. The economic and judicious water application was also ensured by these guidelines. So the entire principles of irrigation, its theories and practices, depends on:

1. How much water to apply? i.e. Measurement of irrigation water;
2. When to apply the supplemental water as irrigation? i.e. proper timings and scheduling of irrigation application; and
3. How best to apply irrigation? i.e. methods of water application to the crop for sustainable production.

Green water i.e water present in soil, management (in rainfed agriculture) does not get enough attention at the policy or development programme level in India and West Bengal in particular. In general, this area of water management is a '**blind spot'**. Blue water resource development (dams, hydropower, irrigation) typically receives all the political attention and financial resources. Discussions on water productivity tend to focus on irrigation efficiency and crop productivity – summarized in the 'more crop per drop' paradigm. The importance of green water management, the factors that drive it and the practical improvements that can be made are not well understood. Agricultural extension has a large contribution to make, but extension services are generally weak.

Better management of soil moisture, i.e. green water management, is essential in achieving higher yields from rainfed agriculture. Soil moisture is often the most unreliable and scarce resource, so the challenge is to enhance the availability and productivity of water for biomass production. There are usual methods followed in West Bengal to enhance soil moisture availability: conservation tillage; mulching and compost use; in-field water conservation; improving overall soil moisture by avoiding deep drainage.

Inter sectoral management is a relatively new, holistic approach that offers a promising framework for better understanding and pro poor mobilization of potential development synergies. In IFAD's (International Fund for Agricultural Development) approach to water, this theme is not central, but is considered a holistic element in strengthening poor rural people's livelihoods and resilience. IFAD investment approaches to water-related interface management take into account the region/district/block specific structures of the rural political economy.

In so doing, they support the development of pro-poor, community-based natural resource management (NRM) institutions, which in turn improve farmer-led agriculture, natural resource technologies, and the sharing of knowledge of these achievements. With regard to managing green water, there are a number of approaches that can make a substantial difference in food security – each approach within the context of its local area.

Institutional approaches

- Strengthen local extension services and other methods of agricultural innovation; prioritize conservation tillage, in-field water conservation, mulching and composting activities in areas dependent on rainfed agriculture.
- Build local understanding of water retention and moisture conservation practices in order to identify a range of measures that can improve soil moisture on a large scale, and institutionalize such understanding in local training centres and vocational schools.

Technical approaches

9. Introduce improved moisture management techniques, such as conservation tillage, mulching and in-field water conservation. Innovative methods may be used to promote these techniques on a large scale in the absence of wide-spread or effective extension services. Alternative routes to farmer learning may be used – through local organizations, religious groups, farmer clubs, and joint learning events such as farm festivals, which can provide effective farmer-to-farmer learning.
10. Undertake participatory technology development in the above areas – involving farmers closely in the development of modified techniques and farming practices so as to maximize relevance and acceptability
11. Create better understanding of green water productivity among professionals and decision makers, supported by clear visual materials and convincing evidence.

Investment approaches

1. Invest in the necessary traction power – animal or mechanical – to improve methods for moisture management. After a major drought or conflict, restock the area and ensure that its livestock population is adequate. Live stock population needs to be increased in the drought prone areas of West Bengal, like, Purulia, Bankura, West Midnapur , parts of Bardhaman and Birbhum districts.

2. Invest in water retention and drainage control measures that will improve soil moisture over a larger area– for example gully plugging, controlled drainage, and subsurface and sand dams.
3. Explore investment in the production of mulch and compost by converting urban and industrial wastes into useful farm products.
4. Invest in infrastructure such as roads, market facilities, plant breeding and livestock breeding centres to help increase the productivity of rainfed areas of the state.
5. Therefore, for better and advanced management options relating to those groundwater and soil moisture may also be undertaken in future for effective utilization of NRM which are still urgent need.

Contingent crop plans and management strategies to deal with the late onset, intermittent breaks and early withdrawal of monsoon rains have been developed. Overexploitation of groundwater during lean period should be avoided and for that crop diversification of low water requirement is necessary instead of growing *boro* rice. Judicious irrigation schedules for major crops resulted into savings of 20-50% of irrigation water without compromising yield . Efficient micro-irrigation methods and techniques for utilizing available water in water deficit areas were developed for irrigation of high valued horticultural, vegetables and plantation crops with simultaneous savings of 30-50% water and also increase in yield to the level of 20-40% .

Water quality guidelines for irrigation with good , naturally occurring saline / sodic and arsenic, fluoride , nitrate containing ground waters have been developed. Existing guidelines were replaced by those based on crop tolerance, soil texture and rainfall for the monsoon climate of West Bengal for deriving maximum benefit from water resources for crop production as well as conservation of soil resources. Recent cropping systems of West Bengal is largely controlled by factors namely, convention, convenience and other socio-economic conditions rather than the availability and suitability. Water recycling and reuse are an integral part of water resource development for conserving and extending water supply to meet the current and future need. Aquaculture can add value to water resources by improving the water quality and in producing food of high biological value.

The total water requirement for growing crops has been modified by identifying suitable crops of low requirement, critical growth stages, cropping systems etc. Substantial amount of water savings (20-50%) is still possible through contingent crop planning, shifting to low water requirement crops viz. oil seeds, pulses, cash crops, spices etc. discarding *boro* rice particularly in the dry summer season, Recharging of aquifers through watershed management and development raised the ground water level of Aravali foot hills by about 2 meters. There is a change in the cropping systems in West Bengal during the 15 years. Greater exploitation of ground water in West Bengal resulted in depletion of water table and other environmental problems. So, diversification of agriculture including cropping systems matching with zone specific is most important. There is a recommendation for shifting of crop cultivation in different districts and blocks of West Bengal considering the availability of soil types and water resources . Conjunctive use of irrigation water are also followed in West Bengal. The residual moisture after harvest of paddy are being utilized through cultivation of paira crop like lentil, gram, linseed , rape seed – mustard etc. In diara lands of West Bengal especially in the district of Malda , groundnut, maize, Yambean are efficient crops in *rabi* season. The technology of **potato cultivation** in West Bengal using residual soil moisture of paddy field has been developed and are being practiced Besides, the technology of sugarcane cultivation after **dew harvest** in the arsha block of Purulia district are also being practiced during the last 15 years. In coastal areas of the state , moong, sunflower, cotton are cultivated in paddy fallows as rainfed or with limited water supply. The area under summer or *boro* rice has been replaced by cultivation of groundnut, pulses, elephant foot yam as rainfed or with life saving irrigation during critical growth stages. Saline water can also be utilized for the irrigation purposes if it is judiciously used. Management practices are to be followed for optimal crop production with brackish water / saline water irrigation must aim at preventing the build up of salinity , alkalinity and accumulation of toxic ions at the root zone to the levels that limit the productivity of soils , control salt balance in soil-water system as well as minimize the detrimental effect of salinity on crops. Establishment of water sheds through rain water harvesting, their management and development particularly in the rain fed districts of Purulia, Bankura and West Midnapur are to be given more emphasis , although very little development has so far been achieved in this regard.

New Technology for **ratooning of jute** has been currently developed for the state of West Bengal by the State Agricultural University, BCKV and that needs to be apprised to the rural farmers through extension linkages.

Terrace and *Jhum* cultivation are followed by the farmers of the hill tracts of West Bengal.

Selection of appropriate method of irrigation water application to the crop field is depended on soil type (clay, silt, sandy loam, loam etc), topography (undulating or flat), sources and amount of water available, crop to be grown and management practices adopted. The appropriate method would lead to give good storage and distribution efficiency. Pramanik and Mallick, (1996) described on-farm participatory field trials in West Bengal brought positive improvements towards better water use efficiency following the recommended methods of water management practices in the farmers field in DVC command. Therefore, , in future macro- and micro site specific considering the available water resources of the particular site/ zone , an appropriate and judicious irrigation schedule for different types of crops need to be followed for efficient utilization of water resources in West Bengal.

Road Ahead

1. Diversification and intensification of agriculture as well as improvement of productivity of all the major crops through adoption of newer and sustainable technologies, use of better inputs, adoption of organic farming.
2. Creation of irrigation facilities in un irrigated areas especially in western part of the state.
3. Diversifying the cropping pattern from rice based cropping system to bringing additional land under cultivation of millets, maize, pulses and oilseeds.
4. Emphasis on soil Health Management through soil testing infrastructure and adoption ofa time bound strategy for soil survey and soil analysis with specific reference to the micro nutrients and introduction of Soil Health Cards on a large scale basis. Developing location specific and soil status specific INM practices and propagating the same among the farming community of the state. However, the existing soil and water conservation practices to arrest soil erosion and reclamation measures for other soil degradation processes also need to be re-looked. Soil buffering system and land use policy are also vital components of NRM to attain sustainability that needs to be activated.
5. Leaf Colour Chart (LCC) and SPAD meter based technology for effective nitrogen management has been developed for rice and wheat although in

a very limited way and hence needs to be extended on a large scale covering all agro-climatic zones of the state since this technology can save nitrogen to the tune of 15- 20 kg per hectare.

6. Promotion of Integrated Farming System model having food grain, vegetable, flower, fruit plants, medicinal plants along with cattle, duck, goat, fish etc, for maximum return.
7. Identification of crop specific seed production zones based on agro climate, soil and water resources availability. In addition, integrated watershed management with decision support system (DSS) should be given an emphasis for effective NRM of the state.
8. Emphasizing on decentralized production of TL/certified seeds through ***"seed village concept"*** with active involvement of progressive farmers, farmers' clubs, PACs/societies,SHGs.
9. Active involvement of KVKs both in production as well as extending technical support to farmers/other agencies involved in seed production
10. Establishment of centralized seed processing infrastructure at potential blocks/district level
11. Encouraging Public- Private Partnership (PPP) mode in existing government seed farms for better utilization of resources.
12. Adoption of fully organic Bio-seed villages in each block where an integrated approach have to be taken for overall livelihood development.
13. Promotion of System of Rice Intensification (SRI) technology in the State in general and more specifically in Western part of the State. This can be adopted in other upland condition also and in hilly areas.
14. Institutional support through skill up gradation of extension workers, farmer to farmer extension, public-private partnership, strengthening ATMA, participatory research, credit support, marketing and post-harvest management, risk management, price support system
15. Convergence and synergy between state and central initiatives, role and accountability in implementing the schemes
16. Improved farmers income (diversification, agricultural marketing, agro-processing and value addition, contract farming)
17. Strengthening of the extension mechanism through both formal and informal channels, introduction of training and visit with assured timely supply of critical inputs at the farmers' door step.

18. Promoting organic farming, large scale production and application of FYM, vermin compost, biofertilizers etc., to improve soil health.
19. Promotion of productivity enhancing and environment friendly technology through channel partners like KVKs, NGOs, Farmers Clubs etc.

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Natural Resource Management for Improved Agricultural Productivity in Central and Eastern Regions of Uttar Pradesh

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Introduction

India’s total gross cropped area is about 192.2 million hectares and net sown area is 140 million ha. Over the last three to four decades, net sown area remains stagnant and possibility of increasing it is minimal due to increasing demand on land for other purposes. The ultimate irrigation potential of the country is estimated to be about 140 million ha out of which about 76 million ha is met by surface water and remaining 64 million hectare from ground water resources. Presently, about 63 million ha (45%) of cropped area, is reported to be irrigated.

Development of natural resources (land, water and perennial biomass), negligible attention towards sustainable socio-economic management of these resources have reached to unprecedented levels. For making agriculture sustainable, tomeetcountry’s food requirement, soil health and water availability are to be maintained at levels that would re-use farmers to pursue agricultural activities with higher level of productivity.

Land is a basic natural resource on which development of human with other living beings along with water and plants are going on from the beginning of the creation. Inadequate management of natural resource affected bio diversity, agriculture productivity and ecological balance. It is necessary to implement on priority basis, Soil and Water Conservation programmes in problematic areas, to ensure planned development and to achieve required production of food grains, fodder and bio fuel. Schemes implemented also provide local employment to the agriculture labourers, small and marginal farmers.

Uttar Pradesh occupies an important place in the polity and economy of the country. The economy of U.P. is predominately agrarian. The performance of agriculture and allied activities such as horticulture, animal husbandry, dairying & fisheries is critical in determining the growth rate of the State. Total geographical area of the state is 24,170 thousand hectare, out of which 16,573 thousand hectare is under cultivation. Gross cropped area is 25,414 thousand ha with the cropping intensity of 153%. Uttar Pradesh is largest producer of wheat, potato, sugarcane and milk whereas third largest producer of rice. Rice and wheat are the principal crops in central and eastern regions. It is interesting to note that maize was occupying area ranging between 3-10 percentinthecentral and easternregions.Agriculture still constitutes the backbone of the state economy, more so, because it provides livelihood to about two-third population of the state. The state is endowed with ample alluvial soil along with diverse agro-climatic profile which can support the cultivation of variety of crops. Due to large cultivated area, its share in national agricultural production is quite impressive but low crop productivity has hindered the realisation of ultimate potential.

The state constitutes 7.3 per cent of the geographical area of the country. It is the 2nd largeststate-economy and contributes about 8.0 per cent to country's gross domestic product. The economy is predominantly agriculture covering a sizeable part of the highly fertile Upper GangeticPlain.About 79 per cent population lives in the rural areas and 62 per cent of the total workers are employed inagriculture.The state is known for itswide diversity and variations in natural resources in terms of climate, soil, water resources topography, vegetationandsocioeconomic conditions across its regions. However, the resources need to be judiciously managed to meet the growing demands of human and animal populations and bring about economic prosperity in the region with equitable growth and development.

The state divided into 9 agro-climatic zones, namely, Bhabhar&Tarai, Western Plain, Central-Western Plain, South-Western Plain, Central Plain, Bundelkhand, North-Eastern Plain, Eastern Plain, and Vindhyan region and is also divided into four economic regions, viz., Western, Eastern, Central andBundelkh and Regional disparities are most pronounced among two major geographical regions of the state. The eastern region is the most populous, with a share of 40 percent in the state population. About one fifth of the population lives in the central region. The central region was industrially more developed but now has witnessed economic decline in last few decades the eastern region has been divided into three agro-climatic zones namely, North Eastern Plain Zone (NEPZ), Eastern Plain Zone (EPZ) and Vindhyan Zone (VZ) and in the Gangetic plain.

Rising population and divisions in families is directly correlated to fragmentation of holdings in the state. Consequently size of holdings are continuously becoming smaller. During last one decade average size of holding has come down from 0.97 ha to 0.83 ha as a result numbers of marginal and small farmers are increasing every year. In Uttar Pradesh size of holding is around 0.83 ha and per capita land area is 0.14 ha, which is less than a half of the national average of 0.32 ha. Marginal farmers are those who cannot meet out their annual food requirement from lands they own and in Uttar Pradesh 76.88% farmers are categorized in this class.

Features of Agro-climatic zones

Uttar Pradesh is divided into four economic regions i.e. Western region, Central Region, Eastern Region &BundelkhandRegion. The Western region comprises of 27 districts and the eastern region 27 districts. Ten districts constitute the central region whereas the Bundelkhand region has only 7 districts. Districts of different regions are given in table 1. State is divided into 9 agro climatic zones, namely, Bhabhar&Tarai, Westrn Plan, Central- Western Plain, South-Western Plain, Central Plain, Bundelkhand, North-Eastern Plain, Eastern Plain, and Vindhyan region (Fig.1). Details features of the agro-climatic zones are presented in table2.

Table 1. List of districts in different economic regions of Uttarpradesh

Region	Districts
Western Region	Agra, Mainpuri, Firozabad, Aligarh, Kanshiramnagar, Bareilly, Badaun, Bulandshar, Etah, Etawah, Farrukhabad, Mathura, Meerut, Ghaziabad, Muradabad, Pilibhit, Rampur, Muzaffarnagar, Saharanpur, Bijnor, Shahjhanpur, Begpath, Gautam Buddha Nagar, Hathras, JB. Nagar, Kannauj, Auriya.
Central Region	Barabanki, fatehpur, Hardoi, Kanpur Nagar, Kanpur dehat, Khiri, Lucknow, Raibareilly, Sitapur, Unnao.
Eastern Region	Allahabad, Kaushambi, Azamgarh, MaunathBhanjan, Ballia, Bahraich, Basti, Siddharthnagar, Deoria, Faizabad, Ghazipur, Gonda, Gorakhpur, Mahrajganj, Jaunpur, MIrzapur, Sonbhadra, Pratapgarh, Sultanpur, Varanasi, Balrampur, Shravasti, chandauli, SantRavidasnagar, Kushinagar, SantKabir Nagar, Ambedkarnagr.
Bundelkhand Region	Jhansi, Jalaun, Hamirpur, Mohabba, Banda, Chtrakut, Lalitpur.

Fig. 1. Different agro-climatic zones of UP

Table 2. Details of Agro-climatic zone in the state

S.N.	Agroclimatic Zone	Total Geographical Area in ha	Districts	Soil Type	Average Annual Rainfall (mm)	Temperature (^0C)		Major Crops	
1	Bhabhar and Tari Zone	1847319	Saharnpur (58%), Muzaffarnagar(10%)	Alluvial least to meadium phosphorus medium to high potashium and highly carbonised matter	1400	5.5	38.4	Rice	509818
								Wheat	608051
								Sugarcane	458965

2	Western Plain Zone		Saharnpur (42%) Muzaffarnagar(901637424 %) Meruut, Bagput, Gaziabad, G.B. Nagar, Bulandshar,	Alluvial PhValu Normal to Sodic and organic matter from least ot medium	795	1.50	43.3	Rice	159651
								Wheat	611658
								Sugarcane	606439
3	Mid Western Plain Zone	1697125	Barailly (81%) Badaun, Pilibhite (25%) Muradabad(79%) J P Nagar, Rampur (60%) ,Bijnour(21%) ,	All most Alluvial Normal to Slight sodic and content Medium carbonic Matter	1032	4.5	45.4	Rice	480409
								Wheat	830800
								Sugarcane	306878
4	South Western semiarid Zone	2234222	Agra, Firozabad, Aligarh, Hathras, Mathura, Mainpuri, Etah,	Alluvial and Arawali	662	4	47.0	Rice	219531
								Wheat	1134853
								Sugarcane	26088
5	Central Plain Zone	5647307	Shahjahanpur (94%), Kanpur Nagar, Kanpur dehat, Etawa, Auraiya, Farrukabad, KannaujLauknow, Unnao, Raebareli, Hardoi, khiri(61%) Sitapur, Fatehpur,	Alluvial Ph Normal to Sodic and containing Carbnic matter from least to medium quantity	863	5.5	45	Rice	1335506

			Allahbad (58%), Kaushambi.						
								Wheat	2252146
								Sugarcane	377355
6	Bundelkhand Zone	2961006	Lalitpur, Jhansi, Jalaun, Hamirpur, Mohabba, Banda, Chtrakut,.	Rarakarparwa, kabar, Maar,	867	3.0	47.8	Rice	74009
								Wheat	692895
								Sugarcane	10511
7	North eastern Plain Zone	2955485	Gorakhpur, Maharjgaunj, deoria, Kushi Nagar, Basti, S.K. Nagar, Siddarth Nagar, Gonda, Bahriach (63%) Balrampur and Shrawasti (29%)	Alluvial, Calcarius,	1240	4.9	44.2	Rice	1288605
								Wheat	1297030
								Sugarcane	282901
8	Eastern Plain Zone	3808718	Azamgarh, Mau, Ballia, Pratapgarh, Faizabad, AmbedkarNagar, Barabanki, Sultanpur, Varanasi, Chandauli, Jauinpur and	Alluvial, Sodic, and DiaraSoil,	803	5.7	41.4	Rice	1546424
								Wheat	1718672
								Sugarcane	117038

			S.R. Nagar(86%)						
9	Vindhyan Zone	1381840	Allahabad(42 %) S.R. Nagar (14%) Mirzapur and Sonbhadra	Kali, bhari red, Granus and llunial soil in Plane area	1134	5.0	45.2	Rice	222102
								Wheat	243416
								Sugarcane	2475
Total	24170446								

Source: Government of UP (2009-27)

Land utilization statistics

State is predominantly a small landholdingstate with large regional variations in average farm sizeand land and labour productivity (Tables 3&4). About 92 per centholdings are small occupying 63 per cent cultivatedarea in the state. Of the two regions, the number of small farm holdings is highest in the Eastern region, about 95 per cent cultivating 72 per cent of land. The average size of landholding in Uttar Pradesh is 0.80ha and for small farm category, it is only 0.55 ha. The average size of farm holding is lowest in Eastern region, 0.64 ha, the performance of agriculture varied considerably across the regions in the state.

Table 3.Area Operated by Operational holding (ha) in Central UP

Type of farmers	**Area (ha)**	**Per cent**
Marginal/small	2303195	69.38%
Medium	964300	29.05%
Large	51922	1.564%
Total (ha)	3319417	

Source: Pandey and Reddy (2012)

Table4.Area Operated by Operational holding (ha) in Eastern UP)

Type of farmers	**Area (ha)**	**Per cent**
Marginal/small	3374254	72.76%
Medium	1167408	25.17%
Large	95612	2.06
Total (ha)	4637274	

Source: Pandey and Reddy (2012)

Areas of crops and their production

The area of important crops grown and their production in the central and eastern regions of Uttar Pradesh is given in table 5.

Table 5.Area production and yield of different crops in central and eastern regions of U.P.

Central region 2011-12				Eastern region 2011-12			
Crops	Area	Prod.	Yield	Crops	Area Prod. Yield		
Rice	781650.0	2107283.0	30710.0				
Wheat	1783025.0	4090593.0	28882.0	Rice	2257887.0	4802717.0	52118.0
Sorghum (Bajara)	40065.0	59543.0	12834.0	Wheat	6852483.0	2416357.0	55643.0
Pearl millet	62301.0	74482.0	10917.0	Sorghum	64728.0	82890.0	22757.0
Maize	135521.0	143087.0	25398.0	Pearl millet	29757.0	30968.0	19186.0
Linseed	1845.0	864.0	3325.0	Maize	1269562.0	319004.0	51520.0
Rapeseed Mustered	1540035.0	158534.0	13217.0	Linseed	11792.0	4770.0	6194.0
Onion	7205.0	105211.0	270449.0	Rapeseed Mustered	57230.0	49709.0	18892.0
Potato	68957.0	1464535.0	196772.0	Onion	16112.0	168235.0	622108.0
Sugarcane	406923.0	23582833.0	524086.0	Potato	68284.0	1527136.0	452160.0
Other oil seed	564.0	1126.0	12324.0	Sugarcane	286602.0	14534238.0	977619.0
Ground nut	21953.0	17606.0	8030.0	Other oil seed	166.0	353.0	23375.0
Sesamum	68704.0	12305.0	1841.0	Ground nut	13984.0	17474.0	19725.0
Other pulses	229498.0	167233.0	44250.0	Sesamum	15054.0	2857.0	3626.0
Chick pea	92411.0	115052.0	8881.0	Chick pea	63880.0	66741.0	20663.0
pegion pea	60587.0	65117.0	10851.0	pigeon pea	1120883.0	94298.0	16924.0
Sunflower	544.00	1126.0	12324.0	Other pulses	219575.0	201340.0	674337.0
-	-	-	-	Sunflower	166.0	353.0	23375.0
-	-	-	-	Linseed	11792.0	4770.0	6194.0

Note: Area=’000ha; Production=’000tonnes; Yield=kg/haSource:FAI(2011-12)

Important feature of central and eastern regions

The comparison, amongst two regions in terms of population, geographical areas, cropping intensity and irrigation is given in table 6.

Table 6. Important Feature of central& Eastern Regions of Uttar Pradesh

Particulars	Regions		Total averages
	Eastern	Central	
Total population (Million) (1991Census)	52.722	24.187	76.909
Percent age of States Population	37.90	17.38	55.28
Density of Population Person Km^{-2}	614	528	1142
Urban Population as Percent age of total	11.58	23.99	35.57
Geographical area(Mha)	8.585	4.583	13.168
Cultivable area (Mha)	6.447	3.647	10.090
Net sown area (Mha)	5.677	2.967	8.644
Area sown more than once-Mha	2.854	1.523	4.377
Gross sown area (Mha)	8.531	4.490	13.021
Intensity of copping (9/7x100)	150.2	151.3	301.5
Net irrigated area (Mha)	3.705	2.109	5.814
Percentage of Net irrigated to Net sown area(11/7x100)	65.26	71.10	136.36
Gross irrigated area	5.00	3.042	8.042
Percentage of Gross irrigated to Gross sown area (13/7x100)	58.6	67.75	125.81

Source :Government of India, 2009

Land use plan Vis-a Vis Food Requirement

The land use projections were made of the two regions is given in table 7. In central region, the whole agriculture could be brought under some form of irrigation. In the eastern region, the south of the Ganga area in some and Tons sub-basins is some-what similar in topography to Bundelkhand, hence a larger net rainfed area is projected. Using the yields and land use as projected, and making assumptions about land for noon food crops, the agricultural production possible is computed of the two regions as follows (Table 8)

Table 7.Possible Land Use Plan (All area in M/ha)

S.No	Particulars	Eastern	Central	Total
1.0	Cultrurable area	6.447	3.647	10.094
2.0	Net sown 0.66 area -2050	3.2	6.3	9.5
3.0	Net irrigated area (current)	3.703	2.109	5.811
4.0	Gross irrigated area (current)	5.000	3.042	8.042
5.0	Assumed Net Ultimate irrigated area 2050	4.800	2.700	7.500
6.0	Resultant sown area without irrigation 2050	1.00	0.50	1.50
7.0	Gross irrigated area assumed ultimate	8.9	5.1	14.0
8.0	Gross cropped area (current)	8.531	4.440	12.971
9.0	Gross cropped area ultimate	10.40	0.66	11.06
10.0	Gross cropped area under rainfed condition ultimate	1.50	0.66	2.16

Source :Government of India, 2009

Table 8. Assumed ultimate Development scenarios (Agricultural production capacities)

All Figures as Areas in M ha

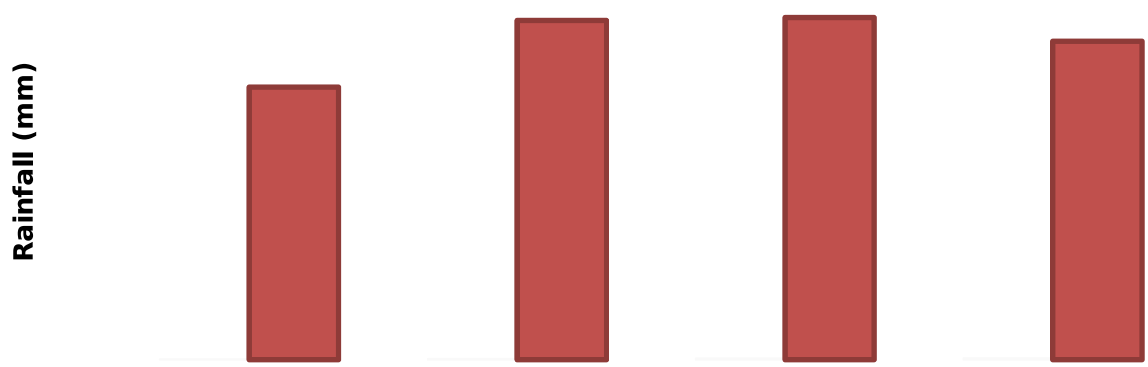
S.No	Particulars	Eastern	Central	Total
1.0	Gross cropped area (total 2050)	10.40	5.76	16.16
2.0	Gross crop irrigated area	8.9	5.1	14.0
3.0	Gross crop rainfed	1.50	0.66	2.16
4.0	Gross food crop (irrigated) (about75% of GIA)	6.47	3.82	10.29
5.0	Gross food crop rainfed area(about70%)	1.05	0.46	2.16
	All figure in Million Tonnes/year			
6.0	Ultimate yield irrigated yield 4.5t/ha(2050)	29.11	17.19	46.3
7.0	Ultimate yield rainfed area yield 1.5t/ha(2050)	1.58	0.69	2.27
8.0	Total yield 2050	30.69	17.88	48.57

Source : Government of India, 2009

Rainfall Trends

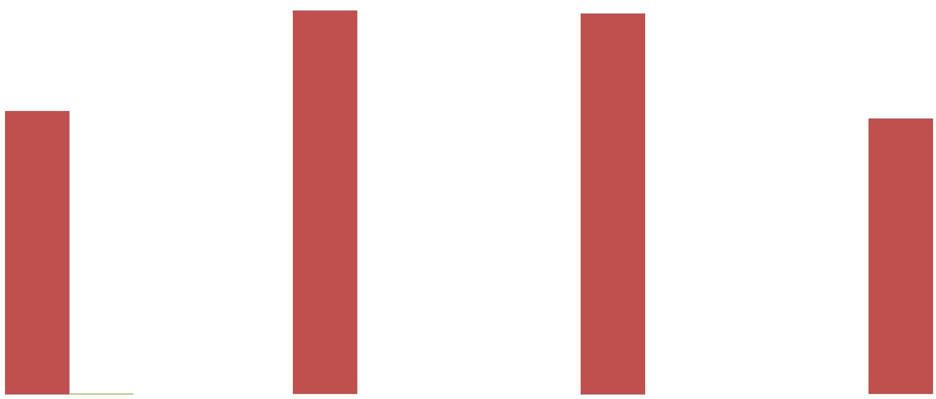
The central and eastern regions receive its major share of rainfall from mid-June to mid-September from the monsoon clouds of the Bay of Bengal. In the winter, north-westernly cyclones bring showers, averaging between 60 and 100 centimeters to areas in the north western district of the state. The annual rainfall in the eastern part of the U.P Monsoon lasts in both the regions from June to September, covering about 83 percentage of the total rainfall while winter rains cover the remaining 17 per cent. Erratic Mansoon trend and occasional moisture stress conditions with long dry spell especially in rainfedareas of eastern region and run off from sloppy lands causing severe erosion also results in poor productivity and production. Trends of the annual rainfall of eastern and central regions is depicted in fig 2&fig.3 .

Fig. 2. Rainfall trends in Eastern region (2011-12)



Source: FAI (2011-12)

Fig. 3.Rainfall trends in central region (2011-2012)



Source: FAI (2011-12)

Climate change effects in the regions

Climate-related disasters have brought wide spread and huge economic losses to central and eastern regions of Uttar Pradesh, adversely affecting public health, food security, agriculture, water resources and biodiversity. The situation is likely to worsen if human beings continue to pump 'green house gases' like carbon dioxide in to the atmosphere. These gases trap heat from the sun and thus lead to 'global warming'. As the Earth's temperature rises, a series of reaction take place such as rise in sea levels and inundation of land, changes in weather patterns and impact on agricultural productivity, faster precious fresh water evaporation, increase in disease carrying vectors leading to epidemic etc. Some impacts of climate change on agriculture and water resources in the two regions are as:

1. Agriculture in central and eastern regions will be adversely affected not only by an increase or decrease in the overall amounts of rainfall, but also by shift in the timing of the rainfall. Changes in the soil, pests and weeds brought by climate change will also affect agriculture in the regions.Forinstance, the amount of moisture in the soil will be affected by changes in factors such as precipitation, runoff and evaporation.
2. The quantity of surface runoff due to climate change would vary across river basins as well as sub basins in central and eastern zones of the Uttar Pradesh.However, there is general reduction in the quantity of available runoff.An increase in precipitation in Ganga is projected under climate change scenario. This may be due to increase in evapotranspiration because of increased temperature or variation in the distribution of rainfall.

Major soil orders

In Uttar Pradesh, nearly 70.1 per cent is under Inceptisols followed by Entisols (18.9%, Alfisols (4.9%), Vertisols (1.6%) and Mollisols (0.2%). Eastern UP has large areas under Tal, Diara and Chauras lands. The soils of Diara land occurring in alluvial and flood plains of U.P.is young and stratified with AC profiles and have very faint and poor pedogenic manifestations, which are classified as TypicUstifluvents. A sizable population lives in this area and is fully dependent on agriculture. The topography of Tal land is such that rain water from the area gets accumulated up to a depth of about 5 meters. Since the area is low laying and does not have drainage facilities, it remains inundated for a period of 3 to 4 months in a year, covering almost the entire *kharif*season.Alluvial soils are most important in both central and eastern regions, occupying nearly 61.8 per cent of the total area of Uttar Pradesh. Based on topographical features, the soil associations recognized in these soils are (i), Khadirs or the recent alluviums, (ii). soils of flat land; (iii) uplands soils and (iv) lowland soils. At great group level, these soils are classified as Hapludalfs, Paludalfs, HaplustaJfs, Ochraqualfs, Eutrochrepts, Ustochrepts,Ustipsarnment, Psammaquents, Ustifluvents, Ustorthents and Calciorthents.The upland soils of Vindhyan in eastern UP belong to great groups Haplustults, Rhodostultsand and Rhodostulfs. The flat lands and lowland soils generally fall within the great group Haplustalfs, Ochraqualfs, Eutrochrepts, Ustochrepts and Ustitluvents.

Fertility status of the soils

The soil in the central regions comprising LakhimpurKheri, Sitapur, Lucknow, Barabanki, Hardoi, Kanpur and Azamgarh districts is loamy and sandy loms. In the eastern part of the state, the districts of Gorakhpur, Basti, Mahrajganj, Siddarthnagar and Gonda contain two varieties of the soil, which are locally known as ‘Bhat’ and ‘banjar’. The alluvial soil is called ‘dhuh’. The one described as ‘mant’ is loamy sandy- calcareous, comparatively. The soil in the north western district of the state contains less of phosphate. The district of Jaunpur, Azamgarh and Mau are found to be lacking in potash and the drier areas are known as ‘usar’ and ‘reh’ . The soil of Aligarh, Mainpuri, Kanpur, Etah, Etawah, Sitapur, Unnao, Raibareilly and Lucknow is salt affected and known as ‘usar’ and ‘reh’ soils. Mixed red and black soil is found in the Jhansi division of the state and the districts of Mirzapur and Sonebhadra as well as the karchhana and Meja tehsils of Allahabad besides Chakia and Varanasi district. Black soil is sticky, calcareous and fertile. It expands as it soaks moisture and contracts on drying up. In the upper plateau of these districts the soil is red and is of two kinds – ‘parwa’ and ‘rackar’ ‘parwa’ is light sandy or sandy-loam while ‘rackar’ is alkaline

Recent results of Singh and Kumar (2012) for the available major nutrients and sulphur content in farmers field of eastern UP showed that black, alluvial and red soils varied widely in their content of available nutrients status (Table 9).The magnitude of N deficiency was highest in red soils (78.0%) followed by alluvial soils (34.0%) and black soils (28.0 %).Poor content of organic carbon and limited addition of N through external sources which have made red soils poor in content of available N. On an average about 85.0, 67.0 and 40.0 per cent soils were found to be low in available phosphorus content of red, black and alluvial soils, respectively. The low availability of phosphorus in red soils is mainly due to P fixation by Fe and Al oxides and less use of phosphatic fertilizers by the pulses grower farmers. The magnitude of K deficiency was highest in red soils (51.0%) as compared to black soils (23.7%) and alluvial soils (20.4%). Highest K deficiency in red soils may possibly be due to acidic parent material containing only a small percentage of K- bearing minerals and leaching loss of K from uplands. Pulses growing upland red soils have comparatively higher S deficiency to the tune of 92.0 per cent followed by 48.0 per cent in alluvial and 37.0 per cent in black soils. Poor organic matter level and coarse textured are the main reasons for severe S deficiency in upland red soils. On the other hand, S deficiency in black and alluvial soils has been attributed due to use of S-free high-analysis fertilizers by the vegetables grower farmers.

An assessment of soil available S, Zn and B of GIS based of eastern UP was reported by Singh et al 2012 .Altogether2334 surface soil samples collected(534 from Varanasi, 714 from Mirzapur, 528 from SantRavidas Nagar and 558 from Chandauli) covering m different blocks and villages district revealed that S, Zn and B were deficient in soils of these districts of eastern Up to a tune of 39 to 63, 16 to 46 and 30 to 61%, respectively (Table 10).Results further revealed that Ph and organic carbon in these soils varied widely(Fig 4 & 5).

Table 9. Fertility status of vegetable and pulses growing soils of Varanasi in eastern UP

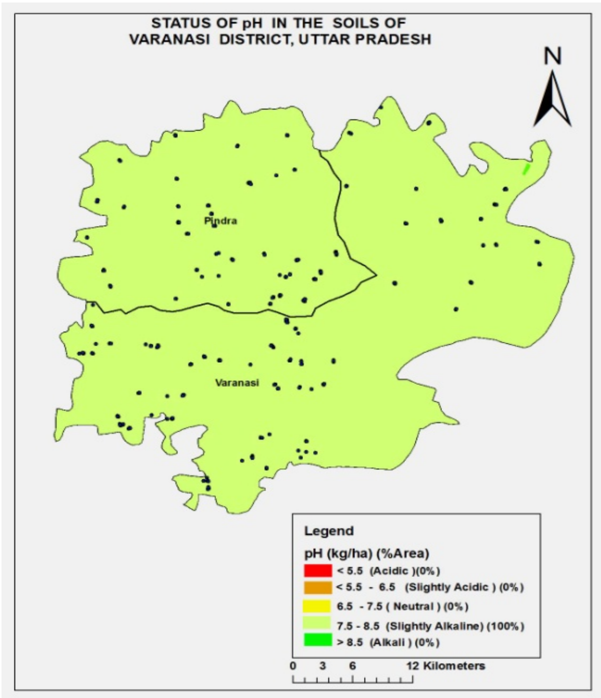
Soil available nutrients	Vegetable growing soils		Pulses growing soil
	Deficient level (%)		Deficient level(%)
	Black soils	Alluvial Soils	Red soils
Nitrogen	28.0	34.0	78.0
Phosphorus	67.0	40.0	85.0
Potassium	23.7	20.4	51.0
Sulphur	37.0	48.0	92.0
Zinc	31.0	36.0	9.0

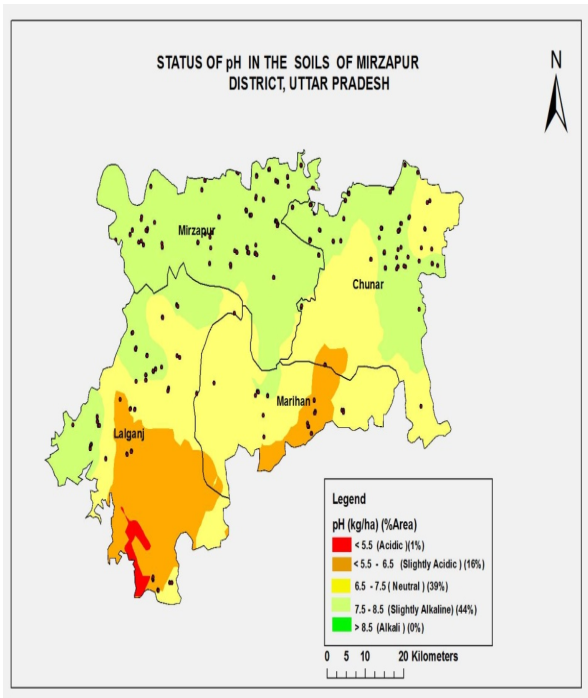
Source: Singh and Kumar (2012)

Table10. Nutrients deficiency (%),pH and organic carbon at District level in eastern region of Uttar pradesh

Name of Districts	S	Zn	B	pH Range	OC(%) Range
Varanasi *(534)	56	46	37	7.1 to 9.5	0.10 to 1.11
Mirzapur (714)	63	30	61	5.0 to 10.4	0.01 to 0.63
SantRavidas Nagar (528)	45	16	30	6.1 to 10.1	0.1 to 2.12
Chandauli (558)	39	37	55	4.9 to 10.1	0.01 to 0.69

Source:Singh, 2012* Figures in parenthesis shows number of samples





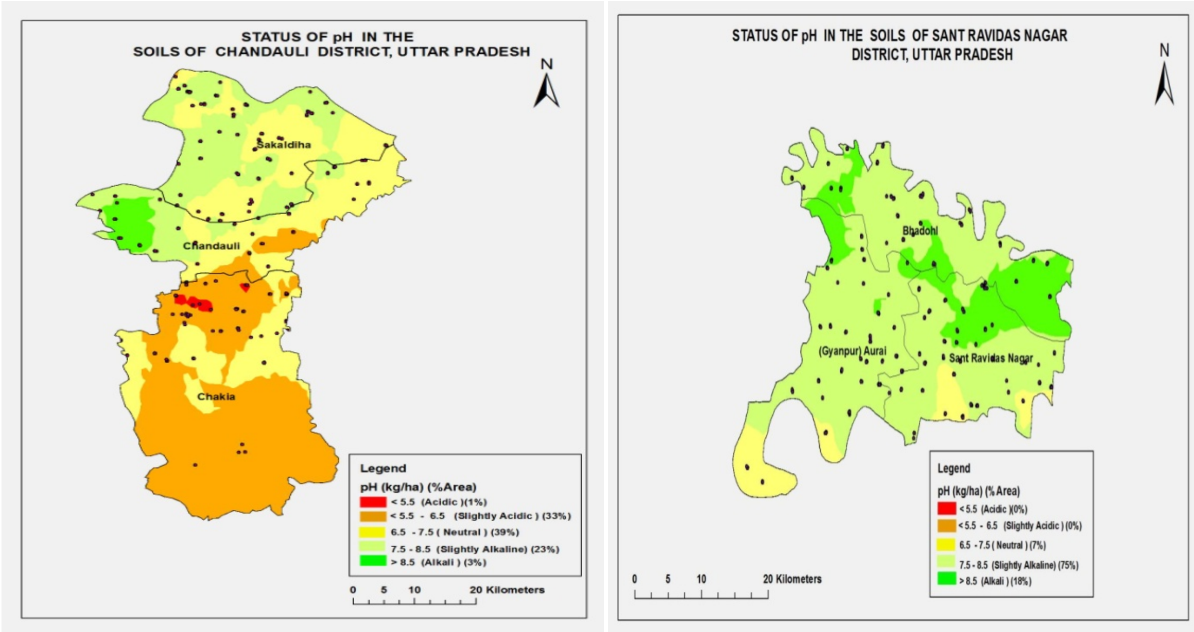
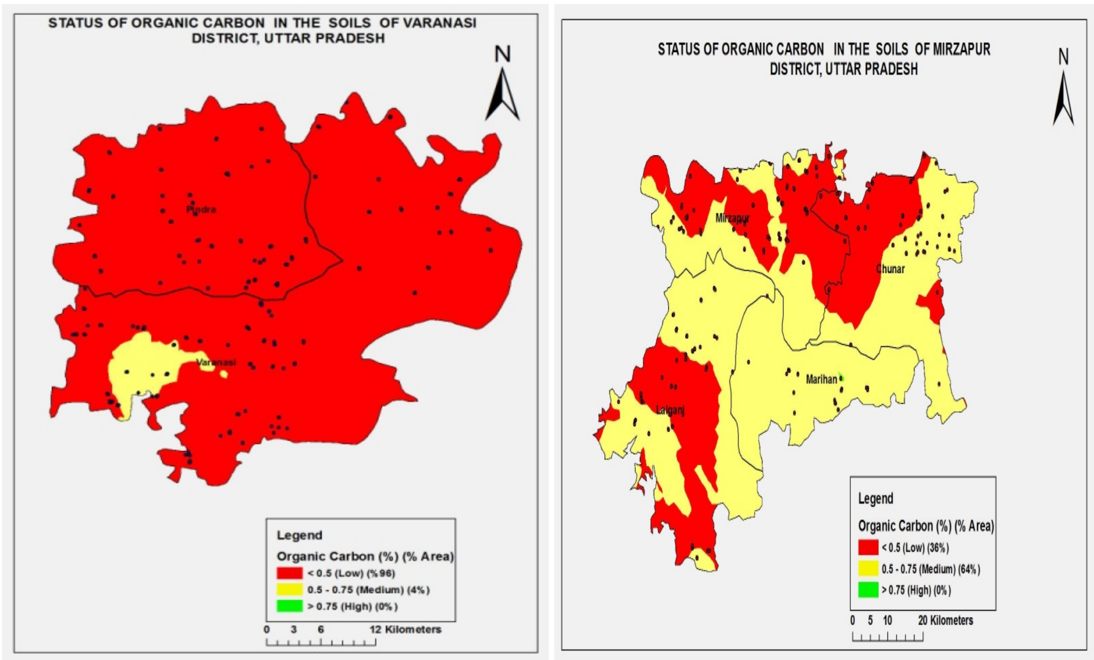


Fig4.pH Map of District Varanasi, Mirzapur, Chandauli&Santravidas Nagar of eastern Uttar pradesh



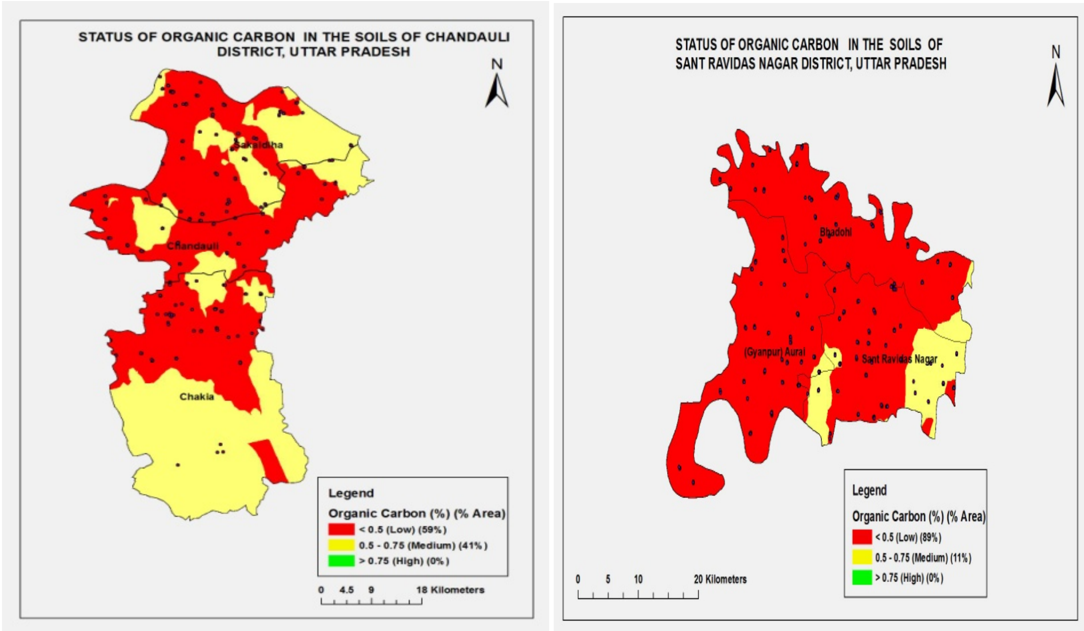
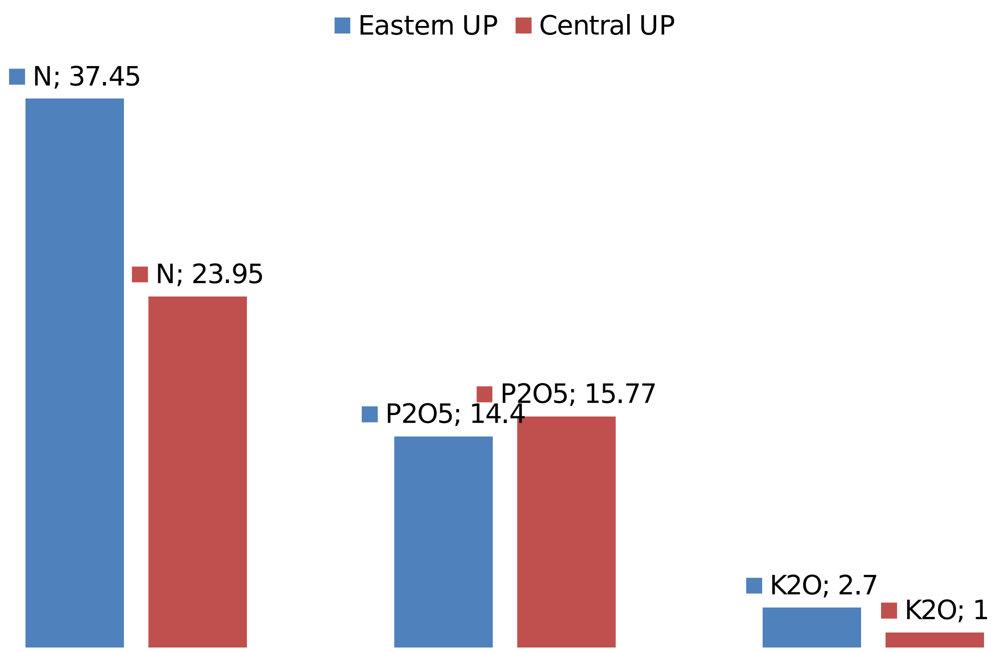


Fig 5.Organiccarbon content showing map of Districts Varanasi, Mirzapur, Chandauli&Santravidas Nagar in eastern Uttar pradesh

Fertilizer consumption

Consumption of chemical fertilizers is going ahead in a positive trend but there is a threat of imbalance use which caused the deterioration of soil health. The recommended fertilizer use is focused on NPK ratio which should be in the ideal form i.e. 4:2:1. The pattern of present fertilizer consumption (20011-12) in the state shows that the NPK ratio is gradually narrowing. Fertilizer consumption ratio of central and eastern regions are shown infig6. & table 11.

Fig 6.NPK Consumption ratio in Eastern and Central UP



Source: FAI (2011-12)

Table 11. NPK Consumption ratio in Eastern and Central UP)

Nutrients	Nutrient Consumption ratio	
	Eastern UP	Central UP
N	37.45	23.95
P_2O_5	14.4	15.77
K_2O	2.7	1

Source: FAI (2011-12)

Soil related constraints in crops and cropping systems

Soil fertility, soil water and other soil physical constraints in soils of eastern and central regions of UP have been narrated below in the following situations.

1. The black soils having swelling type montmorillonite clay poses the problem of internal drainage during rainy season and it cracks during dry spells and Limited availability of soil water is the major constraints in crop production under rainfed condition.
2. Upland red soils of vindhyan region in eastern part of Uttar Pradesh are coarse- textured having low water retention capacity and hence the plants often suffer from water stress and also suffering from. nutrients deficiencies of N, P, K and S due to restricted use of external sources of nutrients.
3. Soil fertility status in Indo-gangetic alluvial soils showed nutrients deficiencies of P, S and Zn due to imbalanced fertilization of excess use of nitrogen over the phosphatic and potassic application.
4. Alkali soils high in salt content ($EC>4dS\ m^{-1}$) and exchangeable Na percentage (>15) and have poor aggregate stability, low organic matter content and poor microbial activity due to unfavourable Ph and reduced availability of N, K, Zn Fe etc,also affect the productivity of these soils.
5. Eastern and central regions of UP have problematic area other than alkalinity which includes erosion, soil salinity , ravines, waterlogging, diyara lands etc. This affects productivities from these areas.
6. Erratic Mansoon trend and occasional moisture stress conditions with long dry spell especially in rainfed areas and run off from sloppy lands causing severe erosion also results in poor productivity and production.

7. Poor soil health and low organic matter content in the soil is also a major cause for low productivity. Soils are getting deficiency is some important nutrients like Sulpher, Iron, Zinc, Boron etc. which also results in low productivities of different crops.

Alternate nutrient sources

Alternative nutrient sources aims to meet crop requirements in soils. This will help in reducing the need ofchemicalfertilisers use for maintaining soil health and sustain crop productivity.,

1. In red soils of eastern part of UP, soil nutrient imbalances may be suitably managed in the e through use of optimum dose of fertilizers and promoting bio-fertilizers, practices like green manuring, legume intercropping, *in situ*and brought up mulches etc. .
2. Traditional organic manures like FYM orcompost,inclusion of legumes in crop rotations, use of organic and green manures, bio-fertilization, residue management, in situ legume or weed mulching in wide spaced rainy season crops, agro- forestry need to be applied in integration with inorganic fertilizers to replenish nutrients deficiency in soil-plant system in Indo-Gangetic plains of central and eastern part of UP to restore the soil health and fertility.

Organic farming

Organic farming is an agriculture production system which avoids or largely excludes the use of chemical fertilizers, pesticides and growth regulators. The traditional organic farming system relies upon crop rotation with leguminous crops, addition of crop residues, animal manures and green manuring. Practicing exclusively organic farming will have the limitation of being a low input-low output system but when integrated with bio-inputs like bio-fertilizer, bio-pesticides and effective micro-organism the higher yield level could be obtained.

Field experiments were conducted with wheat (var. PBW-443) on organic farming at Agricultural Research Farm, BHU, Varanasi based on cereal and legume cropping sequences during rabi seasons of 2006-07 and 2007-08.Yadav and Verma (2012) reported that creation of organic farming of wheat is more feasible with conjunctive use of composted cow dung along with Azotobacter + PSB + Trichoderma in legume-based cropping sequence rather than rice –based cropping sequence. However, organic farming of wheat is also possible in rice-based cropping sequence with application of FYM along with use of PGPR (Azotobacter + PSB + Trichoderma) in alluvial soils of Indo-Gangatic belt in eastern Utter Pradesh.

The findings on organic farming with inputs like FYM, bio-fertilizers and effective micro-organism (EM) is summarized below.

Cereal Based Cropping Sequence

Results pertaining to organic farming of wheat in rice based cropping sequence as influenced by application of FYM levels in combination of PGPR that conjunctive use of 30 t FYM ha^{-1} along with *Azotobacter + PSB +Trichoderma*(I_3) produced significantly higher grain yield of wheat. The interaction effect of FYM levels with PGPR was also significant. Highest grain and straw yields was recorded with 30 t FYM ha^{-1}and *Azotobacter + PSB +Trichoderma.*Organic farming of wheat may also be possible in rice-based sequence by application of 30 tones ha-1 FYM with PGPR. Green manuring in summer is pre-requisite in summer for maintaining adequate level soil fertility.

Legume-Based Cropping Sequence

Performance of wheat yield as influenced by application of different composted cow dung and different crop residues with PGPR revealed significant increase in grain and straw yields of wheat(Table 12).Among the composted cow dung and different crop residues, application of composted cow dung @ 24 t ha-1 has proved superiority than that of other composted crop residues with PGPR for enhancing higher grain yield of wheat. Organic farming of wheat may be taken in legume based cropping sequence by using composted cow dung or mixture of composted cow dung, legume and cereal residues with PGPR (Azotobacter + Pseudomonas + Trichoderma).

Table 12. Effect of PGPR and organic manures of different sources on grain and straw yield of wheat under legume - based organic farming in eastern region

Treatment	**Yield of wheat (q ha^{-1})**			
	2006-07		2007-08	
	Grain	Straw	Grain	Straw
T_1= Composted cow dung	23.85	32.25	31.67	44.50
T_2= Composted cereal straw	18.01	24.33	25.61	33.26
T_3=Composted legume straw	22.95	36.05	27.86	35.26
T_4= Composted legume + cereal straw	21.61	33.05	26.03	34.39
T_5= Composted cow dung + legume + cereal straw	21.08	36.58	30.39	43.78
T_6= Cow dung compost + PGPR	29.04	39.81	35.94	49.06
T_7= Cereal compost + PGPR	21.06	29.62	28.18	40.71
T_8= Legume compost+ PGPR	24.85	36.62	31.28	39.95
T_9= Legume + cereal compost + PGPR	23.89	36.44	31.47	41.93

T_{10}= Cow dung +Legume +cereal+ PGPR	23.75	36.91	35.67	47.45
C.D. (P=0.05)	2.995	5.751	3.621	7.829

Yadav and Verma(2012)

Soil and water pollution

In the central and eastern regions, the groundwater level has been declining due to heavy use of private and public hand pump sets and tubewells for domestic, agricultural, industrial and other uses in both urban and rural areas. Over extraction of groundwater affects the water quality directly. Sometimes, pollution poses a serious threat to all groundwater aquifers in the state. With the expansion of irrigated area and increased use of fertilisers and pesticides groundwater gets polluted ultimately causes health hazard.

The excess or inappropriate consumption of various fertilizers than the recommended quantity or ratio leads to polluting the soil, which ultimately causes for the decline of productivity of various crops in both the regions. The excess amount of nitrogen applied in the soils automatically converts into nitrate. As nitrate is not absorbed by most soils, it remains in solution. If it is not taken up by plant roots, it is either washed into the drainage water or biologically reduced to dinitrogen gas. Nitrate that is washed out of the soil represents an economic loss to the farmers and possible health hazard.Rao (1994) found that the major source of environmental degradation in rural areas is the misapplication of yield increasing inputs like water, chemical fertilizers, and pesticides causing waterlogging, salinity and pollution of drinking water and loss of fish etc.

Water resources and irrigation status

Central and eastern regions of Uttar Pradesh are endowed with bountiful water resources which were considered abundant but because of increasing demand for various purposes namely irrigation, drinking and domestic, power, industrial and other uses, its scarcity is becoming apparent which shall get more pronounced with increasing population Prominent sources of irrigation in the central and eastern Uttar Pradesh are bore well, canal and tank. The percentage distribution of these three sources of irrigation in central and eastern Uttar Pradesh is similar with bore well being prominent, followed by canal and tank. The distribution of bore well, canal and tank is approximately 78.6, 20.7 and 0.5 % in the central Uttar Pradesh and that of eastern Uttar Pradesh is approximately 77.2, 21.2 and 1.4 % respectively,(Fig.7a&b).

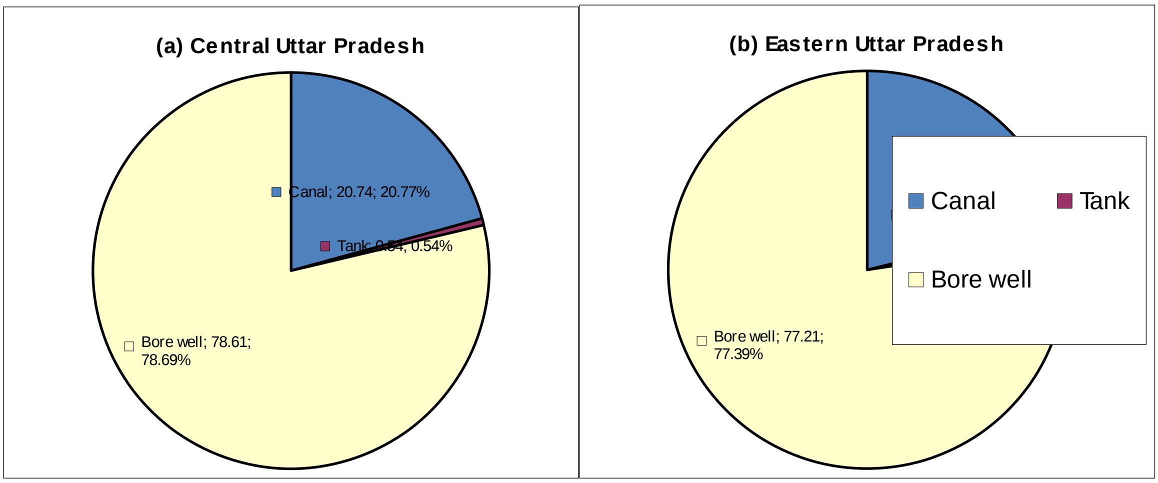


Fig. 7 (a &b) The distribution of bore well, canal and tank in central and eastern regions of UP

The state average of irrigated area is 79% but there is wide variation among districts. The districts wise irrigated area varies from 29% to 100%. The districts of central Uttar Pradesh are well irrigated and the net irrigated area varied between 64 to 92 % with the areas with higher net irrigated area in Lucknow-Raebareli-Unnao region whereas Fathpur and Kanpur districts had lower net irrigated area and higher percentage of total area under rainfedcultivation.Eastern Uttar Pradesh had even higher variation in the area under net irrigation varying between 21 and 93 %, with Sonebhadra being the lowest and Ambedkar Nagar being the highest**.** Shravasti, Sonebhadra and Balarampur had more than 50% of the net cultivated area under rainfed cultivation (Table13).

Table 13. Irrigation Status (Area in 000 ha.) of districts of central and eastern Uttar Pradesh

S. No.	Names of Districts	Net Cultivated Area	Gross Cultivated Area	Net Irrigated Area	Gross Irrigated Area	Net Irrigated %	Rainfed	
							Area	% of net Cultivated Area
Central Uttar Pradesh Districts								
1	LakhimpurKhiri	485.935	705.752	395.645	560.034	81.42	90.290	18.58
2	Sitapur	438.052	646.373	375.915	516.922	85.82	62.137	14.18
3	Hardoi	421.532	669.524	363.743	544.644	86.29	57.789	13.71
4	Unnao	302.166	468.987	278.436	370.206	92.15	23.730	7.85
5	Lucknow	145.407	217.52	133.237	187.416	91.63	12.170	8.37

6	Raebareli	271.732	409.399	248.384	349.523	91.41	23.348	8.59
7	KanpurDehat	223.981	317.129	164.232	211.804	73.32	59.749	26.68
8	Kanpur Nagar	189.861	272.088	134.666	183.645	70.93	55.195	29.07
9	Fatehpur	292.966	407.693	187.848	265.232	64.12	105.118	35.88
10	Barabanki	292.101	533.264	252.401	453.825	86.41	39.700	13.59
Eastern Uttar Pradesh Districts								
11	Pratapgarh	222.361	298.128	195.191	262.5	87.78	27.170	12.22
12	Kaushambi	133.748	175.861	92.18	119.593	68.92	41.568	31.08
13	Allahabad	315.648	500.031	240.522	392.142	76.20	75.126	23.80
14	Faizabad	132.727	213.076	117.866	190.162	88.80	14.861	11.20
15	Ambedkar Nagar	167.635	282.538	158.279	269.095	94.42	9.356	5.58
16	Sultanpur	283.651	433.886	233.309	364.295	82.25	50.342	17.75
17	Bahraich	324.862	501.28	167.324	188.693	51.51	157.538	48.49
18	Shravasti	131.877	186.582	53.709	59.029	40.73	78.168	59.27
19	Balrampur	212.579	313.83	73.462	121.562	34.56	139.117	65.44
20	Gonda	293.983	441.135	263.672	303.586	89.69	30.311	10.31
21	Siddharth Nagar	235.602	393.904	188.549	191.054	80.03	47.053	19.97
22	Basti	209.73	300.883	149.041	204.346	71.06	60.689	28.94
23	SantKabirNahar	121.93	208.387	100.220	107.24	82.19	21.710	17.81
24	Mahrajganj	201.767	363.944	168.793	180.446	83.66	32.974	16.34
25	Gorakhpur	250.496	381.673	205.520	236.372	82.05	44.976	17.95
26	Kushinagar	225.228	342.222	167.532	264.019	74.38	57.696	25.62
27	Deoria	195.36	319.136	172.387	240.978	88.24	22.973	11.76
28	Azamgarh	302.916	515.205	283.651	477.543	93.64	19.265	6.36
29	Mau	124.453	207.49	115.064	188.685	92.46	9.389	7.54
30	Ballia	221.171	351.683	172.981	257.731	78.21	48.190	21.79
31	Jaunpur	279.085	454.937	243.408	372.099	87.22	35.677	12.78
32	Ghazipur	254.313	415.443	214.391	349.108	84.30	39.922	15.70
33	Chandauli	135.341	261.386	124.452	227.681	91.95	10.889	8.05

34	Varanasi	95.842	158.388	80.006	133.778	83.48	15.836	16.52
35	SantRavidasNagar	69.986	97.645	55.984	77.37	79.99	14.002	20.01
36	Mirzapur	190.726	281.979	113.159	168.343	59.33	77.567	40.67
37	Sonbhadra	152.352	192.835	32.041	40.858	21.03	120.311	78.97

Source; Government of Uttar Pradesh (2009-27)

Strategies for Enhancing Water-use Efficiency in Agriculture

The strategies for increasing water use efficiency in eastern and central part of UP include appropriate integrated land and water management practices like

1. Soil-water conservation measures through adequate land preparation for crop establishment, rainwater harvesting and crop residue incorporation,
2. Efficient recycling of agricultural wastewater,
3. Conservation tillage to increase water infiltration, reduce runoff and improve soil moisture storage,
4. Adequate soil fertility to remove nutrient constraints for maximizing crop production for every drop of water available through either rainfall or irrigation.
5. In addition, novel irrigation technologies such as supplementary irrigation (some irrigation inputs to supplement inadequate rainfall), deficit irrigation (omitting irrigation at times that have little impact on crop yield), drip irrigation (delivering irrigation water to plant rooting zones) and sprinkler irrigation can improve the water use efficiency of crops.
6. In sandy soils of low fertility, nutrient deficiencies often override water shortage as the main factor limiting crop productivity. Crop growth may be so poor that it can utilize only 10 to 15% of total rainfall, the remaining being lost through evaporation, deep percolation and runoff.
7. Rainfed area occupying abundant areas in central and eastern regions of Uttar Supplemental irrigation combined with on-farm water-harvesting practices, such as mulching or bunding, reduces vulnerability to drought and helps farmers to get the most out of the scarce resources.

Integrated Plant Nutrient Management

Integrated plant nutrient management has an important role to play in maintaining or improving soil health, stabilizing productivity of crops, reducing the environmental pollution and increased quality of food material used for human consumption. It comprises of application of organic manure, green manure, biofertilizers and cropping system along with minimum use of chemical fertilizer to produce optimum crop yield without deteriorating the soil health. Integrated nutrient management aims at efficient and judicious use of all the resource of plant nutrient in an integrated manner, to attain sustainable crop production with minimum deleterious effect of chemical fertilizer on soil health and least disturbance to the plant, soil and environment. The most common available organic resources in the region are farm yard manure, green manure and wheat straw.

A long term fertilizer experiment was set up during 1986-87 under the ages of “All India Coordinate Research Project on Cropping System” at Agricultural Research Farm of the Institute of Agricultural Sciences, Banaras Hindu University to study the impact of integrated nutrient management taking into account FYM, wheat straw and green manure as organic sources on yield and various aspects of soil fertility. Such experiments provide us with valuable data on a regional perspective on the long term effects of such addition. Soil and plant samples were analyzed after 23 years of establishment of the experiment and detailed results has been presented by Prem Kishore (2012) out of which the salient points are being briefly reproduced:

Long term fertilization alone or when integrated with organic manures for 23 years in the rice wheat cropping system under study, had a distinct bearing on the physical properties investigated viz. bulk density, porosity, hydraulic conductivity, mean weight diameter and distribution of aggregates in the aggregate size class.

1. Control soils had the highest bulk density /lowest porosity that decreased increased with increasing fertilization and was the least/ highest when FYM followed by wheat straw and green manure was applied to substitute 50% of recommended NPK.
2. The hydraulic conductivity of treatments that received only chemical fertilization had similar hydraulic conductivities. However with partial substitution (50%) of fertilizers by organic manures, the hydraulic conductivities increased significantly over control or 100% chemically fertilized plots and was more where wheat straw was applied followed by FYM and green manure.

3. The mean weight diameter was larger in plots that that received 50 % N through organic sources as compared to 100% NPK treated plots; among the organic sources, wheat straw addition resulted in larger mean weight diameter.
4. The following chemical parameters were evaluated as indicators of long term (23 years) change in soil quality: pH, EC, organic C, available N, P, K, S and DTPA extractable Zn, Fe, Cu and Mn.
5. There was little variation in pH among treatments , however, lower pH were found in organic manure amended plots, especially with FYM or wheat straw and higher values of pH were recorded in plots receiving fertilizers. Control plots had the lowest electrical conductivity which increased with increasing doze of fertilizer and manure addition.
6. •Twenty-seven per cent higher organic C was observed in plots that received 50% NPK as FYM or wheat straw as compared to 100% NPK receiving plots.
7. The available N content increased with increasing dozes of fertilization. Substituting 50% of the NPK with either FYM, wheat straw or green manure significantly increased the available N content after wheat over 100% inorganic NPK treated plots.
8. The available P content considerably decreased from the initial values after 23 years of continuous cultivation in control plots. Available P increased with increasing fertilization over the control plots. The highest available P content was found in plots receiving 50% NPK as FYM followed by wheat straw and green manure.
9. The available K content also greatly decreased form the initial soil values in the control plots but showed signs of improvement with increasing fertilization. Higher K content over 100% NPK treatment was observed in wheat straw and FYM treated plots but not in green manure treated plots .
10. All inorganically fertilized plots had available S status near the critical limit which improved considerably with manure (either FYM > wheat straw > green manure) integration.
11. In the absence of micronutirent fertilization, the available Zn content was below the critical limit for all the treatments but the green manured plots had considerably higher available Zn content as compared to all other plots. The available Fe content increased with increasing fertilization and was highest where 50% NPK was substituted by organic manures; the

effect of wheat straw being most favorable. There was little variation in copper content among treatments and wheat straw and FYM treated plot had higher available Cu content. Higher available Mn content was however observed in green manure amended plots.

Long term integration of organic manures with fertilizers also brought out distinct changes in biological properties in soil as borne by microbial population, soil respiration and enzyme activities.

12. Bacterial population also increased with increasing fertilization and was further increased by application of organic manures. Similarly the fungal population among all the manure amended plots was also higher in manure amended plots but was similar among each other.
13. The cumulative C mineralization rate also increased with increasing fertilization and was significantly higher with manure amendment. FYM followed by wheat straw and green manure was more effective in increasing the cumulative C mineralization.
14. Highest Dehydrogenase enzyme activity was observed in wheat straw followed by FYM and then by green manure incorporation.
15. β-glucosidase activity after wheat was lower than after rice but increased by fertilization and further increased by incorporation of organic manures; wheat straw being more effective followed by FYM and green manure in that order in increasing β-glucosidase activity.
16. Phosphatase enzyme activity was more after wheat than after rice and increased with increasing fertilization and further increased with manure amendment. Among the manures, wheat straw followed by FYM and green manure, in that order, influenced the phosphatase enzyme activity.

In consequent to the favorable physical chemical and biological conditions and growth characteristics resulting from long term manuring with FYM, greatest yields of rice and wheat and nutrient uptake were achieved in this treatment. The initial depression of growth by wheat straw amendment resulted in lower rice yield, but wheat yields recovered and followed the FYM treatment. Yields with green manuring was always after FYM and wheat straw amendment. Results emanating from the present study conclusively suggest that FYM is the organic amendment of choice over wheat straw or green manure (if considered on equivalent N basis) and should be recommended to farmers.

Problematic Soils.

The eastern U.P. has a sizeable area of problem soils such as Bhat (calcarious) soil and submergence (1-3 weeks) in North-Eastern plain zone, Diara land waterlogged and sodic soils in Eastern Plain zone, Karail(black) soils and red-lateritic soils in Vindhyan zone of Varanasi. Eastern region occupies lager sodic soil areas(2.24 lakh ha) as compared to the central region(1.45 lakh ha).The task is very much significant in the future years to reclaim these sodic soils in both the region. Due to the calcareous nature of most of the sodoc soils in the Indo-Gangetic plains, calcium sources like gypsum or acid formers like pyrites are preferred more as amendments, although large variation in the efficiency of the different sources is reported. Efficiency of pyrites in reclaiming sodic soils depends largely on its water-soluble sulphur content. Various methods are useful to control the salinity/alkalinity dominated problematic soils. The proper use of gypsum and pyrites in terms of quantity and periods are very essential to reclaim alkalanity problems in the soil. Judicious use of fertilizers and inclusion of organics is a key factor for improved crop productivity in sodic soils.

Nutrient deficiencies/toxicities in crops and their correction

Various cropping systems of the eastern and central parts of UP are suffering multiple nutrient deficiencies in soils. The important corrective measures along with nutrient sources are given in table 14.

Table14. Important nutrient deficiency problems identified in crops and cropping system of eastern region of Uttar Pradesh

System/Areas	Nutrient deficiency problem	Corrective measures	Sources of nutrients
Rice-wheat cropping system	*N,P,K,S,Zn&B	S-20kg/ha,Zn-5 kg/ha,B-1-1.5kg/ha	**S-**Gypsum(16%S),Grow More Bentonite S(90%S),N:P:S(20:20:0:13) **Zn-**Zinc Mono(33%Zn),Zinc Hepta(21%) **B-**Borax(10.5%B),Granubor(15%B)
Intensively vegetables growing areas	N,P,K,S,Zn&B	S-30-40kg/ha,Zn-5-10kg/ha,	**S-**Gypsum(16%S),Grow More Bentonite S(90%S),N:P:S(20:20:0:13) **Zn-**Zinc Mono(33%Zn),Zinc

		B-1.5-2.0kg/ha	Hepta(21%) **B-**Borax(10.5%B),Granubor(15%B)
Pulses growing areas	N,P,K,S,Zn&B	S-20-30kg/ha,Zn-5-10kg/ha, B-1.5-2.0kg/ha	**S-**Gypsum(16%S),Grow More Bentonite S(90%S),N:P:S(20:20:0:13) **Zn-**Zinc Mono(33%Zn),Zinc Hepta(21%) **B-**Borax(10.5%B),Granubor(15%B)
Maize -wheat	N,P,K,S,Zn&B	S-20kg/ha,Zn-5-10kg/ha, B-1.0-1.5 kg/ha	**S-**Gypsum(16%S),Grow More Bentonite S(90%S),N:P:S(20:20:0:13) **Zn-**Zinc Mono(33%Zn),Zinc Hepta(21%) **B-**Borax(10.5%B),Granubor(15%B)
Groundnut + pigeonpea	N,P,K,S,Zn,Fe&B	S-40-50kg/ha,Zn-5 kg/ha, B-1.5-2.0kg/ha,	**S-**Gypsum(16%S),Grow More Bentonite S(90%S),N:P:S(20:20:0:13) **Zn-**Zinc Mono(33%Zn),Zinc Hepta(21%) **B-**Borax(10.5%B),Granubor(15%B)

*As per local recommendation based on soil tests for the farmers ofVaranasi region

Water related issues & management

Rain Water Harvesting

Central and eastern regions of UP has diverse agro climatic zones which almost different from each other. For example eastern plain is being presumed as water logged area. A concept of rain water harvesting is to conserve and collect the rain water of rainy season in a water body for their multipurpose use i.e. for live stock, human needs and farm sector. A scheme has been launched in rainfed areas of the region for Drip and Sprinkler irrigation system to the farmers at subsidized rate. Judicious use of rain water demonstration is being made as a component of this scheme for the purpose of its popularization amongst the farming community.

Implementation of Watershed Programme and economic gain

At present the watershed development programme activities are being handled by the department of Agriculture and the Land Development and Water Resources, Department of Uttar Pradesh Government. The Department of Agriculture has got 98 Soil Conservation Units, Ramganga Command Project 53

Units and ShardaSahayak Command Project 44 Units. The Watershed development Programmes in the state were being taken up under U.P. BhumiavamJalSanrakshan Act 1963 where astheLand Development and Water Resources Department of U.P. are working as per G.O.I's guidelines of 1994 and Hariyali Guidelines of 2003. Each of these organizations has got a well organized structure of units working in the districts with Deputy Directors at the Regional level and Additional Director, Soil Conservation under Director of Agriculture at state level in the Department of Agriculture and Administrators of Ramganga Command and ShardaSahayak Command in their area of Jurisdiction.

Several studies have demonstrated the enormous potential of small farmers in reversing degradation of natural resources. An innovative, multi-stakeholder consortium approach is now being tested for the development of appropriate technologies for integrated water, soil, nutrient, and crop management in the selected watersheds in central and eastern regions of Uttar pradesh .This study is part of the ongoing research on integrated management of watersheds(Table 15). Some of the economic gain of the improved watershed practices are noted below.

17. Surplus water for both Irrigation and drinking water.
18. Adequate Water for both Rabi and KharifSeasons with 100% cropping intensity.
19. Introduction of high value crop with doubling the yield.
20. Wellestablishedsupply around individual agriproducts

Table 15.All the Districts of central and eastern regions are covered under the following various watershed programmes.

SI.N0.	Name of Schemes	Sponsored by
1.	Integrated Wasteland Development Programme (IWDP)	Ministry of Rural Development, GOI Deptt. Of Land Resources
2	Drought Prone Area Programme (DPAP)	-do-
3	National Watershed Development Programme for Rainfed Area (NWDPRA)	Ministry of Agriculture and Cooperation Natural Resource Management (NRM) Division
4	River Valley Programme (RVP)/Flood Prone Area	-do-
5	Scheme of Watershed Development	NABARD

	under **RIDF**	
6	Scheme of Watershed Development Programme under Watershed Development Fund (WDF)	NABARD
7	U.P. Land Reclamation Project	World Bank
8	Macro Management of Agriculture	Ministry of Agriculture, GOI
9	State Soil Conservation Programme	U.P. State
10	Kishan Hit Yojana	U.P.State
11	Mitigation of Drought through Rain Water Harvesting and better Water Management	U.P.State
12	Efficient Water Management	U.P.State

Source: Government of Uttar Pradesh (2009-27)

Diversification of Agriculture

Diversification of agriculture refers to a larger crop-mix to augment farm income and enhance resource productivity.Simplestrategy for diversification is to shift crop enterprises in favour of more profitable crops form the less profitable ones. Price signals and market conditions largely determine the path of diversification. In central and eastern Uttar Pradesh, diversification became important when excess production of rice and wheat glutted the market and as a result profit margins declined. Rice-wheat system has also adversely affected the sustainability of natural resources, and threatened the production potential of the gangetic plain. Nature and scope of agricultural diversification was quite dissimilar in the two regions. Some of the salient suggestion for diversification of crops and cropping systems are given in tables 16 &17.Some of the salient suggestions to diversify agriculture are given below.

1. In the Eastern region, it was obviously due to high incidence of poverty, where farmers are forced to produce food crops to ensure their food security and needs diversification for cash crops.
2. Eastern region has niches for winter maize and provides huge promise for diversification during winter season.
3. 3.There is need to diversify lentil cultivation in rice-fallow system in eastern region; heat and mustard in potato- based system in central region; and production of green gram and blackgram during summer season. These could be possible due to availability of short duration verities of different crops.

4. 4.Interestingly, area under vegetables was rising on small and marginal farms. It has been observed that small and marginal farms were diversifying a part of their land to extra short duration crops, like vegetables to augment and stablise their income over seasons. Area under vegetables is growing in both central and eastern regions. Area substitution between different crop interprice suggest that existing conditions favour in both the for diversification.
5. Agricultural research should also shift priorities towards the farming system approach (which encompasses diversification) with multiple objectives of augmenting and sustaining farm income, generating employment opportunities, alleviating poverty and conserving natural resources.
6. 6.The central region is also gradually diversifying towards oil seeds and sugarcane. Rapeseed and mustard are the principal oilseed crops.
7. Intensive soil and water conservation measures following participatory watershed approach need to be adopted in central and eastern regions for sustaining and efficiently managining the natural resources of soil, water and biodiversity.
8. Rainwater/runoff harvesting on micro-catchment/farm/village/watershed basis for sustaining live stock as well as agricultural crops/fruit plants/other cash crops through supplemental irrigation utilizing water saving irrigation methods like drip and sprinkler for improved efficiency of scare and limited harvested water during occasional or acute droughts is desirable in central and eastern regions..
9. Rain water received in both the regions need to be conserved either in situ or harvested at farm/village/micro catchment/watershed level in order to control heavy runoff and soil losses.
10. Consequent upon green revolution in both the regions of UP, cereal-cereal cropping sequences like rice-wheat, maize-wheat, sorghum- wheat, bajara-wheat etc. with high yielding crop varieties were continuously practiced with imbalanced dose of fertilizers in the indo-gangetic plains. This resulted in over- exploitation of nutrients and reduction in soil health, leading to wide spread deficiency of N,P S, Zn and B.
11. The problematic soils of eastern and central part of UP need reclamation/specific management practices by using low cast effective amendments for higher crop productivity.

Table16. Diversification of agriculture in central and eastern regions of Uttar Pradesh

Regions	Commodity groups	Share in value of output(%)	Share in total area(%)
Central	Cereals	66	72
	Pulses	9	11
	Commercial crops	21	14
	Fruits and vegetables	4	4
Eastern	Cereals	77	81
	Pulses	8	11
	Commercial crops	8	2
	Fruits and vegetables	7	4

Source(Basic data): Uttar Pradesh keKrishiAnkare (Agriculture statistics of UP) (various issues) and ICRISAT Database complied by NCAP.

Table 17 . Total vegetable area in central and eastern regions of Uttar pradesh

Regions	TE 1982/83	TE1991/92	TE1992/2000
Central	77.00	90.91	91.75
Eastern	143.00	156.53	152.43

Source(Basic data): Uttar Pradesh keKrishiAnkare (Agriculture statistics of UP) (various issues) and ICRISAT Database complied by NCAP

Institutional mechanisms

There are three state agricultural universities (NDUAT, Faizabad; CAUAT, Kanpur and SVUAT, Merrut), several agricultural colleges and a number of ICAR institutions to meet the diverse research and educational requirements of the two regions in the state. It is desirable to allocate a larger share of agricultural gross domestic product to research. It is equally important to ensure that the optimum use of available resources is made through improved management of research institution.Effectivemechanismsofresearch priority setting need to be evolved in the state. The Uttar Pradesh Council of Agricultural Research (UPCAR) has to play a vital role.Greaternetworking and sharing of information with national and international institutions is required. Spending on research needs to be restructured so that operational funding can increase and investigating scientist have greater control over research resources. Some innovative methods are in progress under the aegis of a mega- project entitled "RastriyaKrishiVikashYojana". These are based on the principle of demand-driven research and extension. Initiatives likeNHM, NHSFM, KVK, ATMAand NGOs are under experimental stage to develop demand-driven research and extension agenda at the district level.These programmes have active involvement of the stakeholders in determining research and extension agenda

Policy Guidelines

Agriculture in central and eastern region of Uttar Pradesh is in the grip of numerous constraints to growth. It appears that the past efforts towards the agricultural sector were very casual. There were no concerted and integrated efforts to boost agricultural growth. This is the reason that despite the geographical advantage in central and eastern regions, in terms of soil, water and climate, the agricultural performance was far from satisfactory.Tremendous potential exists in the agricultural sector provided the existing constraints are mitigated.Importantguidelines which need to be addressed are:

1. Efficient and judicious utilization of natural resources for agriculture would be ensured considering its technical feasibility, economic viability and eco-friendliness besides its social acceptability.
2. On line availability of information regarding inventory of land resources in eastern and central regions based on their capabilities will be ensured.
3. Land use pattern would be monitored regularly and changes if any, would be updated at every five years interval.
4. Waste and degraded lands available in the form of usar barren, ravine, fallow and diara would be reclaimed and subsequently utilized for agriculture, horticulture, forestry and pasture. The farmers are not getting any income from the sodic and waste land in state. On the basis of iel.
5. The unirrigated and erosion affected lands will be managed through integrated watershed management approach using vegetable, mechanical and agronomical measures.
6. The foremost priority of the government should be to mobilise resources for investment in those areas that attract private sector participation and promote agricultural growth.

7. Mismanagement of the irrigation system is causing several environmental problems. These include falling water table, soil salanity/sodicity/alkalinity and waterlogging. If unattended, these would severely reduce the land capacity to increase agricultural production.
8. Land degradation is rampant in the eastern and central regions. Introduction of cannel irrigation in high rainfall areas without adequate provision of drainage was responsible for the raising water table and growing menance of sodicity.
9. Waterlogging in canal irrigated areas is also posing a serious threat to agricultural production in the eastern and central regions. Most of the canal command areas in the eastern region are seriously affected.
10. Excessive use of groundwater is adversely affecting groundwater table. This problem is more prominent in central region.
11. Nutrient mining is another constraint in agricultural production. There is evidence that soils are becoming deficient with respect to nitrogenous, phosphorus and potash and status of these is deteriorating in eastern and central regions of the state.Zinc,sulphur and boron deficiencies in eastern and boron deficiency in the central is becoming prominent. The crop yields are adversely affected due to nutrient deficiencies.

Policy issues

In the past, the public research and extension played a major role in bringing about the green revolution in the western region during mid-1960s and early 1970s. Later, the technology spilled over to the Eastern and Central regions in the state. During the green revaluation period, the extension agencies performed remarkably in disseminating the research outputs to the farmers' fields. In the post-green revaluation period, however, the extension delivery changing demands of the farming community. Innovative approaches are to be devised to meet the more complex challenging requirements in the era of globalization and liberalization to become more competitive through diversifying agriculture towards high value crops and conserve natural resources for sustained agricultural growth.

The central region is gradually diversifying towards oilseeds and sugarcane. Rapseed and mustard are the principal oilseeds crops in the central region. Eastern region has niches for winter maize. These two regions also need to be intensified towards better utilization of land and other inputs. Introduction of short duration and high- yielding varieties, increased use of fertilizers and better insect and pest management would intensify agriculture in these regions. Following are the salient features of the policy documents in central and eastern regions.

1. Fertilizer (NPK) consumption to be stepped up to 160 kg/ha in crops and cropping systems of eastern and central parts of UP.
2. Agriculture would be encouraged to diversify. Production of fruits and vegetables would be raised. Export of horticultural products would be promoted.
3. Incentives should be extended to encourage use of water-saving devices like drip and sprinkler irrigation system particularly rainfed areas of the region.
4. Research priorities need to be demand-driven. Similarly, the agricultural extension system needs to be completely revamped.
5. Programmes and policies need to be tuned to facilitate of science-based high-tech agriculture to compete in domestic and global markets.
6. In order to improve the production and productivity in different crops, activities like Integrated Plant Nutrient Management (IPNM), Integrated Crop Management, Integrated Water Management, and Integrated Pest Management (IPM) will be promoted.
7. Appropriate strategies need to be evolved which may include integrated land use planning for enhancing resource conservation and employment generation.
8. In fact, since the farmers are having small holdings, farming system approach will be adopted in which animal husbandry activities, vegetables growing, growing of medicinal plants etc. will be promoted in the regions which will improve the income levels of the farmers.
9. Increase cropping intensity and expand area of existing salt affected soil by reclaiming them.
10. Irrigation, credit, seed and technology transfer sectors need complete revamping. These sectors are gulping sizeable public resources and need to be managed in a decentralized pattern by involving participation of stakeholders.

The evolution of the above mentioned policy changes are addressed to accelerate agricultural growth, attack poverty and conserve natural resources. It is expected that these policy reforms will have for- reaching implications in enhancing income, generating income and improving the environment. The success of these policy measures would rely on how effectively and sincerely these are implemented.

Expected gain

A multi-purpose strategy and integrated approach would facilitate promotion of sustainable development in eastern and central part of Uttar Pradesh. Isolated and ad hoc approaches of the past may be completely ineffective in an open and competitive market regime. The future development efforts must focus on innovations that improve of land and farm of labour. There is a strong need to interface farm, firm and innovation.

In central and eastern part of Uttar Pradesh, the performance of agriculture varies considerably across districts and regions and has strong linkages and implications for poverty reduction. Agricultural growth and rural development in the state call for a regionally differentiated strategy.Therearemore districts in both eastern and central regions where the agricultural productivity is low. These districts have low irrigation, low fertilizer-use and less area allocated to high-value fruits and vegetable crops. Irrigation and fertilizer-use have been found to be the major determinants of level and variations of agricultural productivity across districts and regions. Proper natural resource management practices under rainfed and irrigated condition will help to the farmers of their better livelihood in terms of food security, nutritional security and economic security in years to come.

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Way Forward

Our country is very rich in natural resources, but owing to its over-exploitation over the years to meet food, fibre and fuel requirements of the growing population, it has become a threat to future sustainability. Historically, eastern India was the most prosperous agricultural tract of the country. During 1950-51, the foodgrain productivity in the eastern region of India was 6.4t/ha, compared to 6.1, 3.9, and 5.5t/ha in northern, western and southern regions, respectively (NASS, 1998). With the development of input oriented agricultural production during and after the Green Revolution,the region lagged behind other parts of the country.This was mainly due to poor public investments in agriculture for eastern region during 1969 to 1985 , which was grossly in-adequate.Productivity of major crops in this tract continue to be much lower than that of the states like Punjab, Haryana, western Uttar Pradesh etc.This is the reason that eastern India is often called resource rich but low productive region.

India with 142mha area under cultivation has 60% area (85 mha) as rainfed. Out of 329 mha total geographical area, about 146mha is degraded due to salinity, alkalinity, water logging, acidity, erosionetc. With increase in the size of farm family, resources such as land and water are becoming scarce, resulting into conflicts and distress among major parts of rural India. At present, about 80% of the farmers in India are categorized as small and marginal, with un-economical farming situations with low farm profits, posing a serious threat to long term security of food and nutrition. Soil health is deteriorating, misuse and inefficient use of irrigation water, depleting aquifers and extensive diversion of good farm lands for non-agricultural purposes, has made the situation complex.

Crop productivity levels in India are fairly low compared to the neighbouring countries. Average productivity of rice, wheat, maize, pulses, and oilseeds is 3.0, 2.9, 2.5, 0.70, & 1.3t/ha. This is much lower compared to the potential yield of these crops. Total factor productivity growth in agriculture in India is around 2.0% per annum, while it is 6.0% in China. Cereal productivity in China is about 5.5t/ha, while it is 2.5t/ha in India and 3.6t/ha in SriLanka. A major reason is the deteriorating soil health over years. Indian agriculture operates today with a negative balance of about 10 million tonnes of plant nutrients (N,P,K).fertiliser use in agricultural lands is about 60% of that of China. we use 140Kg NPK to produce 2500 Kg cereals per hectare, while China uses over 300 Kg NPK to produce 5313 Kg cereals per hectare. What is apparent is that there is no focussed attention towards nutrient starved croplands and their remediation to augment crop production as per demand of the growing population.

Distinguished scientists from eastern and north eastern states have critically examined the current scenario of soil and water resources and have identified the major challenges and policy issues aimed at food security for the masses. They have also put forth suggestions to overcome the discrepancies. Some of these are enumerated below:

Soil resource Management

1. Soil health needs to be improvedwith adequate and balanced nutrients using organic manures, cropresidues, biofertilisers, green manures, in conjunction with chemical fertilisers. It is necessary to create awareness among farmers about the need of periodical soil tests to decide on the use of nutrients. Soil testing should be an integral part of the soil health assessment programme. Soil health cards should be provided to all farm families.
2. Nutrient mining from soil must be checked.All essential plant nutrients (major, secondary and micronutrients) removed from soil by growing crops should be replenished. Input supply situation in block/ panchayat/ village level should be improved interms of timely availability, cost and quality. For this, there is

need to use information technology on key inputs and knowledge empowerment of farmers. Some of the missing nutrients and their sources in the context of eastern India are: boron (borax, boric acid), sulphur (phosphogypsum, gypsum), calcium (lime, dolomite, basic slag), phosphorus (SSP, rockphosphate), biofertilisers (Cultures of Rhizobium, Azotobacter, Psolubilisers etc.).

3. Site specific nutrient management, location specific profitable farming systems depending on soil conditions and water availability, must be promoted.
4. The vast rainfed area (about 60% of the TGA) of eastern Inda has been neglected in the past in terms of technological, infrastructural, and investment support. Sustained governmental efforts are essential for implementation of agronomic and engineering measures on soil and water conservation.It is necessary to build up confidence level of farmers and empower them for strengthening the cause of natural resource management.
5. More than 40% cultivated soils of the eastern and north-eastern region of India are acidic in reaction (pH less than 5.5). The crop production (mainly pulses, oilseeds, maize, wheat, vegetables etc.) in these areas suffer due to soil acidity induced low nutrient availability, nutrient imbalances and sometime toxicities of Al^{3+}.Lime application (lime. dolomite, basicslag, paper mill sludges etc.) and nutrient use will boost the crop productivity by amelioration of such soils.
6. Widespread deficiency of secondary (sulphur) and micronutrients (Zn,B) has now become a common occurrence in many intensively cultivated areas. This result in poor crop yields and sometimes no yield crippling the economy of farmers.Technologies are now available for correcting such deficiencies, which need to be promoted in a large scale for adoption by farmers. This will have a positive impact on human and animal healths, which are adversely affected due to consumption of food deficient in these nutrients.
7. There is need to build up the soil organic matter level by regular application of organic manures.The present methods of composting in rural areas need to be replaced by quality composts, such as enriched compost or enriched vermicompost. As per quality control guidelines, compost must be rich in Phosphorus and Potassium besides Nitrogen. It is largely accepted that meeting 75% of the nutrient needs of crops by fertilisers and 25% by organic and biological sources can help in sustaining soil organic matter level of soils with positive influence on crop yield and quality.

8. Land should be used as per capability.Depending on the quality of land, different crops like foodgrain, horticulture, flowers, foddercrops, forest trees etc. should be grown so that the inherent fertility of soil can be maintained over years. National Bureau of Soil Survey & Land use Planning (NBSS& LUP), State Land Use Boards should provide necessary guidelines and technical knowhow to the planners, village level workers and progressive farmers for implementation.

Water resource Management

1. Water resource planning should be based on micro-watersheds especially in rainfed areas with active support of government and participation of farmers. ITKs available in the location must be considered after its upgradation for better results. Technological interventions, such as water harvesting, rainwater conservation and runoff recycling should be implemented for greater improvements. Women empowerment must be done for realising benefits.
2. Efforts should be made to improve the efficiency of water use in canal command areas, which is very poor at present.This will help to save water to a considerable extent.
3. Series of farm ponds and on farm-reservoirs in farmers fields need to be constructed to intercept runoff, reduce peakflow, enhance groundwater recharge and create irrigation potential to intensify and diversify cropping systems in rainfed areas.
4. Investment on community borewells to retain groundwater will help farmers especially for vegetables and other high value crops.
5. Action oriented implementation of “more yield and income per drop of water” in suitable sites and crops will optimize water use in agriculture.
6. In view of the large spatial variability of rainfall, harvesting of rainwater and aquifer recharge is essential to ensure sustained supply of water especially during Rabi and Summer seasons.
7. Conjunctive use of surface water and groundwater resources will help in greater water use efficiency. Synergy of water use with plant nutrients, high yielding or hybrid crop varieties and necessary soil amendments in case of problem soils will help in high farm profits.
8. Poor water quality needs priority attention.Pollution of water with Arsenic, Flouride, Nitrate, heavy metals, pesticide residues needs to be monitored

and corrective measures adopted. Over-exploitation of groundwater for drinking and irrigation should be minimized by growing low water requiring crops, changed management systems and use of surface water (river, lake, ponds, canals) and rainwater as far as possible.

9. Equity in distribution of available water should receive priority through "PaniPanchayat" in every village to avoid water conflicts and social tensions arising from water shortages.

What is needed is an integrated thinking on the issues and their implementation keeping site specific problems in sight.