

Working Group Report

on

Natural Resource Management in Haryana



Haryana Kisan Ayog

CCS HAU Campus, Hisar-125004

Government of Haryana

Working Group Report
On
Natural Resource Management in Haryana

Chairman: I. P. Abrol

Member: S. R. Singh

Member: H. S. Lohan

Nodal Officer: D. P. Singh

Haryana Kisan Ayog

CCS HAU Campus, Hisar 125004

Government of Haryana

CHAIRMAN
HARYANA KISAN AYOG
CCSHAU CAMPUS
HISAR-125004

FOREWORD

The State of Haryana has made great strides in food production during the era of Green Revolution. However, this success resulted in second generation problems such as declining resource base, especially reduction in soil organic carbon content, multiple nutrient deficiencies, poor soil health, hydrological imbalance, decline in underground and above ground biodiversity and pollution of soil, water and environment. Also there had been gradual decline in water table in areas having good quality ground water due to cultivation of high water requiring crops like rice, wheat, sugarcane and cotton. On the other hand, inland basin with underground brackish water, introduction of canal irrigation with poor on-farm water management, in the absence of effective drainage, has resulted in rise of water table and soil degradation (salinization, sodification, water logging). In south western region, having poor quality ground water and low rainfall, drastic decline in water table has taken place due to dominance of sprinkler system of irrigation. The farmers are increasingly using gypsum to mitigate adverse water quality effects, thus increasing the cost of cultivation. Agriculture intensification, associated with technological and policy regimes with little attention to natural resource management and diversification, has led to serious problem of resource degradation, the nature of problem being regional/location specific.

As a consequence, the farmers of the State are facing los of problems arising from increasing cost of cultivation, declining factor productivity and uncertainty associated with increasing variability in rainfall and temperature regimes. Therefore, it is critical now to have an introspection of the past accomplishments and undertake a SWOT (strength, weakness, opportunities, threats) analysis in order to halt/reverse the processes contributing to degradation of natural resource base and its quality. We urgently need now appropriate resource conservation, augmentation and management strategies for achieving more sustainable growth of agriculture in the State.

It gives me an immense pleasure to learn that a working group on "Natural Resource Management in Haryana" led by Dr. I. P. Abrol as its chairman, Dr. S. R. Singh and Er. H. S. Lohan as members and Dr. D. P. Singh as Nodal Officer has analyzed the complex and immediate problems of natural resources (Land, soil, water, climate, biodiversity), identified the sustainable ways and suggested appropriate policy, research and development related interventions for improving resource base and quality to sustain higher agriculture growth in the State. The working group had conducted a series of meetings facilitated by Haryana Kisan Ayog with scientists, policy makers, field functionaries and farmers, visited NRM related ongoing research projects in various institutions and saw the development related programmes on the farmers fields, including different water storage and delievery structures in the State for coming out with these recommendations. I am sure, institutions like CCSHAU, Hisar, HARSAC, CSSRI, Karnal, State Departments of Agriculture, Irrigation, Forestry, Pollution Board, Farm Advisory and other related Developmental Agencies will take full advantage of these recommendations to help specially resource poor farmers of the State. I also believe that this important publication will be of immense use to the planners, administrators, scientists, students and farmers alike so as to improve the natural resource base so critical for sustainable growth of agriculture in Haryana.

(R. S. Paroda)

MEMBER SECRETARY
HARYANA KISAN AYOG
CCSHAU CAMPUS
HISAR-125004

ACKNOWLEDGEMENTS

This report of working group on Natural Resource Management in Haryana is an outcome of series of meetings, field visits and fruitful discussion carried out with policy makers, scientists, field functionaries and selected farmers in the State. The expert group consisting of Dr. I.P. Abrol, Chairman, Dr. S.R. Singh and Er. H.S. Lohan, Members and Dr. D.P. Singh as Nodal Officer was constituted by the Chairman of Haryana Kisan Ayog and requested the Working Group to complete the assignment on “Natural Resource Management in Haryana” . The Ayog is indebted with a deep sense of appreciation for the vision and leadership of its Chairman Padam Bhushan Dr. R.S. Paroda who selected one of best experts who have not only excellent expertise and leadership in the field of natural resource management but also have good experience of the past and present status of Haryana Agriculture. The Ayog would like to express its sincere thanks to Dr. I.P. Abrol, Dr. S.R. Singh, Er. H.S. Lohan and Dr. D.P. Singh for completing this important task by identifying the complex issues and problems of natural resources and by suggesting appropriate solutions for sustaining farmers' and eco-friendly progress of agriculture in the State.

The Ayog also feels highly indebted to Sh. Roshan Lal, IAS, Principal Secretary, Agriculture, Govt. of Haryana, Dr. K. S. Khokhar, Vice-Chancellor, and Deans, Directors, Incharge of different Regional Research Stations, KVKs and other faculty of CCSHAU, Hisar, Vice-Chancellor and Deans and Directors of LALRUVAS, Hisar, Dr. R. S. Hooda, Chief Scientist, HARSAC and his staff, Mr. Ashok Yadav &

Mr. A.K. Singh DG, Agriculture, Dr. B.S. Duggal, ADG, Agriculture, Govt. of Haryana and his selected staff, Dr. Satyavir Singh, DG, Horticulture, Govt. of Haryana, Chief Engineer, Irrigation, Govt. of Haryana, Director, State Pollution Board, Govt. of Haryana, Chief Engineer, Bhakra Beas Management Board and other field functionaries for their active participation and keen involvement in the relevant meetings and fruitful discussion as well as comments and suggestions to improve the draft on natural resource management in Haryana.

The Ayog is also grateful to Dr. A. K. Singh, DDG (NRM), ICAR, New Delhi, Dr. D. K. Sharma, Director, CSSRI, Karnal and his staff, Director, Regional Cotton Research Station (ICAR), Sirsa and his staff for their fruitful interactions during the visits of Working Group and valuable suggestions for improving the draft. We also thank Dr. D. K. Sharma, Director, CSSRI, Karnal, Dr. S.K. Srivastava, Director, DSR, Indore, Dr. J.S Chauhan, Director, DRMR, Bharatpur and Scientists of CCSHAU, Hisar for providing photographs of agrotechnology relevant to resource management and crop diversification in the State.

The Ayog is also thankful to the farmers who made their valuable suggestions in the divisional meetings and also during the field visits of Working Group at selected sites in projects being operated on farmers fields on Natural Resource Management in the State.

Finally, Ayog thanks its Consultants, Dr. M.P. Yadav, Dr. K.N. Rai and Dr. M.L. Chadha, our Research Fellows, Dr.(Mrs.) Anupama Deora, Dr. Gajender Singh and Dr. Ravikant, and Computer Programmer , Ms. Meenakshi as well as other non-technical staff of the Ayog for their support and necessary help in the preparation of this important report on Natural Resource Management in Haryana.

(R.S. Dalal)

CONTENTS

ABBREVIATIONS

BCM	Billion Cubic Meter
BMC	Bhakra Main Canal
CA	Conservation Agriculture
CCA	Canal Command Area
CCSHAU	Chaudhary Charan Singh Haryana Agricultural University
CSSRI	Central Soil Salinity Research Institute
DG	Director General
DDG	Deputy Director General
DSR	Direct Seeded Rice
FC& PS	Finance Commissioner and Principal Secretary
FPARP	Farmers Participatory Action Research Project
GHG	Green House Gas
HAMETI	Haryana Agricultural Management and Extension Training Institute
HARSAC	Haryana Space Applications Centre
HIRMI	Haryana Irrigation Research and Management Institute
HKA	Haryana Kisan Ayog
HLRDC	Haryana Land Reclamation and Development Corporation
HSPCB	Haryana State Pollution Control Board
ICAR	Indian Council of Agricultural Research
IFS	Integrated Farming System
JLN	Jawahar Lal Nehru

KVK	Krishi Vigyan Kendra
LLRUVAS	Lala Lajpat Rai University of Animal and Veterinary Sciences
Mha	Million hectare
Mham	Million hectare meter
Msl	Mean sea level
MT	Million Tonnes
NPOF	National Program on Organic Farming
NPOP	National Program on Organic Production
NRM	Natural Resource Management
RKVY	Rashtriya Krishi Vikas Yojana
RRS	Regional Research Station
SAU	State Agricultural University
SHG	Self Help Group
SLUB	State Land Use Board
SRI	System of Rice Intensification
STP	Sewage Water Treatment Plant
UNDP	United Nations Development Programme
WG	Working Group
WTC	Water Technology Centre
WYC	Western Yamuna Canal

EXECUTIVE SUMMARY

After formation as a new State with the bifurcation of Punjab on November 1, 1966, Haryana has made tremendous progress on all fronts of agriculture. During the past four decades, the Govt. of Haryana has put great emphasis on improving irrigation facilities, road network and other infra-structure to support farming community and agriculture. Haryana with just 1.4 % (4.4 Mha) of the total geographical area of the country is the second largest contributor of food grains (17.6 % in 2010) to the central food basket. Green revolution technologies generated by scientists and practiced by hard working farmers with positive Govt. policy support enabled the State to increase food grain production from just 2.6 million tonnes (MT) in 1966-67 to 16.2 MT in 2010-11. During this period, the agricultural production has increased by about 11 times in wheat, 16 times in rice, 8 times in oil seeds, 6 times in cotton and 9 times in sugarcane. Significant shift in the cropped area included an increase of 34 % area under wheat, 87 % area under rice and 81% area under cotton between 1990-2010, all intensive input use (water, fertilizer, agro-chemicals) crops. Out of 86% of the total geographical area under cultivation, about 84% is irrigated with cropping intensity around 181%. While these achievements have contributed in building food grains stocks at the national level, yet distorted trends in land use, cropping pattern and overall natural resources base pose serious questions to future of agriculture in the State. Thus, there is a need to reinvent future course of development which is more sustainable and in long term more farmers and ecofriendly.

Over the years, the indiscriminate use of natural resources in intensively cultivated area of Haryana has deteriorated soil health, ground water hydrology, biodiversity, input use efficiency, factor productivity and environment. There is also threat of climate change on agriculture. Therefore, it is an opportune time to address the complex issues of natural resource management (Land, soil, water, biodiversity, climate) by reorienting education, research and development agenda for sustainable use of resources in the State. Keeping these objectives in view, the Haryana Kisan Ayog (HKA) constituted a working group (WG) on “Natural

Resource Management in Haryana" under the chairmanship of Dr. I. P. Abrol along with Dr. S. R. Singh and Er. H. S. Lohan as Members and Dr. D. P. Singh as Nodal Officer. The TOR of WG and other details are given in Annexure-I.

The report of Working Group on NRM provides a brief accounts of status and dynamics of natural resources, identifies sustainability issues and strategies to reverse the trend of deterioration of natural resources and their subsequent improvement and management for sustainable progress of agriculture in the State.

The diversion of fertile agricultural land to non-agricultural activities, deterioration in quality of resource base (Soil, water), inappropriate on-farm water management practices and presently no proper substitute to replace high water requiring puddled rice crop are real threats for sustaining desired growth of agriculture in the State. The organic matter content of soils is declining and impacting hydrological and biological properties of soils. The poor soil health because of low carbon content, multiple nutrient deficiency of secondary and micro-nutrients, imbalanced nutrition, inadequate addition of organic manure and green manure, little recycling of crop residues and non-inclusion of legume in rice-wheat sequence are affecting input use efficiency and productivity in several production systems. The sodic soils reclaimed earlier are also showing the symptoms of resodification. In the State, more than two third of ground water is of poor quality, while fresh water aquifers are over-exploited and showing the symptoms of mixing with brackish water in NE region under rice-wheat system. Inappropriate on-farm water management practices in the absence of effective drainage in canal irrigated areas of inland basin underlain with poor quality water are increasing the problems of water logging and soil salinity. In Shivalic Foot Hill fragile area, there is a problem of soil and water erosion. The north-western part is affected by the problems of both rise as well as decline in water table, while south-western Haryana dominated by tubewell irrigation is facing problem of decline in ground water table at an alarming rate, despite major area being under sprinkler irrigation using brackish ground water. The deep ground water table and use of gypsum to mitigate the ill effects of sodicity are adding to the cost of cultivation. There is increasing problem of water pollution due to diversion of untreated sewage and industrial effluent in fresh water streams which adversely impacting soil health, food chain and environment.

In the quest of attaining high productivity of some selected high water requiring crops (Rice, wheat, cotton, sugarcane) in shortest possible time during the era of green revolution, little attention has been devoted to address the issue of biodiversity and its dynamics which started reflecting in appearance of new diseases and pest scenario, seriously threatening the production base. The present forest cover is also very inadequate to moderate the ill effects of harsh climate. These are serious concerns that are not amenable to straight forward solutions and, therefore, call for a comprehensive look at the issues and plausible approaches to deal with them. Thus, the complex and interlinked issues mainly concerning land use, soil and water resources, biodiversity, climate change and environment need to be critically addressed for their critical monitoring, management and utilization for attaining sustained growth of agriculture in the State.

To address these complex issues and interlinked problems of natural resource management, there is an urgent need to build up effective lateral and vertical linkages at different levels: Central, State, institutional and stakeholders. Infact, the current agricultural practices are proving increasingly unsustainable, causing worsening of natural resource base and posing serious questions in face of emerging challenges. There is an urgent need to look for solutions which probably lie in fundamental shifts in the way agricultural research for development and addressing NRM problems have been viewed and addressed in the past. In this report, the working group has reviewed these issues and emphasized that proper resource characterization, monitoring, conservation, augmentation and utilization at the field, farm, watershed and basin levels constitute an important part towards sustainable use of resources under different production systems and agro-ecological regions of the State. Currently, there is lack of existence of multidisciplinary teams of scientists to address location specific complex issues of NRM at HQ, RRS and KVKs of SAU in the State. This report provides the solid reasons and need for strengthening Soil Survey Unit of University, revival of activities of State Land Use Board, setting up a school of Natural Resource Management and strengthening Department of Agrometerology at CCSHAU, HQ and Regional Research Stations in the area of natural resource management and social science, developing effective linkages with overseas institutes of repute and need to revisit course curricula of

NRM at SAU to improve human resource quality, strengthening and focusing the activities of different State Govt. Departments (Departments of Agriculture, Irrigation, Forestry, Rural Development) and institutions (HIRMI, HAMETI, HARSAC, SAU etc) in a coordinated and time bound manner are urgently required to address the researchable, developmental and training related NRM issues and needs in the State. The need to activate the functioning of State Pollution Board and Central Pollution Board and proper coordination between Govt. of Haryana, Delhi and Uttar Pradesh for not to divert untreated sewage and industrial effluents in fresh streams of water has also been emphasized in this report.

Inefficiencies on account of inappropriate location specific decisions in the absence of proper resource base understanding are at the root cause of resource and environmental degradation. These deficiencies include not to undertake and implement location specific based decisions on soil health, water, nutrient and crop management at field, farm, location of a water harvesting or storage structures and secondary reservoir in canal commands. The planning and improving excess water disposal through effective drainage, crop diversification to substitute high water requiring puddled rice, water conservation and recharge options to arrest decline in water table, pressurized systems of irrigation and other water saving devices, diversion of only treated sewage water and industrial effluent in fresh water streams, proper crop rotations to include legumes and green manure, use of organic manure, biofertilizers and other need based diversification and intensification of production system for resource optimization, mitigation and adaptation measures to climate change and global warming are the major issues which have been deliberated along with their plausible solution and implementation under different production systems and agro-ecological regions in this report.

Implementation of location/regional specific management options calls for development of scientific land use planning and strengthening the regional research stations to undertake adaptive research projects for development in farmer participatory mode by involving SAU and concerned State Departments. The working group suggested the location specific adaptive research projects by forming multidisciplinary groups to address need based specific issues of natural resource management in different parts of the State.

The soil organic matter is the key factor impacting soil health and hydrological and biological properties of soils. To address this important factor of soil health, the soil health cards based on nutrient analysis of surface soil should be modified into "System of Soil Nutrient Management." The farmers should be encouraged through proper incentives to use organic manure, green manure, legumes in crop rotation, recycling of crop residues in soils, alternate sources of bioenergy to save cowdung and organic farming for improving organic carbon content in soils.

Water is another most important scarce and valuable resource affecting the use efficiency of different inputs and resources. The crop diversification and water saving technologies such as laser leveling, substitution of puddled rice with aerobic rice (DSR, SRI), single cross hybrid maize/soybean based cropping/intercropping, use of pressurized system of irrigation and other water saving devices (Furrow irrigation, raised and sunken beds, plasticulture), holistic approach of watershed management, conservation and augmentation of water resource and addressing other interlinked issues such as drainage, biodrainage, secondary reservoir in CCA, farming systems and value addition have been suggested to improve water use efficiency and productivity of water in Haryana.

The report also dwells on control of water pollution, encouragement of agroforestry/forestry in saline water logged area, conservation agriculture based technology, mitigation and adaptation measures to climate change and use of modern tools (Modeling, GIS, resource use optimization, use of system approach etc) for sustainable use of natural resources.

Farmers decision making and adoption of new technologies reflect a deeper understanding of system and to guide desired action in system perspective. The working group strongly recommends the adoption of bottom up approach in farmer participatory mode to guide and implement research and development agenda at all levels-local, regional, State. The suggested measures once initiated/adopted will certainly prove as a way forward to reverse the trend of resource degradation and subsequently augmentation and improvement in quality of natural resources, their efficiency and environment for creating confidence among farmers and attaining ecofriendly progress of agriculture in the Haryana State.

1.0 INTRODUCTION

Carved out as a separate State from the erstwhile State of Punjab on November1, 1966, Haryana has total geographical area of 4.42 million ha that accounts for 1.4% of the total geographical area of the country and less than 2.6% of country's population (Yadav and Kumar, 2010). Agriculture being the primary livelihood base, nearly 85% of the area is under cultivation, 3.52% is under forestry while remaining area accounts for non-agricultural uses.

The Haryana State, located between 27°30' and 30°35' N latitude and 74°28' and 77°36' E longitude is a part of the north western arid and semiarid plains with an average rainfall of 545mm that ranges from 1200mm in the extreme north-east to less than 300mm in the arid west. The State is bounded by Siwalik hills in the north, river Yamuna in the east and Aravali hills in the south. More than 98% of the area of the State is covered by alluvial plains including the western deserted terrain of sand dunes. River Yamuna and Ghaggar flood plains constitute a large part of the State and the entire area is covered by three basins (Fig.1): namely, Yamuna basin (16330 sq. km.), Ghaggar basin (10675 sq. km.) and Inland basin (17207 sq. km.). The altitude in the State varies from 190m to 1200m above msl whose consequential physiography is depicted in Fig.2. Topographically a large part of Haryana plains constitute a widely spaced topographic depression between Siwalik hills and Aravali hills which has created typical internal drainage condition in the central and western parts including the districts of Rohtak, Jhajjar, Bhiwani, Hisar, Sirsa and parts of Sonipat (Fig 1). Haryana has a unique geographical feature whose water travels both into Indus and Ganges basins.

The State has made great strides in food production and contributes significantly to the national food basket. The Green Revolution has helped to bring around 85% of the total geographical area under cultivation with a cropping intensity of about 181%. However, recent agricultural trends in agriculture production are not very encouraging. The indiscriminate use of natural resources in intensively cultivated areas of Haryana has started showing negative impacts on soil health, progressive decline in input use efficiency and total factor productivity and increase in cost of

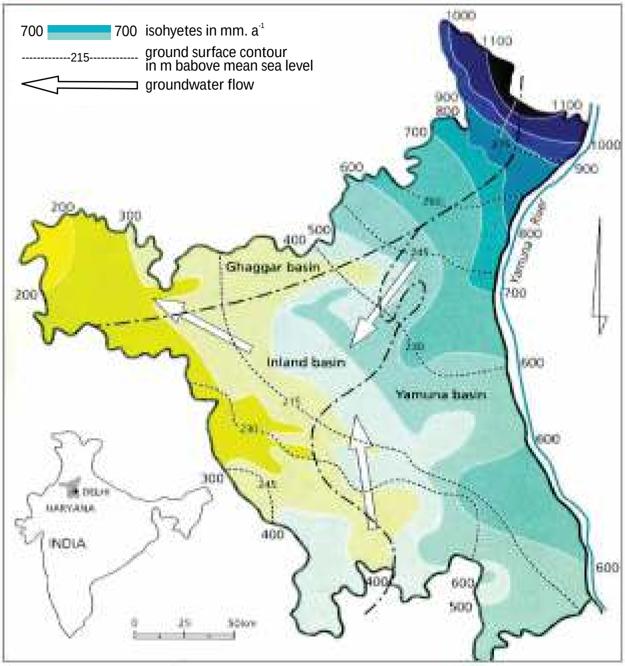


Fig.1: Geographic domain of Haryana

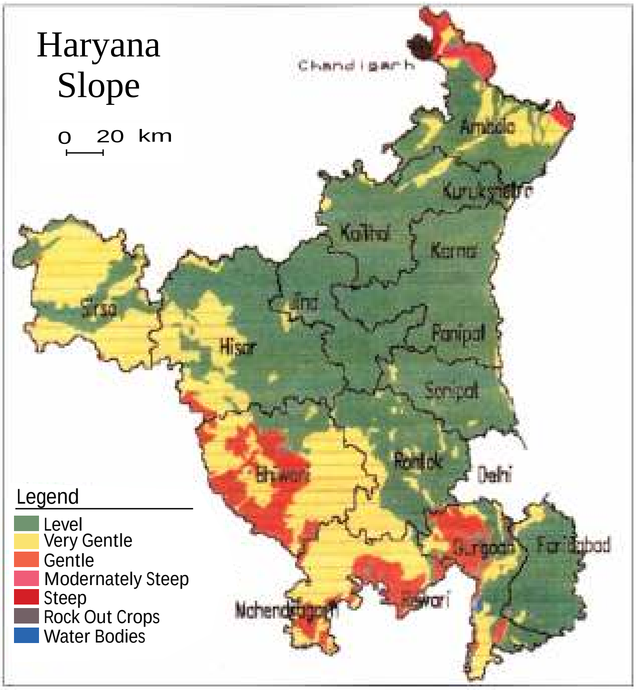


Fig.2: Haryana physiography

cultivation, pollution of water and environment and threat of climate change on agriculture, and thus a real challenge to sustain 4% or higher growth of agriculture sector in the State. Inevitably, the food security situation is likely to become critical in the changing scenario if urgent actions to prepare the farmers to adopt appropriate soil, water and crop management practices to face the futuristic problems of resource constraints are not taken.

There is need to change the fatigue of green revolution by improving the resource base and environment. For Haryana, water is the key issue for sustainable growth of agriculture. The GCM models predicted that the Indian Sub-continent will be warmer by about 1.5°C during the middle of the current century. It is also the fact that each 1°C rise in temperature will increase the demand for irrigation water by 2-3 percent to sustain production at the current level, and the competing demands of fresh water for drinking and industrial purposes will further reduce availability of fresh water supplies for agriculture. It implies that agriculture will be the major user of poor quality waters; hence, unproductive loss of water through evaporation and other processes have to be reduced to sustain food production. The productive and economic efficiency of water and other inputs is interlinked and could be increased by maintaining proper soil health, resource conservation and augmentation, selection of location specific water management technology and crop diversification as well as by shifting the focus from purely crop commodity approach to integrated farming system approach to help the resource poor farmers of the State. Thus, the complex and interlinked issues concerning land use, soil and water resources, biodiversity, climate change and environment need to be critically addressed in a holistic way for their critical monitoring, conservation, augmentation and utilization for the sustainable progress of agriculture in the State.

2.0 NATURAL RESOURCES

2.1 Soil Resources

Soil resources of the State are developed on alluvium in the plains and on detrital and alluvial materials in northern sub-mountains tracks, an aeolian material in the extreme western fringe and on alluvium modified by aeolian activity in southern and south western part of the State. Taxonomically, Inceptisols are dominant soils occupying about 58% of the area followed by Entisols (28%), Aridisols (9%) and Alfisols (2%) (Fig.3). Texturally, fine loamy soils are dominant and cover 43% of the area, coarse loamy soils cover 34% and sandy soils 23% of the total area.

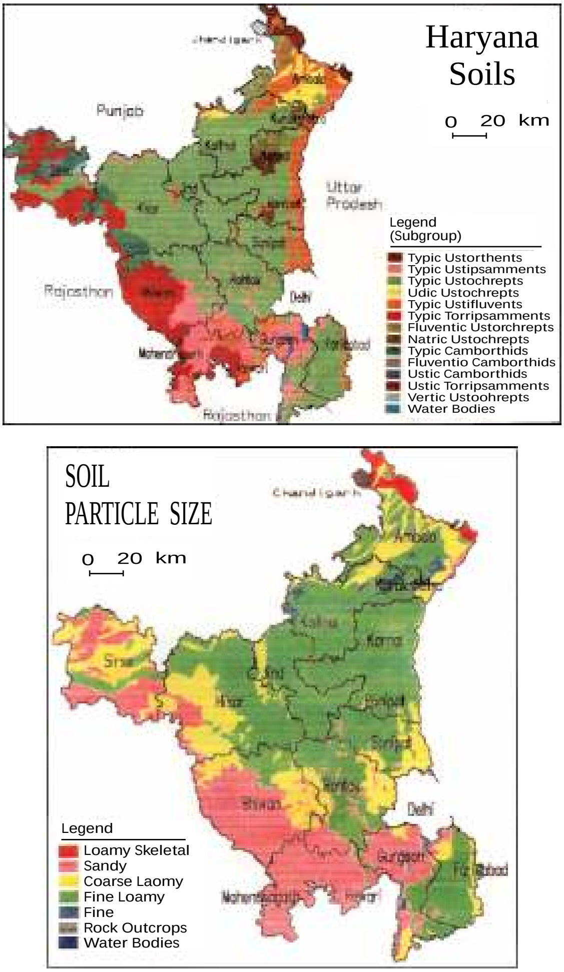


Fig.3: Soil resources of Haryana (Textural classification)

Soils of the State are highly prone to degradation on several accounts. Erosion by wind and water is dominant over some 20% of the area. Organic matter content of the soils and their nutrient supplying capacity are low and thus necessitating intensive use of organic manure, green manure and biomass along with fertilizers and irrigation in high yielding varieties to achieve enhanced crop productivity. Large parts of the State are highly prone to degradation due to redistribution of salts in the soil profile in time and space.

Some reports suggest that around 54% of total geographical area in Haryana suffers from different types of land degradation processes. Waste land map published in 2005-06 indicates about 3 lac ha area under such lands (Fig 4).

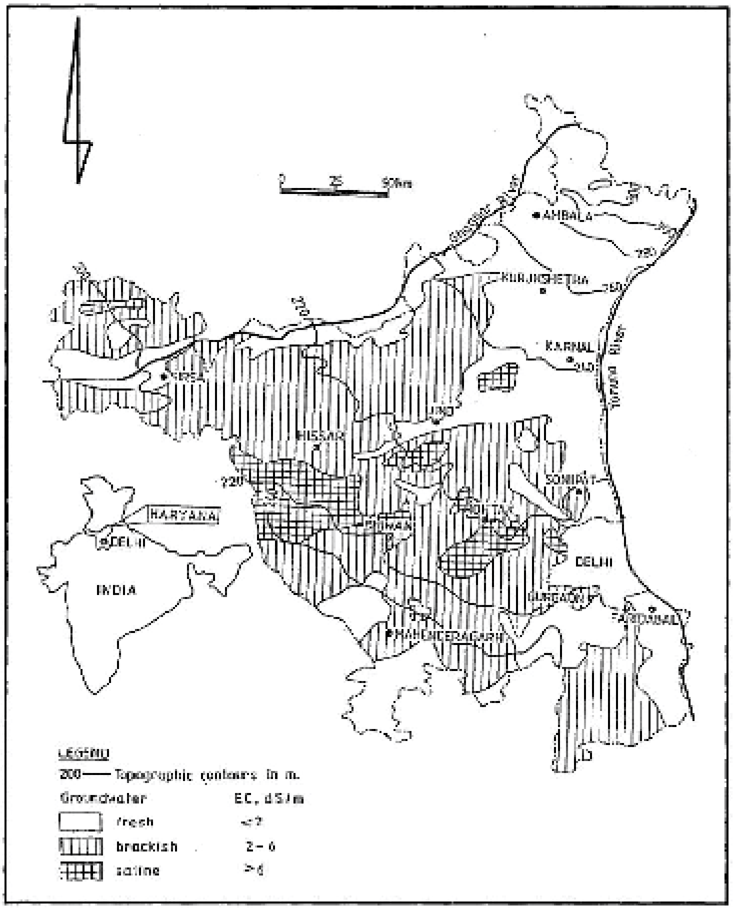


Fig.4: Wasteland map of Haryana

Current agricultural practices are proving increasingly unsustainable, causing worsening of natural resource base and posing serious questions in face of emerging challenges.

2.2 Water Resources

The total potential of surface and ground water resource is estimated at 1.51 and 1.24 m ha m respectively, amounting to 2.75 m ha m including ground water of marginal quality (Figs. 5, 6). The north eastern part of the State is extensively underlain by fresh ground water, the remaining 28,000 km² (about 60%) is underlain by brackish to very saline groundwater. Considering urban and industrial needs of water resources, existing available water resources can meet hardly 60% of the irrigation requirements. Over the past 4 to 5 decades, all out efforts have been made to tap all available resources to meet agricultural needs. Western Yamuna Canal originating from river Yamuna, and Bhakra Canal originating from river Sutlej constitute the main surface irrigation system. The Western Yamuna Canal which takes water up to Hisar is one of the oldest canals of this region, constructed in 1351AD by Ferozshah Tuglak and remodeled later by King Shahjahan. Secondary

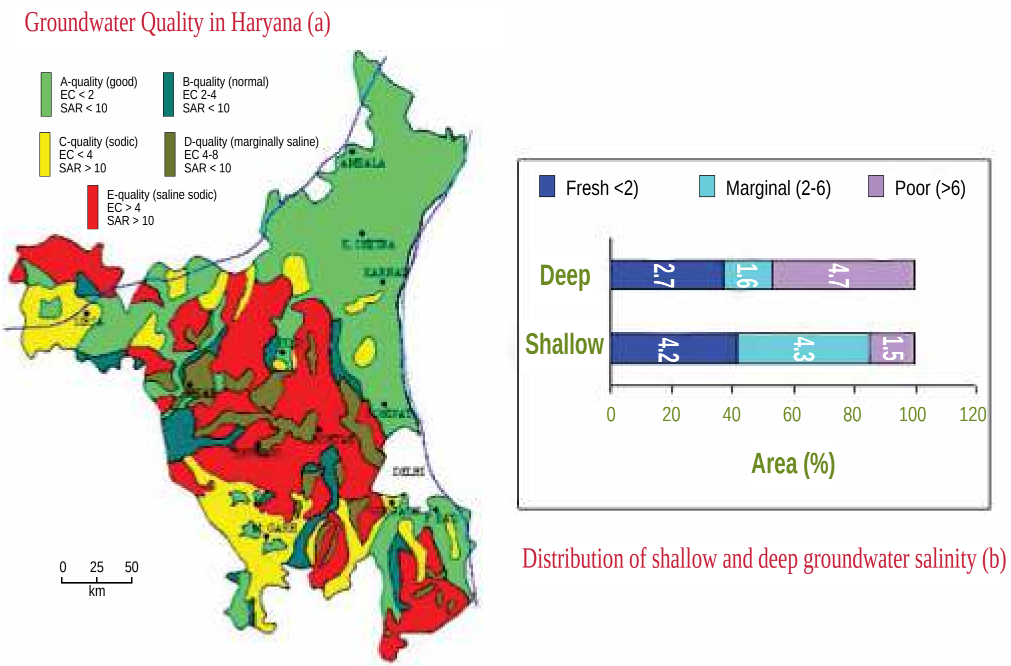
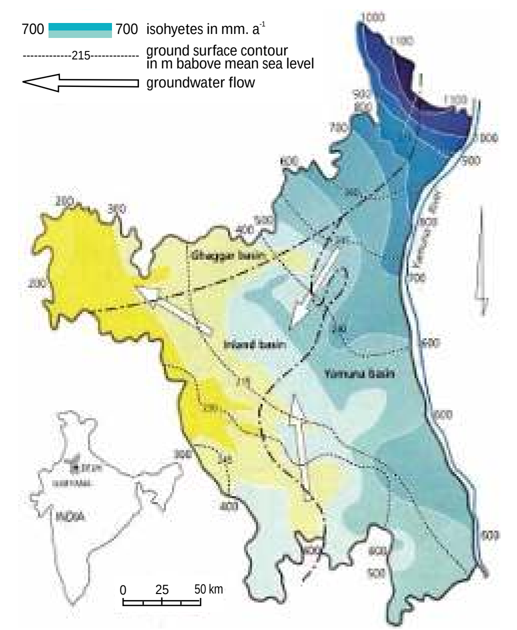
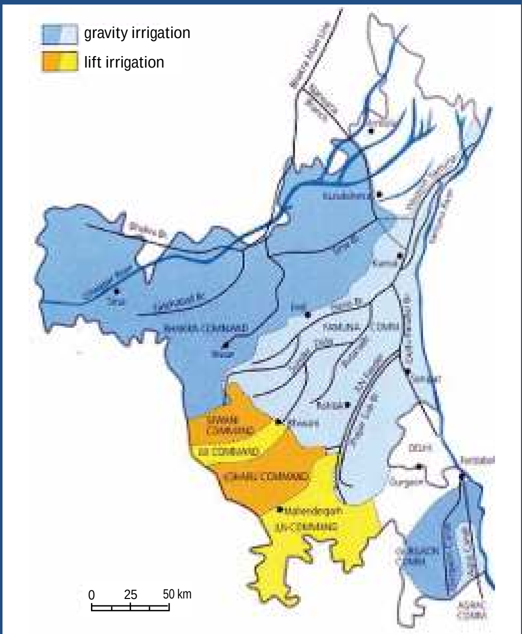


Fig.5: Ground water quality (a) and its distribution (b) in Haryana



Source	Amount available (BCM)
River Sutlej	4.94
River Ravi-beas	4.05
River Yamuna	5.88
River Ghaggar	0.48
River Soamb/pathrala, Drais and escapes	1.13
Sarda-Yamuna Link	0.29
Total	**16.77**

Fig.6: Source and amount of available surface water in Haryana



Name of system	CCA (ha)
Bhakra Canal system	**11,66,398**
WJC systems	
WJC	10,84,028
Gurgaon Canal	1,30,588
Jui Canal (lift)	30,160
Loharu Canal (lift)	1,06,715
Sewani Canal (lift)	73,563
JLN Canal (lift)	2,49,901
Naggal Canal (lift)	23,200
Agra Canal channels	**61,165**
Total	**29,25,718**

Fig.7: Surface (canal) water supply system and its CCA in Haryana

and tertiary canal systems include Gurgaon and a number of lift irrigation projects including Jui, Indira Gandhi, B. N. Chakraborty and Jawaharlal Nehru lift irrigation schemes that raise water in stages upto 174m to bring irrigation to sandy tracks of western and southern Haryana (For other details, see Fig.7).

The inadequacies of the present irrigation system in the State are accentuated by insufficient water allowance. Irrigation intensity from Bhakra Canal system is 62% while from Yamuna system it is about 50%. For lift canals the irrigation intensity varies from 4 to 38 % depending upon availability of water and electricity. The State has a good net work of canals with 1830 km length of main canals and branches, about 8400 km length of minors and distributaries, including more than 10,000 water courses. Eastern part of the State is relatively less covered with canal irrigation.

Over the past decades, the State has witnessed extensive development of groundwater through tubewell irrigation. The number of tubewells in the State has increased from less than 40,000 in sixties to 6.97 lacs as on April 1, 2011. Of these, while 4.62 lac are electrically operated, the remaining 2.35 lac are diesel sets. As a result of these efforts ground water now accounts for about 55% and canal based surface water accounts for 45% of the net irrigated area of 3.02 mha (85.98% of the gross cropped area of 6.458 mha). *While water resources and irrigation development have constituted the key strategy to improve agricultural productivity; technological, institutional and policy environment have contributed to serious problems raising concerns of sustainability of agriculture and past approaches.*

2.3 Climate and Agroecological Zones

The climate of the region being semi arid and arid, water resources of the State have played a critical role in the improvement and sustainability of agricultural production. Mean annual rainfall of 545 mm, is received unevenly in the State (Fig. 8) and the annual evaporation demand exceeds 1500 mm. The GCM models predicted that the Indian Sub-continental will be warmer by about 1.5°C during the middle of current century, and the second half of the winter will be warmer than the first half. It is also predicted that the Indian sub-continent would receive about 6% more rains which could be irregular and more intense. There will be some reduction in the incident radiation and increase in the concentration of CO2 and other green

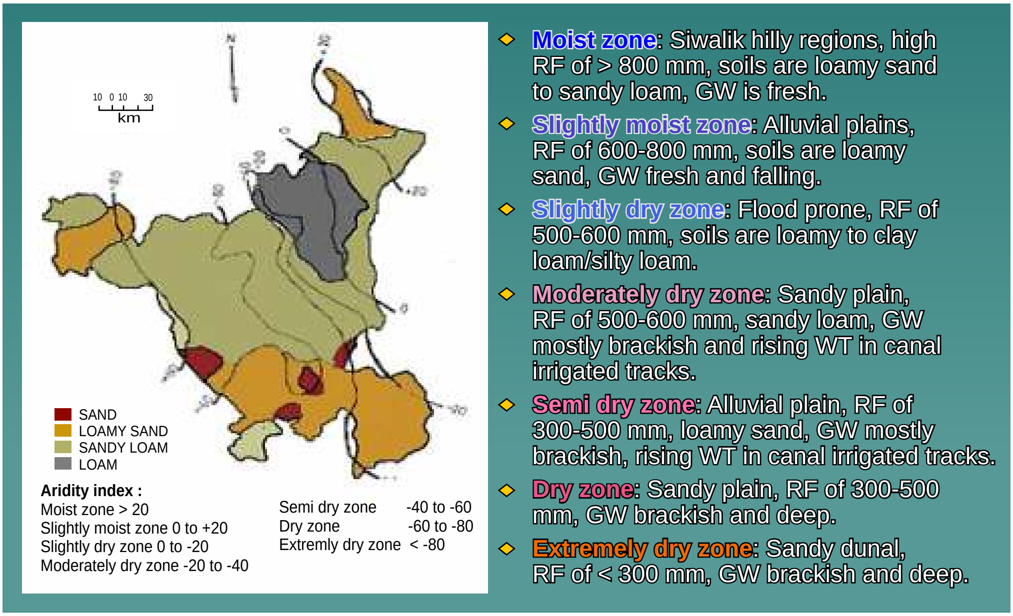


Fig.8: Agro-ecological zones of Haryana

house gases during the current century. Thus, there is a need to undertake appropriate adaptation and mitigation measures to address the impact of climate change on agriculture.

Based on agroecology and cropping pattern, the State can be broadly divided into 3 zones. Zone-I: It consists of 8 districts, namely Panchkula, Ambala, Kurukshetra, Yamunanagar, Karnal, Kaithal, Panipat and Sonipat. This zone forms nearly 32 percent of the total area of the State. Zone-II: It has 7 districts, namely Sirsa, Fatehabad, Hisar, Jind, Rohtak, Faridabad and Palwal. This zone forms nearly 39 percent of the total area of the State. Zone-III: It covers 6 districts, namely Bhiwani, Mohindergarh, Rewari, Jhajjhar, Gurgaon and Mewat. This zone forms nearly 29 percent of the total area of the State.

Based on agro-ecological conditions, the CCS HAU has established four Regional Research Stations (RRS) to address the location specific problems in different parts of the State alongwith their fruitful linkages with various Departments at its H.Q., Hisar. The Regional Research Stations established during the operation of NARP Project are at Karnal, Sirsa, Rohtak and Bawal. The Regional Research Station at

Karnal has the mandate to address problems in relation to rice, wheat, sugarcane and maize based cropping systems, while RRS Sirsa deals primarily with cotton-wheat system. The area mandated for RRS Rohtak is dominated by rice, wheat, sugarcane, mustard and sorghum crops. This inland basin covers major area subjected to rise in water table, water logging and salinity problems. The Dry Land Research Station at Bawal has pearlmillet-wheat/mustard, clusterbean-wheat/mustard and pulse based cropping systems. All these regional research stations have basic infra-structure facilities including multidisciplinary team of scientists sanctioned during the operation of NARP project. Recently, a good network of KVKs has also been developed covering each district of the State with a view to transfer need based agro-technology to the farmers. The scientists at the regional stations are supposed to carry out the need based adaptive research in multidisciplinary mode, including addressing the location specific problems of NRM. However, there is lack of existence of *effective multidisciplinary team of scientists to address location specific issues of NRM both at RRS and KVKs of SAU in the State*.

2.4 Crops, Cropping Systems and Biodiversity

Agro-climatic resource conditions, development of water resources and the State policies have contributed to the prevalent crops and farming systems in different parts of the State. The main aim of research and development was to maximize the productivity of crops with relatively little attention to sustainability of resource use and management. The crop cultivars currently grown are mostly modern short statured high yielding and have replaced many of the traditional cultivars adopted earlier by the farmers. With practically little attention devoted to understanding and addressing issue of biodiversity and its dynamics, it has started reflecting in emergence of new disease and pest scenario seriously threatening production base. As an example, introduction of high yielding varieties of rice and wheat crops and improvement in irrigation facilities and use of chemical fertilizers, the indigenous sorghum, maize and millets growing area has been shifted to mainly rice-wheat system. The traditional indigenous crops, their varieties/ races/ biotypes occurring naturally, which were not high yielding otherwise, had many desirable characters like resistance to various biotic and abiotic stresses and better quality. The crops and varieties which have been shifted from this zone include sweet sorghum (Indian Dura), desi maize, desi cotton, sesame, pigeon pea, taramira *(Eruca sativa)*, kangri (minor-millet), sun hemp, sugarcane species *(S. barberi and S. sinense)*, rice varieties (Basmati 370, Jaya), desi wheat (Pb591, C306) etc. The shifted fruit trees include jamun *(Syzygium cuminii)*, *Moringa oleifera*, tint *(Capparis aphila)* and pillu *(Salvadora persica)*; vegetables include potato varieties Kufri Chandarmukhi and Kufri Sinduri, cholai *(Amaranthus polygamus)* and wild cucurbits (phoot); and forest trees include Chilkhan *(Ficus retusa, Ficus glomerata)*, kikkar *(Acacia nilotica)*, Khejari *(Prosopis cineraria)*, bamboos *(Saccharum bambooja)*, jall *(Salvadora oleoides)*, Kendu *(Dysopyrus spp.)*, dhak *(Butea monosperma)*, mulberry *(Morus alba)* and bushy ber *(Ziziphus jujuba)*. The population of animal spp. including jackal, vulture, peacock, sparrow and deer has drastically reduced, whereas, the population of Blue Bull (Neelgai), wild pigs and monkeys has increased dramatically.

The new races of red rot diseases have been identified affecting sugarcane varieties. The prevalence of diseases like Pokkah Boeng and top rot disease in sugarcane has increased. Diseases like yellow rust in wheat, backanae in basmati rice, sheath blight and maydis leaf blight (MLB) and bended leaf and sheath blight (BLSB) and common rust in maize have also increased.

Sporadic incidences of army worms, cut worms and grass hoppers are occurring mainly due to changes in cropping pattern, varieties and climatic factors, and secondly due to changes in farm practices are being reported. In sugarcane, the incidence of whitefly, webbing mite and trips is also being noticed.

The root knot nematode is prevalent in wheat and vegetable crops. In the soil, there is prevalence of algae-Azolla, Anabaena, Fusarium fungi, VAM and Orobanche; whereas the population of nitrogen fixing bacteria – Azotobactor, Azosprilum, Rhizobium; and different species of Psedomonas, Bacillus, Panebacillus and Agrobacterium and earth worms has decreased.

With the intense cultivation under rice-wheat system, the infestation of grassy weeds has increased, whereas the population of broad leaf weeds (like *Chenopodium* *album*, *Circium ravens*) has decreased. Particularly, the weed *Phalaris minor* in wheat has put a threat to wheat cultivation. Similarly the control of orobanche in mustard and other solanaceous crops and Makara grass *(Dactyloctenium aegyptium)* in direct seeded rice is real challenge to the scientists. On the roadside and uncropped land, the population of *Parthenium hysterophorus* and *Chenopodium ambrosoides* has also increased.

In addition to the main field crops viz, rice, wheat, sugarcane, maize, rape seed and mustard, pulses and vegetables crops, the improved varieties of fruit trees like mango, guava, peach, plum, lemon, *Emblica officinalis*, *Ziziphus mauritiana*, *Litchi chinensis*, sapota *(Pouteria sapota)*, pomegranate, papaya and forest trees plantations of eucalyptus, poplar *(Populus nigra)*, *Tectona grandis*, *Azadirachta indica*, *Dalbergia sissoo*, and *Prosopis juliflora* are more prevalent in the current system of agro-biodiversity.

Biodiversity dynamics has important implications for sustainability of production systems. *As of now there is inadequate appreciation and a built in research for development agenda to guide appropriate strategies and interventions for preservation and utilization of agro-biodiversity.* Thus, there is need for effective steps to focus on the large amount of bio-diversity, both the underground and above ground, for their proper utilization and preservation to meet the futuristic needs.

2.5 Agricultural Development and State of Natural Resources

Over the past four decades, the State has made rapid strides to achieve goals of enhanced agricultural productivity and contributed significantly to achieve food grains production goals towards meeting the growing demand for increasing population, export etc. Expansion of area under irrigation involving a network of canals, minors, lift canals, support for sinking tubewells, credit and marketing constituted the core of the strategy to achieve production goals together with availability and adoption of improved high yielding crop cultivars, increased use of fertilizers and plant protection chemicals (Table1). These efforts driven by the Central Government and supported and implemented by the State Government in the form of number of 'schemes' have yielded dividends by way of Haryana emerging as a front runner State in agriculture.

As a result of these efforts, the State has witnessed increased food grain production from just 2.6 million tons in 1966-67 to 16.6 million tons in 2010-11. Haryana with just 1.4% (4.4 Mha) of the total geo-graphical area of the country is the second largest contributor of food grains (17.6% in 2009-10) to the national food basket. Similarly production has increased by more than 8 times in oil seeds, 6 times in cotton and 9 times in sugarcane (Figs. 9, 10; Table 2).

Table 1: Agriculture Development in Haryana

Area (000 ha)	1966-67	2010-11
Geographic Area	4421	4421
Cultivable area (% of total geographic area)	86.45	86.27
Net sown area	3423	3576
Total cropped area	4599	6484
Cropping intensity (%)	134.4	181.3
Net irrigated area		
(i) Canals	991	1277
(ii) Minor irrigation	302	1602
Total	1293	2879
Gross irrigated area	1736	5528
% Net irrigated area	37.8	84.16
% Gross irrigated area	37.7	86.00

Source: website of Agriculture Department, Haryana

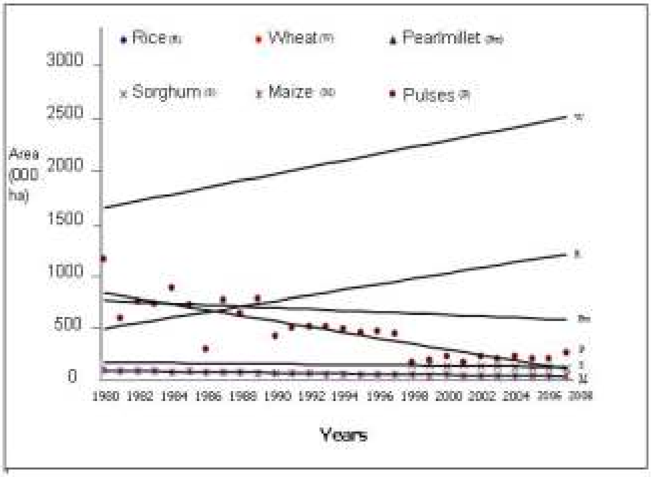


Fig.9: Trends in acreage under food grain crops from 1981 to 2008

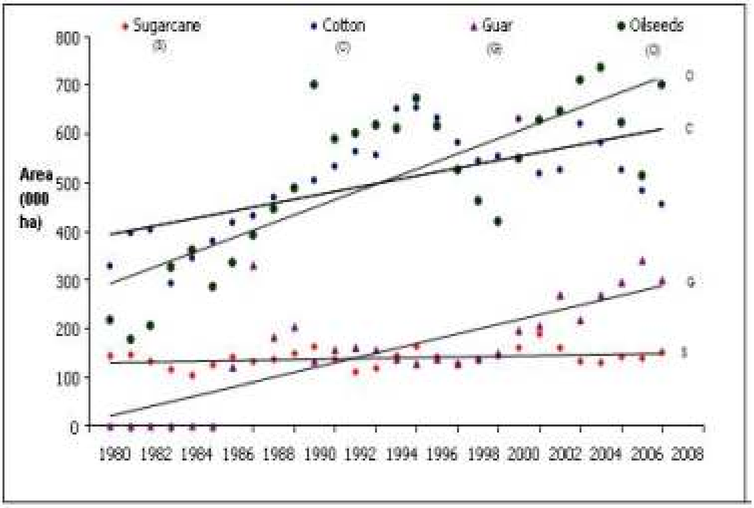


Fig.10: Trends in acreage under commercial crops from 1981 to 2008

Table 2: Agricultural Development in Haryana– Area (A: 000 ha), yield (Y: kg/ha) and production (P: 000 t)

Crop		1966-67	2010-11
Rice	A	192	1245
	Y	1166	2789
	P	223	3472
Wheat	A	743	2512
	Y	1425	4624
	P	1059	11630
Bajra	A	893	661
	Y	418	1793
	P	373	1185
Oilseed (Rapeseed/ mustard)	A	211	504
	Y	435	1869
	P	92	942
Cotton	A	183	492
	Y	283	603
	P	305	1744

Source : website of Agriculture Department, Harayan

The major achievements in agricultural development over the past 40 years have come from expanded irrigation area; 1.293 mha in 1966-67 to 3.025 mha in 2007-08, increased availability and access to seeds of high yielding improved crop cultivars and agro-chemicals. These achievements were made possible through a contribution of technological support, creation of State level institutions that enabled farmers' access to required inputs and policy regimes which focused on increasing productivity of a few crops to achieve national self sufficiency goals within a short time. *While these achievements have contributed in building food grains stocks at the national level, yet distorted trends in land use, cropping pattern, input use efficiency, factor productivity, cost of cultivation and overall natural resources base pose serious questions to future of agriculture in the State. Thus, there is a need to reinvent future course of development which is more sustainable and in long term more farmers and ecofriendly.*

Increased cropping intensity accompanying access to surface and groundwater resource has favored maximum exploitation of water resource by growing high water requiring crops like rice, wheat, sugarcane and cotton in favor of traditional low water requiring crops. Significant shifts in the cropped area include an increase of over 34 % area under wheat and 87 % area under rice and 81% area under cotton between 1990 and 2010, all intensive water use crops (Table 2). In contrast, the area under traditional low water requiring crops including pearl millet and sorghum are on the declining side (Table 3).

Table 3: Decline in area under selected crops in Haryana

Crop	Area (000 ha)	
	1966-67	2010-11
Gram	1062	112
Barley	182	37
Rabi pulses (other than Gram)	50	9
Sorghum	270	72
Maize	87	12
Pearl-millet	893	661

Source: website of Agriculture Department, Haryana

2.5.1 Poor Soil Health

Soils of Haryana are inherently low in organic matter content. Due to all out emphasis on chemical fertilizers to meet the nutrient needs for achieving high crop productivity, farmers' dependence on recycling of green manure, crop residues, FYM, farm composts etc has greatly declined preventing replenishment and maintenance of organic matter. Majority of the soils (70%) have low organic carbon (<0.40%) while some 30% of the soils are in 0.40-0.75% range of soil organic carbon. Imbalanced use of chemical fertilizers favoring excessive use of N relative to P, K and other nutrients is contributing to inefficient use, low response, increased pollution of surface water bodies and ground waters and increased GHG emissions.

Haryana currently uses around 220 kg of nutrients per ha cropped area, being second highest in country (Fig 11, Table 4). Mass of scientific evidence shows that the use efficiency of applied fertilizers is low and this is attributed to a number of factors including a mismatch in the need and supply of nutrients, inappropriate crop, soil and water management practices, superimposed by high spatial variability in the soil characteristics, water management regimes, climate condition etc.

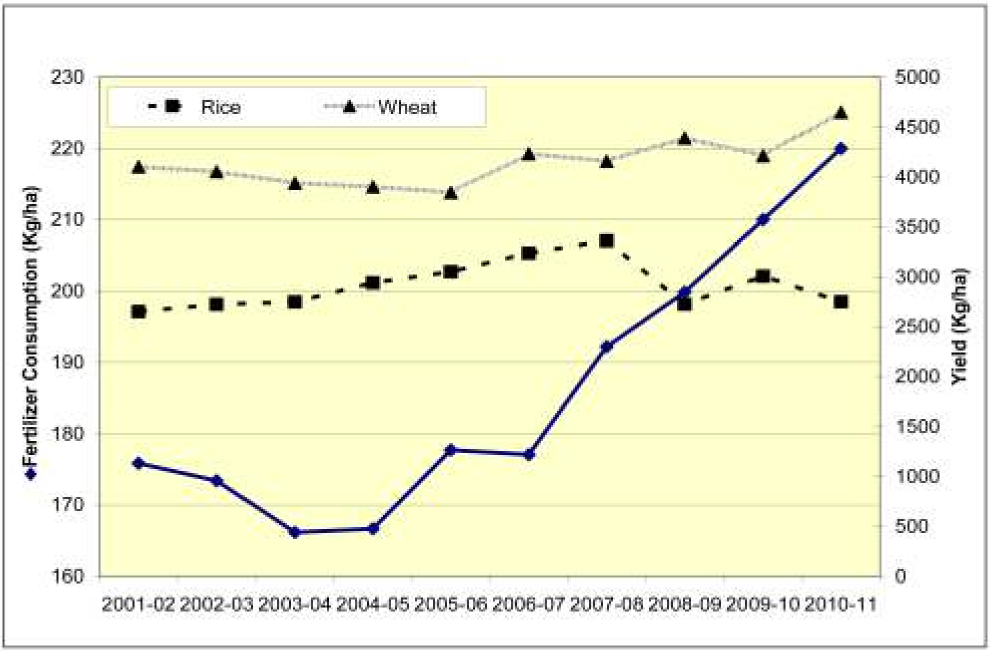


Fig.11: Fertilizer consumption and yield of rice and wheat in Haryana

Table 4: District-wise fertilizer consumption of NPK (kg/ha) in Haryana (2008-09)

Nutrient consumption (Kg/ha)	Districts (No)
>250	Kurukshetra, Karnal, Panipat, Sonipat, Yamuna Nagar (5)
200 – 250	Ambala, Rohtak, Faridabad (3)
150 – 200	Kaithal, Rewari, Jind, Sirsa, Fatehabad (5)
100 – 150	Hisar, Gurgaon, Panchkula, Mewat (4)
50 – 100	Bhiwani, Mahendergarh, Jhajjar, Palwal (4)

Source: Website Agriculture Department of Haryana

An analysis of total fertilizer consumption in Haryana suggests that more than half of the total fertilizer is consumed in one third of districts, primarily dominated by intensive rice-wheat cropping system (Table 4). The NPK use ratio is also highly distorted and varies over the years in the State (Table 5). Out of total 1.7 lac analyzed samples between 2010-2011, 12% showed iron deficiency, 9% zinc deficiency and 2% manganese deficiency (Table 6). The iron deficiency is emerging in several districts in coarse textured soils and in alkali saline situation. The deficiency of sulphur is also becoming very apparent in oil seeds and pulses in the State. Therefore, geo-referenced soil fertility maps are very important to maintain proper balance between different nutrient uses in the State.

Table 5: Consumption ratio of N: P2O5: K2O in Haryana

Year	N	P2O5	K2O
1966-67	67	3	1
2005-06	40	12	1
2010-11	20.5	7	1

Source: Website Agriculture Department of Haryana

Fertilizer use recommendations are largely crop based and rarely take into account the cropping and farming system perspective in building such recommendations. High variability in soil characteristics, water availability and crops & farming systems further render generalized fertilizer recommendations highly inappropriate, economically and environmentally. Extraction and mining of major secondary and micronutrients is causing increasing deficiency of these elements. While deficiency

Table 6: District-wise micronutrient deficiencies in Haryana (2010-11)

District	Total Samples No.	Number of soil samples analyzed and found critical					
		Zinc	Critical %	Iron	Critical %	Manganese	Critical %
Ambala	16564	733	4.4	834	5.0	262	1.6
Yamuna Nagar	4966	446	9.0	307	6.2	57	1.1
Kurukshetra	11897	812	6.8	653	5.5	270	2.3
Kaithal	2350	196	8.3	277	11.8	49	2.1
Karnal	24432	1825	7.5	2594	10.6	342	1.4
Panipat	2100	222	10.5	168	8.0	25	1.2
Sonipat	4040	441	10.9	470	11.6	97	2.4
Rohtak	4714	438	9.3	433	9.2	63	1.3
Jhajjar	4018	520	12.9	597	14.9	164	4.1
Gurgaon	3616	286	7.9	433	12.0	77	2.1
Mewat	1766	209	11.8	292	16.5	96	5.4
Faridabad	2642	276	10.4	359	13.6	178	6.7
Rewari	17988	1213	6.7	2394	13.3	395	2.2
Mahendergarh	10931	1271	11.6	1888	17.3	343	3.1
Bhiwani	5558	663	11.9	964	17.3	209	3.8
Jind	17686	1967	11.1	2761	15.6	176	1.0
Hisar	9035	578	6.4	674	7.5	101	1.1
Fatehabad	11395	1547	13.6	2177	19.1	209	1.8
Sirsa	15875	1403	8.8	2021	12.7	413	2.6
Total	173413	15046	8.6	20480	11.8	3636	2.1

Source: Website of Agriculture Department of Haryana

of nitrogen is almost a rule, P status is also low to medium in majority of soils. K status is low in about 20% of the area while 70% of soils have a medium status. The use of ZnSO4 as a fertilizer has been increasing over the years. So has the need for application of elements like sulphur, iron and manganese. The need for regular application of soil correctives like gypsum has been on the increase. Gypsum helps temporarily overcome problems relating to water infiltration and sodicity build up due to use of brackish groundwater. All these developments have serious implication towards sustaining agriculture in a State with great majority engaged in agriculture based livelihoods.

2.5.2 Unsustainable Water Use

While development of water resources has been a key strategy towards the agricultural development in Haryana over the past decades, the State now faces serious challenges in sustaining agriculture on account of a variety of issues relating to sustainable water use. Both surface and groundwater resources are critical to agriculture. Of the 5.45 mha gross irrigated area, nearly 55% area receives irrigation from a large number of tubewells and about 45% from the vast canal network. The pattern of groundwater dynamics in the State varies according to the geo-hydrological setting and cropping pattern as have evolved and the related water management practices and pursued policies. Trends in groundwater development with regard to the ground water exploitation in the State show that out of the total 119 blocks in the State, 70 are already overexploited (ground water development >100%) , another 21 blocks are in critical range (90-100%), 9 blocks are semi critical (70-90%) and the remaining 18 blocks are safe (<70%) (Table 7). However, the Morni Block of Panchkula could not be assessed due to complete Hilly area.

Water table during past 34 years (1974-2008) on an average declined to 5.75 m across the State. However, during subsequent period of three years (2008-2011), there has been drastic decline in water table depth reaching to 15.94 m (Table 8). Over exploitation of ground water is higher in districts Mohindergarh (43.68 m), Kurukshetra (29.18 m), Gurgaon (24.54 m), Bhiwani (21.44 m), Rewari (21.03 m), Fatehabad (20.93 m), Kaithal (20.68 m), Sirsa (17.34 m), Karnal (16.17 m), Panchkula (14.96 m) and Faridabad (13.63 m) in the State. Declining water tables have serious implications by way of increased pumping costs as farmers have to shift to costly deep tubewells where in some area there are indications of water quality decline due to possible intrusion of brackish water from adjoining saline groundwater regions. Contrary to the north-eastern districts, rise in water table is a serious concern in the largely canal irrigated central and western districts. It is estimated that about 68,800 ha area is completely waterlogged, 2, 51,800 ha is categorized as partially waterlogged while 1.66 mha is considered to be potentially water logged.

Table 7: Categorization of the blocks based on utilization of ground water resources (As on 31st March 2009)

District	Over Exploited > 100%	Critical 90-100%	Semi Critical 70-90%	Safe < 70%
AMBALA	Barara, Naraingarh Saha	Shazadpur, Ambala II	Ambala I	
PANCHKULA	Barwala	Raipur Rani, Pinjore, Morni*		
FATEHABAD	Fatehabad, Ratia Tohana, Jakhal	Bhattu Kalan, Bhuna		
BHIWANI	Badra, Dadri-I Kairu, Loharu	Dadri-II, Siwani		Bhawani Khera Tosham, Bhiwani
HISAR	Narnaund	Adampur	Agroha Uklana, Hansi-II	Barwala, Hansi-I, Hisar-I, Hisar-II
GURGAON	Farukhnagar, Sohna Gurgaon, Pataudi			
MEWAT	Tauru, Ferozepur Zhirka	Punhana		Nagina, Nuh
FARIDABAD	Faridabad	Ballabhgarh		
PALWAL	Hodel, Palwal Hassanpur	Hathin		
JHAJJAR		Jhajjar	Bhadurgarh Salhawas	Matanhail, Beri
JIND	Alewa, Narwana, Safidon	Jind, Pilukhera Uchana		Julana
KAITHAL	Gulha, Kaithal, Pundri Kalayat, Rajaund, Siwan			
KARNAL	Assandh, Karnal Gharaunda, Indri Nilokheri, Nissang			
KURUKSHETRA	Babain, Ladwa Pehowa, Shahbad Thaneswar			
MAHENDERGARH	Ateli, Kanina Mahendergarh, Narnaul Nangal Chaudary			
PANIPAT	Bapoli, IsranaMadlauda, PanipatSamalkha			
REWARI	Nahar, Rewari Bawal, Khol	Jatusana		
ROHTAK			Rohtak Lakhan Majra	Kalanaur, Meham Sampla
SIRSA	Ellenabad, Rania Sirsa, Ns Chopta	Baraguda	Odhan	Dabwali
SONIPAT	Ganaur, Rai Sonipat	Gohana, Kharkhoda		Kathura Mundlana
YAMUNANAGAR	Jagadhri, Radour Mustafabad Sadhuara, Chachrauli	Bilaspur		
STATE TOTAL	70	22	09	18

* Not assessed (Source: Department of Agriculture, Haryana)

Table 8: District-wise trends in water table depth during past 37 years (1974-2011) in Haryana

	District	Period	Fluctuation of water table depth (m)			
			1974	2008	2011	1974-2011
1	AMBALA	June	5.79	9.31	9.63	-9.63
		October	5.59	8.69	8.32	-8.32
2	BHIWANI	June	21.24	21.98	21.44	-21.44
		October	21.02	21.58	21.7	-21.70
3	FARIDABAD	June	6.43	10.61	13.63	-13.63
		October	5.25	9.57	13.46	-13.46
4	FATEHABAD	June	10.48	15.98	20.93	-20.93
		October	10.32	16.76	21.79	-21.79
5	GURGAON	June	6.64	22.62	24.54	-24.54
		October	6.33	22.67	24.34	-24.34
6	HISAR	June	15.47	7.58	7.7	-7.70
		October	15.01	6.78	6.91	-6.91
7	JIND	June	11.97	10.43	11.05	-11.05
		October	11.35	9.68	11.2	-11.20
8	JHAJJAR	June	6.32	5.27	4.28	-4.28
		October	5.77	4.35	3.66	-3.66
9	K. KSHETRA	June	10.21	28.79	29.18	-29.18
		October	9.96	28.63	31.05	-31.05
10	KAITHAL	June	6.28	18.34	20.68	-20.68
		October	6.21	18.70	21.44	-21.44
11	KARNAL	June	5.72	15.19	16.17	-16.17
		October	5.37	15.28	17.15	-17.15
12	M. GARH	June	16.11	41.08	43.68	-43.68
		October	15.82	39.68	42.48	-42.48
13	MEWAT	June	5.56	10.31	11.59	-11.59
		October	4.07	9.57	10.67	-10.67
14	PALWAL	June	5.37	-	8.68	-8.68
		October	4.37	-	8.71	-8.71
15	PANIPAT	June	4.56	14.45	15.29	-15.29
		October	4.18	14.34	14.56	-14.56
16	PANCHKULA	June	7.58	12.19	14.96	-14.96
		October	7.64	12.35	14.76	-14.76
17	ROHTAK	June	6.64	4.20	3.63	-3.63
		October	5.83	3.15	2.97	-2.97
18	REWARI	June	11.75	22.21	21.03	-21.03
		October	11.41	20.73	20.8	-20.80
19	SONIPAT	June	4.68	7.56	7.85	-7.85
		October	3.89	7.00	7.08	-7.08
20	SIRSA	June	17.88	14.14	17.34	-17.34
		October	18.45	14.25	17.38	-17.38
21	Y. NAGAR	June	6.26	9.76	11.4	-11.40
		October	5.44	10.50	10.94	-10.94
	State average	June	9.19	15.15	15.94	-15.94
		October	8.73	14.71	15.80	-15.80

The other aspects related to distribution and fluctuation in underground water quality over space and time in the State are depicted in Figs. 12, 13.

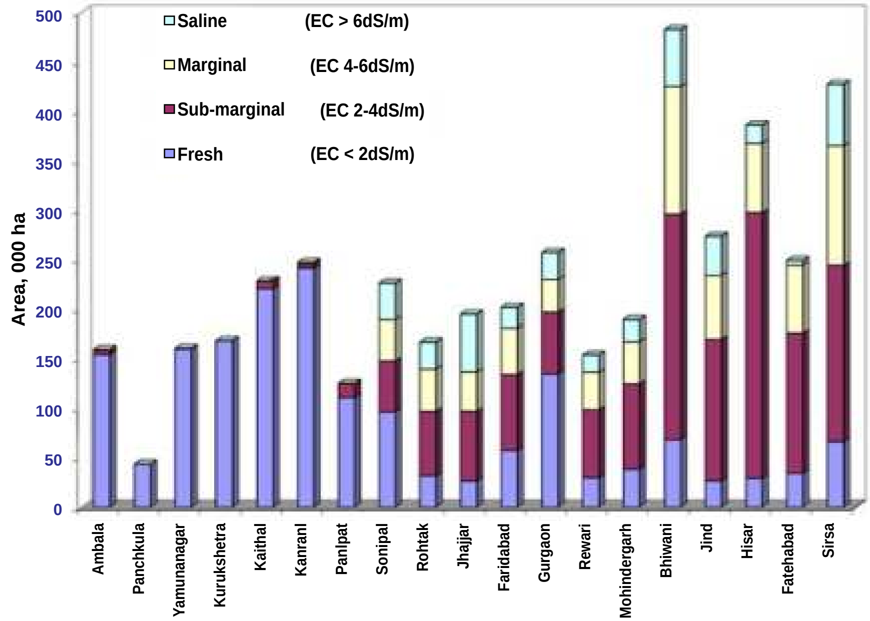


Fig.12: Area under different salinities on June, 2010 in various districts of Haryana

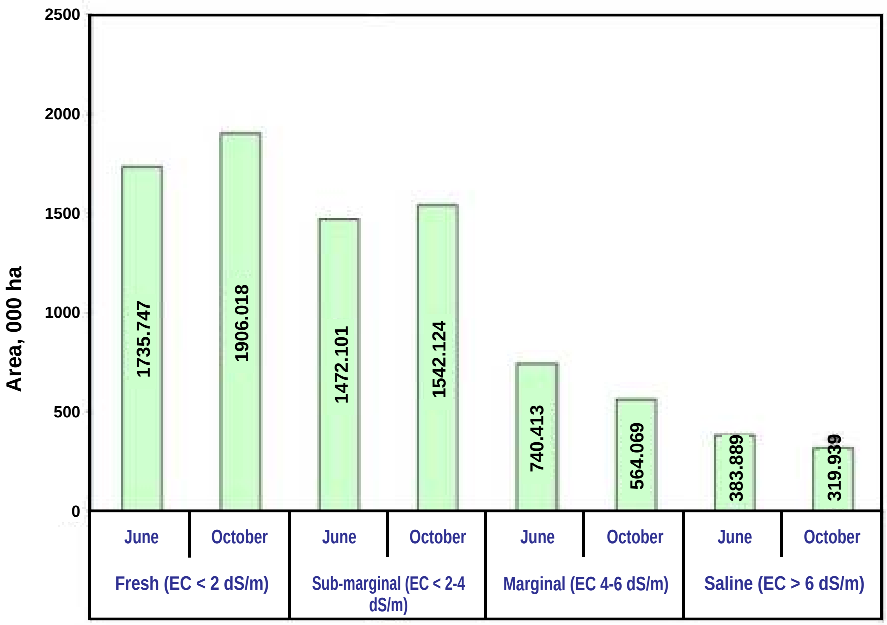


Fig.13: Area under different salinities on June and October, 2010 in Haryana

In the south western districts underlain by poor quality ground water, excessive pumping of groundwater is forcing farmers to use increasingly saline waters with resulting soil salinization/alkalization problems and increased demand for amendments etc.

Release of untreated industrial effluents into canals or disposal by injecting into groundwater in many areas is causing widespread pollution of soil and water resources which is adversely impacting the health of agriculture, livestock and human beings. Similarly, rapid urban development accompanied by limited water treatment plants and their capacity is resulting in uncontrolled land disposal of the sewage water, which is a source of widespread pollution of soil and water bodies. These are serious concerns that are not amenable to straight forward solutions and therefore call for a comprehensive look at the issues and plausible approaches to deal with them.

Problems of sustainable water use in the State are getting further exacerbated pressing demands to divert water resources from agriculture to other development sectors and also due to overall climate induced change events with greater uncertainty in rainfall and temperature regimes impacting sustainable use of resources.

With more than 80% cultivated area, low forestry cover (3.52%) despite very harsh climate, compulsion of diverting land for increasing industrial, urbanization, infrastructure and other needs is putting already degraded and limited land resources under high pressure. Sustaining agriculture in the face of multiple complex problems is the major challenge faced by the policy makers and planners.

2.6 Conclusions

Although the State of Haryana has benefited immensely from its agricultural achievements over the past decades, this success is built on a declining soil, water and biodiversity resource base. Agricultural intensification associated technological and policy regimes have led to serious unfavorable water and salt balances, drop in ground water levels in some areas and water logging and soil salinization problems in other areas. Urbanization, industrialization and changing lifestyles of an increasing population are other reasons for exploitation and deterioration of quality of groundwater. Equally worrisome is the deterioration of land and soil quality due to mining of nutrients, inappropriate use and management of chemical fertilizers, pesticides use and reduction of organic matter. With farmers facing a multitude of problems arising from declining factor productivity, increasing production costs, environmental pollution, uncertainties associated with increasing variability in rainfall and temperature regimes and the scientific community and policy makers having no straightforward or easy solutions to address NRM interlinked complex problems. Thus, agricultural sustainability in Haryana in economic, social and environmental terms is a matter of serious concern. *There is need to look for solutions which probably lie in fundamental shifts in the way agricultural research for development and addressing NRM problems have been viewed and addressed in the past.*

3.0 NATURAL RESOURCE MANAGEMENT ISSUES – PAST AND CURRENT EFFORTS AND NEEDS

3.1 Land Resources

According to available land use statistics, cultivable area in Haryana has remained practically constant at about 85% (3.5 mha) of the total geographical area (4.42 mha). Much of the area for other development needs has come from the so called 'wastelands' category of land use which has declined sharply over the past 4-5 decades. With demands for land growing for urban, industrial and infrastructural needs, the pressure for diversion of prime productive agricultural lands to other land uses is increasing. Past developments have also been accompanied by degradation of land resources through physical, chemical and biological processes. Land degradation issues are getting increasingly reflected in widespread contamination and pollution of surface and groundwater bodies from sewage and industrial effluents, changes in salt and water balances in the spatial and temporal contexts, increasingly choked surface drainage systems, silting up of reservoirs due to continued erosion of surface soils, declining biodiversity of both cultivated spp. and other overall living spp. contributing to increasingly ecological fragility.

The land should be used as per its capability. However, besides land degradation, there are other issues which impact its sustainable use. In addition to the physical and biological dimensions of deteriorating resource base, the connected socio-economic features relating to sustainable use of land resources relates to fragmentation of holdings and its varied implication.

At present, there is little scientific and policy backing to resolve increasingly complex land related issues which directly impinge upon sustainability of agriculture. The State Land Use Board (SLUB) has Chief Minister as chairman and other stakeholders as members with guidelines from the ministry in GOI. The aim of this board was to undertake a review of all land based schemes and if a change in land use from agriculture to urban or industrial use was involved. Unfortunately the Board has never met except, perhaps, once or twice during the last 25 years. The activities of this board needs to be reviewed and made functional.

In the past, the CCSHAU Hisar has done good work, especially during the operation of UNDP Centre of Excellence and Indo-Dutch projects in the field of Soil and Water Management, including mapping of quality of soil and water resources due to existence of strong unit of Soil Survey in the Department of Soil Science. It has also strengthened different Regional Research Stations during the operation of NARP project in term of trained manpower and infra-structure facilities and also through several basic research projects in the field of natural resource management. Thus, the university had properly addressed the issues important at that time and generated useful information in the field of natural resource management. However, many of these efforts have been slowed and the main focus of all efforts currently relates to productivity enhancement, this needs to be diverted for improving resource base and quality to sustain growth of agriculture in the State. Currently the university does not have adequate multidisciplinary teams of scientists with expertise in the field of modeling, ground water hydrology, resource use optimization, farming system, remote sensing/GIS etc to address complex location specific issues of natural resource management. Recently, the staff in the field of animal husbandry and veterinary sciences has already been withdrawn from the KVKs due to the creation of new LLRUVAS University in Hisar. *Thus, there is need to greatly strengthen the quality and number of manpower and capacity building to address the location specific complex issues of NRM in farming systems perspectives more critically and precisely in the present scenario of deteriorating resource base and quality and challenges of climate change.*

Guiding land use issues call for a deeper understanding of what drives land use changes and what should be the guiding principles that enable rational decisions aimed at longer term sustainability of resource use. We suggest that CCS Haryana Agricultural University should set up a multidisciplinary specialists group to undertake issue based studies impacting land use to provide a strong scientific underpinning to the decision making process impacting land use. This group consisting of socio-economic and natural resource streams will need to work interactively with remote sensing and GIS specialists at Haryana Space Applications Centre (HARSAC) established by the Department of Science and Technology. HARSAC has strong expertise and has already carried out a number of studies in collaboration with CCSHAU and other user agencies. This group will also have to work closely with the State Land Use Board which was set up at centrally sponsored initiative.

3.2 Natural Resource Management Issues

The State is endowed with a great variety of soil water resources and agro-climatic conditions, which warrants their proper utilization and management for sustainable progress of agriculture (Figs 1, 2, 3, 4, 5, 6, 7, 8, 12 and 13). Understanding the nature of resources and their dynamics in relation to past and current use and practices is fundamental to defining technological needs and corrective steps needed to address sustainable use issues. Over the past 4 to 5 decades, the singular focus was to maximize productivity of selected crops through enhanced use of inputs (eg. quality seeds, fertilizers, availability of water, pesticide use etc) in short statured high yielding varieties. Little attention was given to the resource base quality and long term implications on the sustainability of interventions. While past efforts have greatly contributed in achieving enhanced production levels, there are increasing problems relating to soil and water resource degradation rendering past approaches highly inadequate. Resource degradation and management problems are regional and location specific and will call for appropriate scientific approaches to address the same.

3.2.1 Shivalik Foothills

The northern part of the State forming the foothills of Shiwalliks (including Panchkula and parts of Ambala and Yamunanagar districts) represents an ecologically fragile region. With high rainfall and rolling topography, the soils of the region are highly prone to water erosion due to high runoff. Earlier this area was having good vegetative cover and less water intensive crops like maize, pearl-millet, moongbean, chickpea, mustard etc. but with time ecological degradation took place and vegetative cover reduced, facilitating more erosion and runoff resulting into less water recharge. As and where irrigation increased, rice cultivation spread and reduction of area under maize took place. The menace of wild animals (like blue bulls, monkeys, wild boars) has also discouraged the farmers to grow maize. Now there is also tendency to level uneven lands to be able to grow crops like rice and wheat which has serious consequences in terms of nutrients mining and over exploitation of ground water resources. It is worth mentioning here that this area also functions as recharge zone for downstream districts like Ambala, Kurukshetra etc.

Since eighties, watershed based approach has been promoted through various State and Central Government programs with the aim to conserve resources and enhancing productivity. The key elements of the approach included construction of small and medium water harvesting structures and planting of trees and other vegetation. Focus was also on construction of gully plugs (cement or concrete) to facilitate in situ moisture conservation and reducing flows towards flood producing rivulets. All these efforts increased water recharge and brought more waste land under productive use. However, more intensive efforts with cost effective resource conservation technology are required in this area. Benefits of water harvesting structures have been reported in a number of studies. These include enhanced productivity of crops/livestock, increased groundwater recharge and reduction in runoff etc.

The NRM Working Group happened to visit Village-Thaska in Yamunagar District where two water harvesting structures were constructed in the past and water so collected was used for irrigating crops with pipe line laid water conveyance system. This has not only changed the cropping pattern but also recharged the aquifer, and water table has risen facilitating the sinking of tubewells and hand pumps in the village which was never a possibility at all in the past. This also enhanced the productivity of milch animals, and as a result of which people have started selling the milk and owned good buffalos and sold cows, reducing grazing pressure up to large extent. Economy has changed, therefore, such efforts must be repeated in this area, and it will have multi-benefits. An important element of the approach is involvement of all stakeholder right from the inception to planning, execution and post construction work management. This was the most difficult aspect (and continues to be so) of the approach and the lessons need to be factored in all efforts. Unfortunately scientific monitoring and evaluation were rarely built into such important projects.

At present, mainly three agencies are having funds for watershed development or related activities viz Forest Department, Agricultural Department and Department of Rural Development. Forest Department mostly implements such works in forest areas, some time also in the nearby areas depending upon the project or fund providing agencies. Agricultural Department does its activities in the cultivable/cultivated areas and implements work with the funds provided by Rural Development Department through district level agencies. Rural Development Department does not have its separate implementing agencies. However, there is also some State constituted boards (Shivalik Development Board, Mewat Development Board) also get some funds for these works from State funding schemes. Thus, there is a need to develop this area by pooling all the resources for implementing good work of water shed in coordinated and effective way.

In addition to the activities of the Departments of Agriculture and Forestry, watershed based activities need to be extended to both forest and cultivated area in a coordinated way. *Thus, establishing coordination of activities amongst various departments to reinforce common objectives among different departments/schemes is another aspect which proved uphill task and it continues to be so. What is needed is to increasingly adopt systems based approaches of holistic watershed development and management like in Bunga and Sukhomajari Projects which are currently lacking.* There is also a need to intensify efforts for afforesting the catchment area and ensuring survival and de-siltation of existing water storage structures and making the defunct dams to be functional.

Based on encouraging results of water harvesting strategies in the shiwalliks, this approach was also later extended to Aravali hill areas in the south western districts of Mewat, Rewari, Mohindergarh and Bhiwani. However, with little or no efforts to check erosion, involve people in conceiving options and little or no post construction maintenance, there are serious questions concerning the sustainability of these costly water conservation interventions.

While during the initial phase of watershed based programs, ICAR institutes and SAUs were actively involved but over the years there has been a complete dissipation of limited expertise in the area of agricultural hydrology, watershed, modeling etc and this is being a serious constrain to the much needed scientific backstopping of major NRM related development programs. It was time when State Govt. started viewing and approaching the problems of NRM with the scientific point of view and implemented some pilot projects with required backing of expertise in the Kandi Area. We believe that the scientific planning and implementation of the holistic watershed development programmes involving experts from the State Government, ICAR and SAU, and other stakeholders should form the basis for the natural resource management.

3.2.2 North-East Central Plain Zone

Comprising chiefly of districts of Kurukshetra, Karnal, Panipat and Sonipat, the region is characterized by good quality groundwater. Rice-wheat, the principal cropping system which has contributed to major gains in production and productivity of food grains in 70s and 80s is now faced with serious sustainability problems on account of several factors.

3.2.2.1 Declining Water Table and Quality

Continued decline in the groundwater table accompanied by signs of declining quality is the single most important factor contributing to unsustainability. Several contributing factors are recognized. Excessive withdrawal over annual recharge is obviously the main issue. Most of the area receives a mean annual rainfall of about 600-700 mm. Puddling soils using tractor power prior to transplanting rice is an important energy intensive agronomic practice aimed at reducing infiltration to help maintain water on soil surface which is considered important for obtaining high rice yields. Puddling reduces infiltration and the capacity of soils to transmit and recharge the aquifer. Constant puddling over the years is also responsible for compactions of surface soil layer below the ploughing zone further restricting movement of water and roots below the compacted zone. As per discussion of NRM working group with the scientists of RRS Uchani, Karnal, there has been deterioration in the ground water quality due to over exploitation of groundwater, and consequently mixing of brackish water from adjoining/deeper acquifers. Deterioration in the physical properties as well as decline in water table and quality due to over exploitation of ground water with tendency to extend rice planting increasingly to rainless months is the principal factor in this rice-wheat system zone.

It should be recalled here that in 60s and 70s the region was widely afflicted with problems of water logging and salt affected soils but reclamation of these soils was made possible chiefly due to intensive tubewell irrigation and addition of soil amendments followed by rice cultivation which made this area good cultivable. Thus, it would appear that sustainability of interventions will depend on much better understanding in relation to quantification of interactive processes contributing to water balance dynamics in the region. It would appear that many of these issues are now well known and appreciated. The question is of defining and pursuing a more multipronged approach which considers soil, crop, water, diversification and other factors in achieving desired results. Modeling approaches which rely on better understanding of processes and their interaction constitute accepted tools to understand and evaluate options to achieve the desirable results. These can also be combined with appropriate economic elements to facilitate decision making process.

It was high time to develop required expertise to look at solution in a more integrative ways. Considering the seriousness of the problems, although knee jerk measures like banning the growing of summer growing paddy are often taken with some benefit, these are unlikely to prove a solution to the problem of deterioration in the quality of soil and water and decline in water table. Similarly artificial recharge of groundwater with runoff during monsoon is being explored as an option to improve water balance. Some of these approaches are highly conflicting – all out efforts to reduce infiltration on the one hand and expensive to make and maintain recharge structures at the same time. Declining quality of ground water is a related and important aspect. Two main contributing factors are seen. First the region is amongst the highest per ha use of chemical fertilizers. With most studies showing that efficiency of fertilizer use rarely exceeding 40-45 percent, a significant fraction of applied fertilizers is likely to join water bodies including ground waters. Second, with declining water table in the region, there are fears that subsurface flows from adjoining high salinity ground waters in some area are already causing water quality declines. Similarly, there are reports of increasing incidence of number of soils requiring regular application of amendments etc to control resodification. The banning of early transplantation of rice is right step in the direction to deaccelerate the declining water table but other measures like improving the hydrological properties of soil, diversification of rice to low water requiring crops, utilization of water conservation and irrigation water saving devices are urgently needed to address the water resource problems of northeast central plain zone.

3.2.2.2 Declining Soil Quality

Soil management problems, in general, have been viewed and addressed in relation to the nutrient/fertilizer needs of the two crops, rice and wheat grown in succession which has become the main problem of the area. Need for increasing levels of nutrient application rates to maintain crop yields (factor productivity), increasing micronutrient deficiencies and fertilizer costs and high subsidies on fertilizer sector are all indicators of the need for maintaining soil quality in cost effective way by the farmers. A large number of long term studies have emphasized the need for adopting more integrated approaches involving use of organics and chemical fertilizers. Unfortunately this has not happened due to limited availability of farm yard manure and little incentive for recycling approaches to use organic fertilizers. Contrary to the need, farmers have been resorting to burning of crop residues, particularly those of rice and wheat, further exacerbating nutrient depletion and causing pollution. However, now steps have been taken to ban the burning of rice, wheat and other straws. *Little emphasis on organics is also a key factor in making the soils more prone to physical degradation in terms of compaction, deterioration of structures etc. Organic matter is also the principal constituent of soils to support biodiversity and various regulatory processes involved in nutrient transformation and release. Inadequate replenishment of organic matter is one of the critical factors contributing to declining use efficiency of different inputs.*

Amongst the major efforts to overcome soil related problems, the Department of Agriculture has implemented centrally sponsored 'National Project on Management of Soil Health and Fertility' during the 11th Plan. As a part of this effort, a large number of soil testing laboratories have been set up, soil health cards distributed and soil testing campaign launched to help farmers to assess fertility status of soils. But the soil testing laboratories are inadequate in technical manpower and hence lack of quality testing. Other efforts have included distribution of seeds of green manure crop, organizing subsidized availability of amendments, like gypsum, and promoting vermi-composting etc. While these interventions are helpful, clearly they are inadequate in terms of the required approach to address the problems. Many of the problems are systemic in nature and defy piece meal approaches to find solutions.

3.2.2.3 Crop Diversification

Cropping strategies focusing on rice and wheat in a sequence over large areas is the major cause of overall unsustainability. Limited crop diversity in the spatial and temporal contexts is a major factor contributing to emergence and spread of new diseases and pests. Limited crop diversity, crop and non-crop plants in the landscape and declining soil biodiversity reflect a weakening ecological foundation for sustainable agriculture. Enhanced biodiversity, both above and below ground, have to be an important part of objectives aimed at sustainability of production systems. Past efforts have included evaluation of alternatives to rice crop, inclusion of a short term summer legume as relay crop in wheat or sole crop following wheat harvest, growing of a green manure crop etc. *These efforts need to be greatly enhanced involving diversification of some area of rice to hybrid maize,soybean,mazie + soybean,soybean + pigeonpea, vegetables, agro-horticulture and agro-forestry systems* (Fig. 14).

Some improved hybrids of maize/HQPM have been reported as probable substitute for rice at RRS,Uchani (Karnal) research farm, but its full technological package

Fig.14: Maize-wheat-mungbean crop rotation as probable substitute to Rice-wheat crop sequence in North-East Haryana

needs to be demonstrated in the cluster of villages covering 500-1000 ha compact area with full monitoring of impact on natural resources and cost-benefit ratio to convince the farmers. There is strong thinking that in the years to come, the rice cultivation has to be reduced in the North Indian States because of increase in production in North Eastern and Central States and thus from here the problem of lifting and storage will be faced.

There is also need to diversify some area from late sown wheat to other crops to reduce yield losses and infestation of *Phalaris minor* in wheat crop. The scientists at RRS Uchani have also done good work on profitable intercropping systems of winter maize + vegetables(Fig. 15)and autumn planted sugarcane + garlic and other crops. Winter maize + vegetables have good scope after late harvest of Kharif season crops, and spring maize and sunflower after harvest of potato and sugarcane ratoon following furrow irrigation or pressurized system of irrigation to economize water use and improve water use efficiency in North Eastern region. However, these technologies need proper demonstrations with full monitoring of resource use dynamics and cost: benefit in farmers participatory mode for their adoption under real world situations.

Fig.15: Intercropping of winter maize with cabbage, coriander, fenue greek and spinach at RRS Research Farm, Uchani (Karnal)

3.2.2.4 Conservation Agriculture: An Integrated Approach to Sustainable Agriculture

Over the past couple of decades, the concept of Conservation Agriculture has emerged as an integrated approach to crop, soil and water management to achieve sustainable agriculture goals (Abrol et al. 2005; Gupta, 2011; Yadav, 2012). In essence the approach is based on application of three broad scientific principles in an integrated fashion. These principles include:

(i) Minimal disturbance of soil through practices such as tillage, ploughing etc

(iii) Leaving as much crop residue on the soil surface as possible, and

(iii) Adopting crop rotations, including intercropping, legumes, agro-horticulture, agro-forestry practices at the farm and land scape levels.

Tillage is an energy intensive operation and forms a significant part of the cultivation cost. Also tillage operations expose large surface of soil to oxidative processes reducing soil organic matter content. Increased retention of crop residues on soil surface is way to enhance soil organic matter, improve soils capacity to retain and transmit water and to increase underground soil biodiversity. Diverse crop rotations help break disease and pest cycles, promote nutrient recycling, and efficient use of water and other inputs. The challenge now is to operationalize this approach in the region on a large scale. This will call for a strong scientific support in developing and refining technologies and overcoming constraints as they show up.

Developing and promoting CA based technologies will call for institutional adjustments which permit multidisciplinary teams of scientists to work with the farmers while testing and refining technologies and trying out alternate management options. Thus, while zero till seeder for wheat in the presence of crop residues has been developed, tillage continues to be a major issue in rice cultivation. Direct seeded rice and alternate crops/ intercrops (hybrid maize, soybean, maize + soybean / soybean + pigeonpea/vegetables) have been suggested and are being explored. There is a need for much better understanding and appreciation of the approach to resolve many conflicting practices. The 'rotavator' an implement which can in one pass pulverize the soil and mix crop residues to be able to seed wheat crop is being extensively used. While an implement of this nature has apparent short term benefits, these have to be seen in view of the high energy needs and the damage that is done to compact subsoil with serious productivity implication. CA based practices have to be evaluated in term of process that contribute to sustainable resource use i.e improvements in the soil physical, chemical and biological properties, improved use efficiency of inputs, reduced production costs, energy saving etc. in addition to the increases in yield per se.

In India while CA based practices e.g. zero tillage and crop residues management etc. have evolved in relation to sustainability of rice-wheat cropping system, the principles are universal in nature. Yet operationalizing these principles under varying soil, climate and cropping (farming) situations will call for much better understanding of local resource conditions, problems faced by the farmers and most importantly, scientists working with farmers to understand the constrains and options for translating CA principles into location specific practices. The approach provides a way to respond to a problem in the context of a situation and cannot be translated through the usual 'transfer of technology approach' being pursued currently by the SAU. This is a concern and challenge which cannot be ignored.

3.2.2.5 Pressurized Irrigation Systems

Surface flooding to irrigate both rice and wheat crops and keeping the soil surface continuously submerged throughout the period of rice growth is a norm practiced by the farmers. Cost of energy (electricity) to pump groundwater being low (being highly subsidized), the tendency is to use water as an unlimited resource and get maximum production even at the cost of being inefficient. Most studies (Wolters and BOS, 1989) came to the conclusion that irrigation project efficiency in rice based projects is often less than 25 percent and unlikely to be more than 40 percent while for systems having non-paddy crops, 40 percent is just average. Based on economic analysis of sprinkler systems installed on tubewells of 90 cultivators spread over three villages in Bhiwani, Mohindergarh and Gurgaon districts, Luhach et al (2010) reported that on an average each tubewell irrigated 3.58 ha area by applying 3-4 irrigation per ha through furrow irrigation. A change over from furrow to sprinkler irrigation, irrigated area increased nearly 3 times per tubewell (9.65ha) with 4-7 light irrigations per ha. The labour used for irrigation declined by 78 percent on the sprinkler irrigated farms and net return increased by about 20 percent over surface irrigation and the resultant benefit-cost ratio for sprinkler set was 1:1.98.

A shift from the current flood irrigation to pressurized sprinkler system offers a single most effective means to enhance water use efficiency and reduction in water use and decline in water table. Sprinkler irrigation for agricultural crops was introduced in southern Haryana in late seventies and by 2004-05 the area irrigated was about 85,000 ha and by 2010 it increased to about 5,18,370 ha, which is about 26% of the potential irrigated area in the State (Luhach et al, 2010). Experimental results from different locations in the country on comparative performance of surface and sprinkler irrigation to crops have shown that there is nearly 40% savings on water and about 20% increase in yield in crops like wheat, maize, pearlmillet etc. The other pressurized forms of irrigation e.g. drip and micro irrigation systems are also being promoted in Haryana and there is an opportunity for their greater adoption in this region for diverse cropping systems.

Adoption of sprinkler irrigation in rice-wheat areas has important implications for a range of management issues but for rice it will be a big departure from the way the rice crop is currently managed. There is sufficient experimental evidence to show that rice can be grown under aerobic conditions and also without intensive tillage and soil puddling by direct seeding, provided appropriate management packages such as weed control, fertilizer application etc could be demonstrated to satisfy the farmers under real world situation. As indicated earlier, conceiving and implementing integrated crop, water, soil and nutrient management strategies to achieve well defined objective (check declines in water tables and quality deterioration) in the regional context is the way forward.

3.2.2.6 Recharge Options

Decline in the levels of groundwater in good quality zone is, no doubt, a major concern. One of the options considered to arrest this decline is to enhance recharge using runoff and excess (rain/canal) water. During 2008-2010, CSSRI successfully installed and tested the individual farmer based ground water recharge structures at 52 sites in Haryana, Punjab, U.P., and Gujarat under a Ministry of Water Resources

(GoI) funded "Farmers' Participatory Action Research Project (FPARP)". The 'well injection technique' involving directing runoff and excess (rain/canal) water through a recharge filter to a tube-well type structure under gravity to a suitable aquifer zone (Kamra et. at., 2006). Based on initial field studies, the scientists suggested taking this work upon a pilot basis for improving the quality of groundwater in inland basin where the poor quality groundwater is at shallow depths and there is a possibility of getting runoff for recharge. The well recharge structures, with intake rate of 4-6 l/sec, have proven highly effective in augmenting ground water, improving its quality (salinity, alkalinity, and fluoride concentration) by dilution, and enhancing farmers' income due to reduced duration of crop submergence by recharge of excess water. During 2009 and 2010 rainy seasons, 0.6-3.3 m rise in water table and 0.2 – 2.4 dS/m reduction in ground water salinity were observed due to recharge of aquifers at different sites in Haryana and Punjab.

The recharge structures helped in reducing the duration of submergence in the lowest part of the catchment at certain sites in Haryana resulting in increased rice yields and associated incomes. The payback period of 30-45 m deep recharge structures, costing Rs. 30,000 - 50,000 has been estimated as 1-2 years only. The upper sandy layer of the recharge filters gets clogged, thereby reducing the infiltrability of water, and hence it needs periodic cleaning. Recharge technique was also suggested to have the potential to improve the quality of groundwater at other places by the scientists of CSSRI, Karnal. While these options look attractive at the first hand, operationalizing these, their long term implications, technically or otherwise will be important consideration. Primafacie, it is difficult to reconcile that while in pre-monsoon period the entire effort in the region is to make the soil impermeable by puddling to prevent infiltration, a month or two later the effort should be to recharge the water in areas which are naturally discharge area. Much better understanding of how the systems will respond over a period of time in relations to alternate interventions is important for any decision making.

3.2.3 Central Inland Basin

As brought out earlier, this zone comprising the districts of Rohtak, Jhajjar, Jind parts of Bhiwani and Hisar forms a part of the trough resulting from physiographic and hydrologic setting. Before partition, this region used to have deep water table. Hence, a Dry Land Research Station was established at Rohtak in 1927 to conduct research on low water requiring crops like millets, pulses and chickpeas etc which functioned till the fifties. With the introduction of canals in the area, the water table started rising in sixties, and currently it is almost floating on water. Rice occupies a large fraction of the cropped area which is further aggravating the already serious problems. The region is underlain by saline ground waters. The natural drainage of the region is being restricted and the groundwater being largely salt laden, introduction of canal irrigation and inefficient water management practices have contributed to the spread of serious water logging and salinity problems. The problems are mainly induced by irrigation, disturbing salt and water balances at the regional and local levels. With rise in the level of groundwater, the capacity of soils to absorb rainwater is greatly reduced causing widespread flooding and surface stagnation during monsoon and post monsoon periods, restricting crop choices and productivity. Table 9 indicates that an area of more than 50,000 hectare is having water table within 1.5 m which has almost been turned into wasteland and another about 3,80,000 hectare under 1.5-3.0 m water table depth, which is turning into potential water logged /saline land.

Mechanism of the soil and ground water salinization is simple. When the rising water table reaches near the land surface, evaporation from the shallow water table becomes a major component of outflow, which in due course of time balances the inflow to the ground water system. Thereafter, the rise in water table is halted. However, during the process of the occurrence of such a hydrologic balance, the entire zone of high water table directly contributing to evaporation gets salinized due to the evaporation of water, which leaves the salts at the evaporating site in the soil profile. Thus, evaporation from the shallow water table degrades the soil as well as ground water by increasing the salt concentration in soil and ground water system. When the water table reaches within two meters of the land surface, the land is classified as waterlogged; on the other hand when the water table rises within 2-3 meters, the area is termed as "potential area for water logging" (Anonymous, 1991).

Control of water table and soil salinization are critical to sustain productivity. The

Table 9: Depth of water table in different districts of Haryana

Sr No.	DISTRICT	TOTAL AREA (ha)	HILLY AREA (ha)	DEPTH TO WATER TABLE ZONES IN METRES 0-1.5	1.5-3	3-10	10-20	20-30	30-40	>-40
1	AMBALA	159585	300	4650	14269	82677	49238	4482	3969	-
2	BHIWANI	487072	4661	8601	53949	149938	96897	35368	20497	117161
3	FARIDABAD	74045	8717	-	792	9395	49729	5412	-	-
4	FATEHABAD	249110	0	477	19688	47167	43916	64617	51713	21532
5	GURGAON	124933	3789	-	-	6014	29803	65016	16546	3765
6	HISSAR	386052	0	3019	27119	272825	82288	801	-	-
7	JIND	273600	0	789	16711	114840	115244	24147	1869	-
8	JHAJJAR	186770	0	12980	75651	85311	11452	1376	0	0
9	K.KSHETRA	168253	0	0	0	570	780	75372	90721	810
10	KAITHAL	228406	0	0	574	50316	68122	74058	22781	12555
11	KARNAL	247112	0	-	-	33534	186079	27259	240	-
12	M.GARH	193947	4646	-	-	4834	12482	29524	26875	115586
13	MEWAT	150027	13900	-	9888	70882	37689	16811	857	-
14	PALWAL	136455	129	499	3691	108868	21765	1503	-	-
15	PANIPAT	124988	0	-	100	39928	60145	19995	4240	580
16	PANCHKULA	78915	39356	-	-	10005	24885	4202	467	-
17	ROHTAK	166777	0	16516	78694	65583	5984	0	0	0
18	REWARI	155900	2308	-	532	40176	55200	28471	15037	14176
19	SONIPAT	226053	0	2892	56097	112354	38254	16456	0	0
20	SIRSA	427600	0	2325	8747	138132	148253	52625	41506	36012
21	Y.NAGAR	175600	15300	1382	13260	74785	51895	17740	1238	
	STATE TOTAL	4421200	93106	54130	379762	1518134	1190100	565235	298556	322177
	STATE %	2	1	9	34	27	13	7	7	

solution to the problem is rendered complex due to unfavorable geo-hydrological conditions and widespread saline ground waters. In early eighties, a number of studies were undertaken by the State Minor Irrigation Corporation (now closed) and FAO as a part of the UNDP sponsored effort involving expertise from Netherlands (Tanwar and Kruseman, 1985; Van Hoorn et al., 1985). During the same period with the assistance from Govt. of Netherlands an operational Pilot Research Project was undertaken by the Central Soil Salinity Research Institute and the Haryana Agricultural University (Kamra et al, 1991, Rao et al, 1995). These studies evaluated the possible options and their practical feasibility. It is recognized that to achieve water table control and soil salinization, it was necessary that three systems be integrated i.e.

(i) surface water drainage system
(ii) irrigation water supply system and
(iii) groundwater drainage system.

The role of surface water drainage system is to:

(a) prevent inundation of soils by monsoon rainfall which otherwise will cause excessive groundwater recharge, and

(b) to evacuate groundwater and drainage water to its place of reuse or final disposal.

The irrigation water supply system provides:

(a) the soil moisture needed by crops and

(b) the leaching of salts left behind by evaporation of irrigation and capillary water.

The purpose of the groundwater drainage system is to:

(a) evacuate excess groundwater to prevent water table rise and consequently to reduce the capillary transport of salt to the root zone and soil surface, and

(b) to evacuate salt that has been leached from root zone by downward percolation of excess rainfall and irrigation water.

The hydrologic balance between the inflow to and outflow from the ground water system could be achieved either through uncontrolled evaporation from the shallow water table or by subsurface drainage. Outflow in the form of evaporation from the shallow water table is an unproductive waste of precious water that has degrading effect on the quality of soil and ground water resources. On the other hand, an out flow from the subsurface drains is an ameliorative process of soil and ground water resources that enhances land productivity and ground water availability.

3.2.3.1 Surface Water Disposal

Earlier the rain water disposal was not a priority. There was one sub-division of drainage at Gurgaon with drainage circle at Rawalpindi in the pre-partitioned days. But when floods threatened in early sixties, the drainage network was strengthened with one circle at Karnal and thereafter diversion drain No. 8, Bawana and other drains were constructed. Now for disposal of surface water during rainy season, about 370 drains having length of more than 4000 km have been constructed, 40 of these fall into the canal network. This net work of drainage system is being used for disposal of rain water, recharge option of ground water and also for the disposal of ground water and drainage effluent, though it is one of the major constraints in Haryana. There is also need to put some canal water during post rainy season wherever possible for recharge of ground water for irrigation and other purposes. River Yamuna is the potential receiver of saline drainage effluent and also up to some extent Ghaggar river for small disposal as it is not having regular flow. Disposal of saline ground waters into Yamuna presents restrictions on account of the fact that Yamuna water is used for Delhi's water supply, and any effort to adopt this approach must precede with detailed studies to evaluate possible implications for end users.

Other disposal options considered unfeasible were storage in evaporation ponds or in areas with deep groundwater levels as subsurface storage. A more promising option is the reuse of subsurface water for irrigation. This will help alleviate the shortage of irrigation water but also implies a quality constrain on subsurface drainage effluent. Water with EC not exceeding 4 to 6 dS/m can be used undiluted for irrigation without or little productivity declines which would be an acceptable limits. Waters with salinity levels between 6 and 10 dS/m can be used after mixing with freshwater. The Govt. of Haryana has allowed 20% mixing of saline water in fresh water of canals. Mixing effluent of salinity more than10dS/m in canal water will have adverse consequences. The problem of effluent disposal has to be considered in respect of quantity and quality.

3.2.3.2 Ground Water Drainage

The possibilities of disposing drainage water require that the salinity of drainage effluent be reduced as much as possible. Groundwater salinity increases rapidly with depth. Consequently vertical drainage of the type installed in freshwater zone is not possible, moreover, in this area availability of aquifer is also a problem. The only possibility is vertical drainage by shallow skimming wells and horizontal drainage by subsurface gravity flow (pipe drainage) system. Shallow well systems have several advantages viz. the water table can be controlled at any depth; they are easy to operate particularly if the groundwater quality permits its direct use for irrigation and that the investment costs are lower than pipe drain systems. The constraints relate to possibilities of upcoming of saline waters, low transmissivity, cost considerations, institutional needs etc. The groundwater quality will gradually improve because the recharge water has better quality than the original groundwater being pumped out.

The horizontal subsurface gravity flow system (pipe drainage) is the other alternative method of groundwater drainage. Based on initial pilot studies, it was decided to replicate the technology with Dutch Government assistance-Haryana Operational Pilot Project-in two separate projects of 1000 ha each in Haryana. As a part of project, trenching machines were imported to mechanize installation of drainage pipes. The subsurface drainage technology comprises of horizontal laying of 75mm to 100mm diameter corrugated and perforated plastic pipes with a polypropylene material and nylon netting envelope woven around it at 1.0 to 2.5m below the land surface at 10 to 120 m spacing. In view of the land size holdings and light textured soils in Haryana, 67m spacing is the recommended spacing of the tube laterals. The network of lateral drains discharge flows to a larger diameter collector drain which carries it to a main drain for its disposal to the natural drainage system. Design of the subsurface drainage system is adequately described by Bhattacharya and Michael (2003). The performance evaluation of several subsurface drainage projects, installed in Haryana and other States of the country, has been reported by Rao et al. (1995).

The members of the NRM working group visited the subsurface drainage project at village-Beri near Jhajjar. Earlier the soil in the project area of about 400 ha was waterlogged and salt affected. The subsurface tube drainage project was installed in 2005. As reported by the villagers led by Ch. Dilip Singh, the soil was reclaimed within two years. The paddy yield prior to subsurface drainage was about 5q/ha. After the installation of the tube drains, the yield increased to about 45q/ha. The subsurface drainage effluent is being discharged into Drain No. 8 by gravity flow during the dry season and through pumping during the wet season. The ground water quality in the project area prior to the installation of the tube drains was unfit for irrigation. However, after continuous removal of poor quality ground water from the waterlogged lands for four years, its quality had considerably improved. Consequently, the farmers started installing about 20m deep shallow tube wells since 2009. The improvement in ground water quality at village-Beri has qualitatively verified the computational findings of Kamra et al. (1991). Presently, the farmers are using surface and ground waters conjunctively for assured irrigation to various field crops. Thus, the subsurface drainage, on account of the improvement in ground water quality, has enhanced the availability of the ground water resource for crop production. It is, therefore, an added advantage of the subsurface drainage system which merits implementation in intensification of the agricultural production programs in water logged saline soils.

Amongst the major constraints observed for such installation were the limited time period of about two months available for laying pipes of drainage system i.e. just between harvesting of the rabi season crop and sowing of Kharif season crop before the onset of rainy season. The need for establishing cooperative effort amongst the farmers and functional links with several other stakeholders and that the arrangements and commissioning of many structures in the field like tubewells, water channels, electric wires, roads, posts, operational difficulties etc was an uphill task. However, at some places good models have been developed with the cooperative efforts of the stakeholders. The long term performance of the systems has not been evaluated nor has any study been carried out on the institutional need and arrangements for involving the farmers. These and other constraints and inadequate evaluation in terms of replicability etc. have prevented any meaningful and substantive effort to address the problem.

Under shallow water table conditions, there exists great possibility for recharging of shallow tubewells with fresh rain water during rainy season after making some space in soil system through lifting of excess water in canal/drain or storing in reservoirs if water quality permits and using it for irrigation during post rainy season. The water injection technology developed by CSSRI Karnal can create some fresh water aquifer zone in the sub-soil. The recycling of fresh water during early rabi season and saline water for irrigation at later stages of crop growth could result in improving the productivity of water and soil quality in long run. Such water injection technology of recharging aquifer with good quality fresh rain water has also been adopted in shallow tubewells/skimming wells by several farmers in Agra and Bharatpur Districts after proper research support by CSSRI, Karnal and its AICRC at R.B.S College, Agra, and financial support by the NABARD and other Banks.

Farmers in Sirsa Distt have developed a novel method on their own to mitigate the effects of excess water of Ghaggar river stagnated in rice fields by diverting it through reverse siphoning in the existing tubewells for their recharging and mitigating the damage to the standing rice crop. As first step, the tubewell is started and then in second step, it is suddenly stopped which results into reverse siphoning and water from field/channel starts flowing directly into tubewell through already out let pipe submerged in the standing water in rice fields. This technology needs evaluation and if found suitable could also be followed in similar conditions at other places to recharge groundwater table from flooded waters.

At the State level, Haryana Land Reclamation and Development Corporation (HLRDC) was established as a part of the Department of Agriculture with the main objective to undertake large scale reclamations of salt affected soils following successful demonstration of alkali soils reclamation by CSSRI. The main task of HLRDC was to supply subsidized inputs, mainly gypsum and making tractors available to the farmers for land leveling. Later the Corporation was also entrusted with the task of producing seeds of different green manure crops, supplying fertilizers, pesticides etc. However, corporation is ill equipped technically to undertake activities relating to reclamation of saline soils which requires high technical skills. Over the years, many of these initiatives have not been pursued by the State Government in institutionalized way. These programs require a strong scientific backing and there has been a gradual decline in the efforts by CCS HAU which were taken up seriously in 80s. The result is that as of now there does not appear to be a serious thinking and effort in place to address these issues vital for the development of agriculture of Haryana. We suggest that:

(i) The NRM group in the University should undertake a critical review of past studies, experience based-on field level efforts and their sustainability with a view to initiating pilot level efforts to build a plan for a larger effort. The review should be undertaken with the help of best expertise and by involving CSSRI. There is a need to look at the problem in an integrative way and find solutions that extend beyond purely technical solutions-institutional and policy issues are as much or more critical.

(ii) There are large chunks of area of salt affected and waterlogged soils where currently economic crop production is not possible. We suggest that:

- These areas be identified and characterized and at one or two sites for the possibility of raising managed plantations for fuel wood. There are reports that such plantations have the potential to lower groundwater table (CSSRI) while contributing to the pressing fuel wood needs of the people. These options need to be reinforced in view of the potential for sequestering carbon, which contributes to improve soil productivity and environment.

- The success of sub-surface drainage technology for amelioration of water logged saline soils in Central Inland basin is very much dependent on post reclaimation efforts by Farmers Societies. Therefore, the Irrigation, Forestry, Fisheries Departments need to be involved to integrate sub-surface drainage executed by Department of Agriculture with surface drainage, tube drainage, aquaculture and agroforestry.

- There is a need for enhancing water productivity through multiple use of water in water logged salt affected soils through bio-saline agriculture. Introduction of salt tolerant field/tree crops/new crops like Buch *(Acorus calamus)*, spider lily, aqua culture and agroforestry through soil configuration and raised and sunken bed technology could help the farmers to enhance water productivity for livelihood security.

- Location specific pilot level projects of multi-enterprize models for rehabilitation of salt affected soils already developed for such conditions need to be demonstrated at selected sites by Department of Agriculture in collaboration of CCSHAU, CSSRI Karnal and other State Departments for building confidence of farmers for their further adoption in the State.

3.2.4 North-Western Region

These are the areas (comprising the districts Sirsa, Hisar, Fatehabad and parts of Bhiwani) where introduction of canal irrigation has enabled double cropping, chiefly Cotton-wheat in a rotation over large areas. The area is underlain by poor quality groundwater and rise in groundwater table levels is increasing salinity and water logging problems. These are also the areas where use of chemical fertilizers and pesticides is amongst the highest causing serious pollution associated health problems. The problems are being further accentuated due to many farmers opting to grow rice in these areas. As in the case of other regions, improving the use efficiency of available water resources by adopting a combination of crop, soil and water management based strategy is important. Amongst others, pressurized irrigation systems constitute a single most promising option to enhance use efficiency. The region mainly being canal irrigated installation of pressurized systems presents challenges.

3.2.4.1 Pressurized Irrigation System – Need for Secondary Reservoir

Canal water distribution in Haryana is based on 'Warabandi' in which water is distributed according to a time roaster over a base period of 168 hrs (seven days) and which cannot be altered. The canal network in Haryana is divided into three systems: (1) Western Yamuna Canal (WYC), (2) Bhakra Main Canal (BMC) and (3) Gurgaon Canal. These systems run on rotational basis (4 to 16 days water supply/month) through sub-systems and distributaries. However, the water allowance and irrigation intensity in these systems are very low. Irrigation intensity in BMC is 62% while in WYC it is just 50% and in lift canals, it varies from 8-38%. Thus, there is a need to shift from flood system of irrigation to pressurized system for improving irrigation intensity and productivity of water in these canal commands.

Maintaining favorable soil moisture and nutrient regime is essential to achieve high and sustained productivity. In a canal irrigated region, this will be achievable only through a reliable need based water supply system involving construction of a secondary reservoir. Thus, the irrigation water diverted from the canal as the farmers' share could be stored in a secondary reservoir for supplying irrigation to crop when needed. Feasibility for adopting this approach over large areas will call for serious evaluation studies.

At present, the State Government is subsidizing construction of such reservoir, for installing drip in horticultural crops. As the water is diverted from canal outlet to a secondary reservoir, there are additional losses due to evaporation and seepage from reservoir. Seepage losses can be reduced by lining the reservoir. Practicing aquaculture is another option for raising productivity of stored water-this would require additional dead storage of at least 1 m to facilitate fish production. Mishra and Tyagi (1988) suggested design requirements for secondary reservoir.

Reservoir for horticulture crops currently being promoted needs to be critically evaluated in terms of costs: benefit, environmental implications, management needs etc to be able to outline a future strategy for wider adoption. In this region drip irrigation has been adopted in a significant way for fruit crops and as well for cotton crops by some progressive farmers. The understanding of operational and technical constraints and overcoming these difficulties for wider adoption offers a way for sustainable use of limited resources.

3.2.5 South Western Region

The area encompassing districts of Mohindergarh, Rewari, Gurgaon, Faridabad, Mewat and parts of Bhiwani and Jhajjar adjoining Rajasthan represents a region which is largely tubewell irrigated underlain by poor quality water and low rainfall. Where good quality groundwater is available, the farmers tend to grow oilseeds, cluster bean, pulses, vegetables and other crops. These are the areas where water tables are fast declining and water quality deteriorating. Areas where groundwaters have moderate salinity levels, farmers grow mustard, pearl millet, using limited amount of groundwater. Any built up of salts due to irrigation get leached in the subsequent rainy season. Farmers are increasingly using gypsum to mitigate adverse water quality effects adding to cultivation costs. Decline in water tables in this domain is leading to serious salinity problem. There is a very high cost of sinking tubewells in the area. The resource poor small farmers cannot afford to have their own tubewells, and thus forced to get irrigation water from neighboring farmers at a very high cost or sometimes give away one third or more of their agricultural produce for irrigation to those who have got tubewells for supply of irrigation water, even when electricity charges are subsidized for tubewell irrigation by the State Govt. These farmers are demanding that the State Govt. should sink some tubewells in this area to help resource poor small land holders. They are also of the view that the funds provided for construction either water tanks or watershade development works are of little use in this rainfall deficit area, and these funds should be diverted for sinking deep tubewells and their water recharge options. There is also demand to supply more canal water or diverting excess rain water to these farmers for irrigation and water recharge options in this water scarce region. *However, long range transfer of water should precede adequate scientific studies on salt and water balance, energy cost and socio-economic benefit on long run.*

The mustard crop often suffers from infestation of orobanche parasitic weed. This weed problem has also been reported in brinjal, tomato and other solanaceous crops in this area. Thus, there is a need to diversify these high hot spots into castor or castor + cluster bean or chicory (*Cichorium intybus*) + mustard mixed cropping systems. Cluster bean is one of the niche cash crop in this area. The RRS Bawal of CCSHAU has done good work for such crop diversification, including resource conservation technology for mustard based cropping system. There is also great scope of arid horticulture using drip system of irrigation and plastic mulch. Some farmers are growing strawberry even on dunal sands by using fertigation and plasticulture. However, there is a need for establishment of more units for processing of cluster bean and horticulture produce, including supply of quality planting material to help the farmers.

There are areas within this region which are entirely rainfed with very high salinity groundwater (some 40 villages). This area should be covered with block plantation of *P. juliflora* by undertaking a pilot project by Department of Forestry of CCSHAU, Hisar through holistic approach from plantation, inoculation with lac insects, to harvesting and value addition (charcoal making, electricity generation through gasification). It is understood that the CSSRI, Karnal has identified some thornless quality planting material of *P. juliflora*. In Haryana, as in many semi-arid regions, a large fraction of rural household is engaged in small scale activity of collecting firewood/producing charcoal from tree biomass. *Well planned and monitored pilot level studies should be able to feed into policy initiatives for larger community level initiatives.*

Presence of Aravalli Hills in the region and canal irrigation to parts of Mewat district brings additional problems requiring specific approaches. These include large areas of waterlogged soils, declining water qualities, all threatening the sustainability of production systems. As stated for inland basin, there is a great scope of forestry, agroforestry and pisciculture. Farmers are also demanding deepening and widening of Kotla Lake to tackle the problem of water logging during rainy season and for using the stored rainwater for irrigation during post rainy season.

Also the region being water scarce, farmers have for long used sprinkler systems and other water saving options. At some places in Mewat and other areas, farmers are carrying fresh water from far off places through underground pipes by purchasing a piece of land in fresh water zone and sinking a tubewell there. However, some farmers do not allow the laying down of underground pipes on their lands, despite the existing of law to do so at below 3 feet depth in sub-soil in Haryana. Therefore, better understanding of ground realities and sound technical approach and supporting policy are a way to sustainable resource use and management.

The south-western highland areas constitute another unique domain. For supplying water to these areas, a number of lift irrigation schemes were conceived to irrigate the sandy tracts. In these schemes water from canals was pumped to heights in many stages up to 174m to supply water to different lift canals serving to the farmers. Not much published information is available on the functioning of these systems, highlighting the operational constrains, energy costs, farmer's response in terms of crop and cropping system options etc. and the lessons which would be important for future strategic interventions.

The whole region has variety of problems but there is a great scope of arid horticulture, forestry/agro-forestry and livestock production, especially goatery. Thus, there is a need for plantation of multi-purpose trees for supplying fodder and fuel wood and commissioning biogas units for saving cowdung from burning to improve soil health. *The well planned adaptive research projects by involving CCSHAU, CSSRI, State Departments of Forestry and Animal Husbandry are required in farmer participatory mode to address location specific problems of NRM in this region.*

3.3 Water Pollution

Owing to rapid urbanization and industrialization in the recent past, water pollution has increased in surface water bodies, drains, rivers and groundwater. At some places, the heavy harmful metals like lead, arsenic, cadmium, mercury etc are being disposed off in sewage water. Currently, in the adjoining State of Punjab, the presence of fluoride and uranium in underground water is a source of cancer and other diseases in human beings. This type of water pollution along with other types of pollutions are being monitored by Haryana State Pollution Control Board (HSPCB) under Water Prevention and Control of Pollution Act, 1974. For this purpose 16 locations at river/ drains/ canals points are being monitored. In Yamuna river, 8 locations are selected viz Palla (Haryana Delhi Border), Agra canal, Gurgaon feeder, Faridabad in its downstream of Delhi etc. For Ghaggar river, the monitoring is at Surajpur in Panchkula district and at 3 locations in Sirsa district, in case of Markanda river it is at Kala Amb. It has been found that water quality of Yamuna river to Delhi is within permissible limit of BOD (1.1 mg/litre to 2.3 mg /litre) during March, 2010 to June 2011. However, water quality exceeds the permissible limit (28 mg/litre against the permissible limit of 3.0 mg/litre) when it comes out of Delhi. Here 26 drains from Delhi and Uttar Pradesh fall into Yamuna river causing major water pollution. For controlling the water pollution in Yamuna river, the matter is being taken up jointly by Government of Delhi, Uttar Pradesh and Central Pollution Control Board. At all pollution points, concerned officials have been instructed to install Sewage Water Treatment Plants (STP) by using latest technology.

As stated above, the other major source of water pollution is the waste water coming from urban and semi urban areas. For this, Public Health Engineering Department of the State has been made responsible and has identified 78 towns. Out of these, in 24 towns 28 STP, have been installed, in another 30 towns, 42 STPs are under construction. Another 6 STPs are being constructed in other 5 towns by Urban Local Bodies. Different treatment technologies like stabilization ponds, up flow anaerobic sludge blanket, moving bed bio-film, activated sludge process and sequential batch reactor are tried for the treatment of waste water. The treatment of sewage water is rather simpler and cost effective than industrial effluent. The anaerobic process for their treatment is slow but energy generating, while aerobic process is fast for their treatment. Thus, the combination of both aerobic and anaerobic technology could be one of the cost effective way to treat sewage waters for their utilization in irrigation for peri-urban agriculture (Yadvika et. al., 2000; Deora, 2012). However, governance of all these STPs is required to be improved and regularly monitored. This treated water is fit for irrigation but no systematic water conveyance is being laid to take this resource to the cultivated fields and farmers are using it as per their convenience. This needs to be systematized as per the treated water available and area to be irrigated in different periods of the year, instead of allowing it to go as waste in river/drains/ canals or causing problem in the adjoining fields.

The sewage waters have been reported to contain some useful plant nutrients in addition to harmful heavy metals and micro-organisms and are being utilized regularly for growing vegetables and field crops, especially in peri-urban areas. Also the soil configuration and planting of vegetables on ridges in ridge and furrow system of irrigation has been reported to reduce contamination of heavy metals and microbes in vegetables and other crops.

There is a need to conduct more research to monitor load of microbes and heavy metals in soil, plant, food chain and environment systems in areas irrigated by sewage waters. A core group of scientists of CCS HAU, Hisar; CSSRI, Karnal; and State (Public Health Engineering) and Central Pollution Boards should be formulated to conduct more research covering various aspects of sewage waters for their reuse in agriculture and also to regularly monitor and advise the Govt. agencies for their proper treatment and impact of their reuse for irrigation purposes on soil and produce quality. As reported by the farmers of the State, the untreated water from different cities in Haryana and NCR in general and from Okhala, Delhi in particular is being diverted in fresh canal systems of Gurgaon division.

3.4 Conclusions

Haryana, though a small State, is endowed with high variability in natural resources and associated socio-economic features on account of geographic setting, topology, soils, geohydrologic conditions, climate features. Over the past decades while the

State has benefitted immensely from its agricultural achievements, this success is based on a declining resource base and quality, especially reduction in soil carbon, poor soil health, hydrological imbalances, decline in underground and above ground biodiversity and pollution of soil, water and environment. Agricultural intensification associated with technological and policy regimes have led to serious problems of resource degradation, the nature of the problem being region/location specific. Urbanization, industrialization, infrastructure development and changing life style of an increasing population are other reasons for over exploitation and decline in quality of the resource base and bio-diversity. With farmers facing a multitude of problems arising from increasing production costs, declining factor productivity, increasing environmental pollution, increasing uncertainties associated with increasing variability in rainfall and temperature regime and the scientific community having no straight forward or easy solution. Thus, there is a need to look for solutions which probably lie in a fundamental shift in the way agricultural research for solution of development problems has been viewed and addressed in the past. Agricultural sustainability in Haryana is too serious a concern to be left unattended.

4.0 NATURAL RESOURCE MANAGEMENT AND SUSTAINABLE AGRICULTURE

4.1 Need for a Paradigm Shift

Natural resource base of a region including elements of climate, land, soil, water, and biodiversity primarily dictate the evolution of agriculture and opportunities for improving the livelihoods of the people of the region. Sustainability of agriculture, the main land use and a livelihood source in Haryana, is therefore intimately linked to the integrity of natural resource base and its capacity to provide goods and services in a sustainable way. Widespread, serious and continuing degradation of resources is clearly unacceptable more so in the face of climate variability induced exacerbated declines in resource quality further impinging on our ability to ensure sustainable livelihoods.

Over the past decades, dictated by the goals of enhancing food production at the national level within shortest period and in line with available technological options and matching institutional and policy regimes in place, favored focus on enhanced productivity of selected crops in the more favorable regions with practically no attention to the longer term consequences and issue of resource use sustainability. What is needed now is technological regimes which integrate concerns of resource degradation while enhancing systems' productivity and environment. These imperatives call for a shift in the overall paradigm that we have to pursue in generating and promoting technologies aimed at enhancing productivity and simultaneously addressing NRM issues. The key elements which will guide such a paradigm shift include:

- Need for Location and Region Specific Approaches

Elements of natural resource base encompassing climate, land, soil, water and biodiversity vary from place to place and region to region and are highly interactive. Technological interventions aimed at finding solutions to the problems, therefore, have to be specific to a given situation. Better understanding of natural resource variability, their potential, limitations and linked use and management issues (socio-economic) are therefore fundamental to define technological needs and options for sustainable use. This is in sharp contrast to the technological needs as have been perceived by the scientific community so far.

- Need to Build System Based Approaches to Research for Development

Elements of natural resource base and socio economic situations are highly interactive and linked in time and space. Addressing problems of small farmers call for much better understanding of their environment (biophysical, socio economic and cultural settings) and the way it impacts their decision making on day to day basis. There is, therefore, the need to shift from the current largely crop focused technological approach to one that addresses the needs of the farmers in the context of farming system. Issues of sustainable use and management of natural resources at the local level (farm, farming system) are deeply imbedded within overall use and management issues at the watershed and regional (water basin) levels. While watershed as a unit of area for natural resource management is well recognized and constitutes the mainstream approach to resource conservation, augmentation and management but there has been little or no sincere efforts to view NRM problem in a system perspective. Therefore, the fragmented efforts and unsound approaches to look for sustainable solutions of complex NRM and its interlinked problems would not work under real world situations. Building system approaches will call for greatly enhanced efforts to adopt modern scientific tools and methods (remote sensing, GIS, modeling etc) and to strengthen technical capacity to adopt system based approaches for optimization of available resources with the farmers.

- Need for Integrated Approaches to generate and promoteTechnologies

Finding solutions to complex NRM issues call for more integrated approaches to generate technological options within farming system perspective. Defining and promoting integrated solutions call for scientists from a range of disciplinary backgrounds to work in a well coordinated and an interdisciplinary way in relation to a common problem. This will call for changes in the way research programs and projects are formulated and funded. With most research programs being top-down and divided in a disciplinary boundary, it is hardly possible to address the complex NRM related issues in the present scenario.

- Need for better Scientist-Farmer Connect-Adaptive Research-the missing link

As of now the transfer of technology efforts have been largely top down and input based with little consideration to the farming situation and natural resource domain in which the farmers work. Also at present, there is little feedback on the need for improving and refining technological options in a participating manner with the farmers. It is the most critical systemic gap in understanding and finding solutions to NRM related issues. There is an urgent need to put in place a strong adaptive research program involving NRM and production system specialists to adapt and refine technological innovations for adoption while providing a feed back to the scientific community as to what works and what not and why? Adaptive research is also a way to build upon indigenous knowledge base accumulated by farmers who are well entrenched in the NRM and productivity issues in the local context.

Climate Change induced enhanced variability in pattern of rainfall and temperature regimes have added a new dimension to issues of resource degradation and sustainable use. Understanding the nature of the changes and the way they interact with and impact natural resources will constitute an overarching consideration to approach NRM problems.

Policy Focus addressing NRM problems and sustainable use call for a strong research focus to feed into policy formulation. There is again a missing link and corrective steps need to be taken.

4.2 Action Agenda

In addressing the TOR of NRM working group, it is important to understand that agriculture and integrity of natural resources devoted to agriculture is the primary responsibility of the State Government, including the responsibility for organizing and reorienting the education and knowledge base and relevant technological and extension needs to address the problems. Over the past decades, however, efforts to enhance agricultural productivity centered on a few crops which have been largely driven and funded by Central Government in tune with centralized thinking, irrespective of the potential and limitations of the natural resource base, highly variable in time and space. In pursuance of this overall strategy, the technological generation process has been promoted by ICAR at SAU level through a number of 'Coordinated Projects' in the areas of crop improvement, soil, water, pest management etc. with each of the projects being implemented in vertically split compartments. This implied little or no interaction amongst scientists either at ICAR or at the University level in relation to building either natural resource base or the associated socio-economic specificities either in the technology generation or transfer processes. Such an approach has led to little institutional capacity to either conceive NRM issues or articulate approaches to find solution there to. This is at present, the most serious lacuna in pursuing NRM agenda both at Central and State levels. However, we believe that initiatives in this regard have to be pursued independently, recognizing the need to build effective lateral and vertical linkages. In this regard we suggest the following priorities covering the institutional and technological interventions with a view to strengthen the foundations of NRM to address location specific NRM related problems of farmers for sustainable agricultural intensification.

4.2.1 Institutional

As emphasized earlier, several institutions existing prior to eighties both at the university and within the State Department of Agriculture have been decimated, either wound up or became totally dysfunctional. Examples are units for Soil Survey both at the university and within Department of Agriculture, a strong Centre for Soil and Water Management built with the support of UNDP/Dutch experts. Minor Irrigation Tubewells Corporation, Haryana Land Reclamation and Developement Corporation, Land Use Board and Biodiversity related issues etc have hardly been a subject demanding attention of scientific community. Agro-meteorology though an area which has been strengthened since eighties calls for a new thrust considering the overarching nature of climate change related issues impinging on sustainability of natural resource use and agriculture. Institutions like Haryana Remote Sensing Centre set up by the M.O.S. and T. to support research and development in relation to NRM have not been tapped meaningfully to address NRM issues in relation to sustainability of agriculture. The dimension and magnitude of the problems call for a relook into the institutional needs for addressing the present and futuristic challenges of NRM related issues and thus the NRM Working Group has following suggestions:

(a) Seting up a School of Natural Resource Management and Environmental Sciences in SAU

This should draw a multidisciplinary team of scientists (say 10-12) involving scientists for Social and Bio-Physical Sciences stream involving specialist modelers with expertise in areas such as Remote Sensing – GIS Applications, Ground Water Hydrology, Watershed Management, Resource Use Optimization, Farming System Research, and Agro-ecology etc. The main objective for the group will include prioritizing, undertaking and guiding education, research and development towards sustainable resource management by addressing the following areas:

- Strategic interdisciplinary research in watershed, subsurface basin and farming systems perspectives
- Characterized and monitory of the state of resources including the polluted waters
- Data base repository
- Policy Research

(b) Human Resource Development

There is a need for initiating concerted efforts towards building enhanced capability to understand and appreciate agricultural productivity issues within the overall context and need for strengthening the ecological foundation of sustainable agriculture. This has assumed criticality in view of the increasing variability in climate events which have an overarching impact on both socio-economic and biophysical elements impinging on resource use and sustainability of agriculture. Efforts to aim at HRD will need to extend from Under Graduate and Post Graduate teaching and research programs for elevating resource consciousness and scientific management ability. So a resource base and use issues have been taken for granted without understanding their complexity and connectivity in the present education and research agenda in SAU. The key features of the HRD relate to understanding resource management issues in relation to socio-economic elements on the one hand and in relation to interconnectedness of resource base elements in a systems perspective on the other. This would require a process based knowledge to view and solve problems. We strongly recommend to:

- Revisiting undergraduate and graduate teaching programs in consideration of challenges and needs
- Establishing viable units of farming systems at the HQ of SAU for on-hand training to the students and stakeholders
- Greatly strengthening NRM training programs at the regional research station levels for the benefit of extension personnels and other stakeholders
- Seriously considering seeking collaboration from an advanced country (eg. Israel) for HRD in the NRM area.

(c) Strengthening of Adaptive Research

Technological interventions require being constantly adaptive to a situation, refined, and improved depending on the feedback from the intended beneficiaries. This component is currently grossly missing in the system and constitutes a most serious lacuna. Natural Resources System being highly variable calls for adapting technologies to the specificities of the region. Adaptive research has to be undertaken by multidisciplinary teams of scientists in a participating way by working together with the farmers. Adaptive research is also an effective way to ensure rapid uptake of technologies. Although the Regional Research Stations of the university were established with the objective of generating and promoting location specific recommendations, much of the current 'transfer of technology programs' continue to be promoted in a top-down fashion with serious implication to their being assimilated. We strongly recommend formulating multidisciplinary teams of scientists at the RRS and KVKs to greatly strengthen the capacity building at the Regional Research Stations to undertake need based adaptive research in participatory mode to address the burning NRM related issues of the region and training in the area of NRM to the field functionaries and stakeholders. Both on-farm and off-farm issues will need to be understood and appropriate solutions found. In particular, there is need to strengthen expertise in the area of water science, farming system research and monitoring of soil, water, environment, biodiversity dynamics etc. Training needs of the extension personnels of the State and NGO communities have to be increasingly process and system based.

(d) Revisiting Institutional Arrangement within Department of Agriculture and other Stakeholders in the Field to address training needs of farmers and farmer schools to be able to better understand and manage their own resources while ensuring their sustainable use. There are two good training institutes, one is Haryana Agricultural Management and Extension Training Institute (HAMETI) at Jind of Agricultural Department and second one is Haryana Irrigation Research and Management Institute (HIRMI) at Kurukshetra with Irrigation Department. There is a need to focus their training capsules on Natural Resource Management by using modern technologies and demonstrating them on their own farms for efficient use of water and interlinked resources.

4.2.2 Technology Focus

4.2.2.1 Resource Characterization and Monitoring

Resource characterization and monitoring at the field, farm, watershed and the basin level have to be an integral part of NR management and development agenda and programs and constitutes an important input towards sustainable use. Great deals of efforts were made to map soil resources of Haryana at the 1:250,000 scale in the eighties. While these efforts contributed to a broader understanding of the resource base, management decisions are often required to be taken at individual field, farm or a watershed level which constitute a basis for individual or group level decision making on issues of resource use and management. Examples include ability to take decisions on water, nutrient, crop management at field, farm, watershed level, location of a water harvesting or a storage structure, possibility of mixing saline groundwater with surface supplies in a command area, planning and improving drainage from field to watershed levels etc. Inefficiencies on account of inappropriate management decisions in the absence of resource base understanding are at the root of resource and environmental degradation. Implementing of location/ region specific management options call for detailed level characterization of soil (say 1:10-20,000 scale) and water (rainfall, irrigation supplies, groundwater) resources, cropping pattern, biodiversity and monitoring them over space and time to be able to take corrective measures.

Advances in remote sensing and GIS tools have now enabled us to routinely use resource base maps for appropriate intervention on improved soil, water and nutrient management at field, farm and watershed levels. While the University has a major responsibility to address methodological needs, training and demonstration, the primary task of assisting the farmers based on sound farm level plans will remains that with the State Department. We strongly recommend initiation of pilot level efforts for resource mapping in selected villages in each of the major agro ecological regions with a view to implement improved on-farm resource management. Appropriate expertise will need to be created at the Regional Research Stations with strong backing of the NRM group at the university. Similarly infrastructure for resource characterization at the State Department level has to be revived to be able to upscale improved management based on sound resource base information.

4.2.2.2 Farming System and Value Addition

4.2.2.2.1 Farming System Characterization

With increasing intensification and resource degradation, much greater attention is now needed to contain and reverse processes of natural resource base and environmental deterioration. This will require that unlike now, agricultural technologies are increasingly tailored to specific locations such that natural resources are used more judiciously and in a sustainable way. With this broad objective in mind, the country was divided into 20 agro eco-region, 60 agro eco-sub regions and 423 eco-homogenous zones under NARP using the criteria of soils, physiography, water supplies, climate, duration of growing period (crops or vegetation) etc. At the State level Haryana was broadly divided into the three zones-eastern, central inland basin and the western zones. Although such a characterization indicates broadly homogeneous regions, it fails to reflect socio-economic elements that determine the production/development opportunities. Further irrigation development adopting range of opportunities to develop water resources has greatly impacted the potential and constrain associated with these developments. The main aim of Farming System/agro ecosystem characterization includes:

- Identifying main feature of the production system within eco region

- Identifying main constrains to sustainable intensification and diversification for sustainable production in these locations
- Bringing to bear inter-disciplinary and inter-institutional team efforts to improve production, profitability, employment and sustainability under farm condition through adaptive research and extension
- Supporting strategic crosscutting research and feed into production systems research

As of now, there is practically no effort in place to characterize and understand the farming systems and build this perspective in either defining research for development agenda or in extending technologies in relation to the identified constrains. Farming systems and agro ecological region characterization entail both the status and dynamics of the natural resource base and understanding the way sustainability of production systems link the socioeconomic features (crops, farmers choice for different enterprises, agricultural practices they adopt, market opportunities etc). Resource characterization and monitoring at different scales is the basis to defining appropriate strategies for their sustainable use and management. We strongly recommend putting in place a Farming Systems/agro ecological characterization as an integral part of research for development agenda at the local, SAU and State levels. This will require greatly strengthening and/or revitalizing expertise in natural resources (Soil, water) and socio-economic aspects. These groups will need to increasingly use modern tools of remote sensing and GIS based technologies to define spatial and temporal variables and relate these to socio-economic drivers to be able to develop appropriate technological solutions.

Strengthening location specific research is fundamental to a shift from the current supply driven (transfer of technology mode) to more need based demand driven research which focuses on current and future constrains to farming in the region. Farming system and agro-ecological characterization is also the key to better understanding of the extension domain of technologies. Both social and biophysical scientists will need to be involved in farming system research. Social science research will need to be strengthened to enhance capacity for farming system research at the regional research stations.

There is a need to develop functional units of secondary agriculture and agrobased enterprizes alongwith value addition and processing of produce at the HQ of CCS HAU to train the agricultural graduates, field functionaries and rural women and youth on regular basis for better employment and income generation. Some of the farmers have also developed successful models of Integrated Farming System (IFS) on their own with some scientific support by combining crops with livestock, fisheries, horticulture, vegetables etc alongwith their value addition for better utilization of resources and generating higher employment and income. However, more systematic research work is required by involving the RRS and KVK's to develop location specific models of IFS by combining complementary enterprises with crops and livestocks alongwith value addition and processing and proper marketing to help the stakeholders in the State.

4.2.2.2.2 Organic Farming:

Organic farming is a system of production management that promotes the agro ecosystem health including biodiversity, biological cycles and soil biological activity. Organic production systems are based on specific standards precisely formulated for food production and aim at achieving socially and ecologically sustainable agro-ecosystems. The demand for organic food is steadily increasing both in the developed and developing countries with an annual average growth rate of 20-25%. Keeping in view the demand of organically grown food for both domestic and export market, Govt. of India and ICAR have initiated programmes i.e National Programme on Organic Production (NPOP) and National Programme on Organic Farming (NPOF), respectively, for generating data base on the feasibility and economics of organic production in the country. Indian Institute of Soil Science, Bhopal has documented the current status and prospects of organic farming in India (Ramesh and Rao, 2009).

Area under organic farming has grown many fold in six years between 2003-04 and 2009-10 in India due to policy backup and thrust given to the chemical-free mode of cultivation in the country. From 42,000 hectares under organic certification in 2003-04, more than 4.4 million hectares area was under organic certification in the country as on March 2010. The Ministry of Agriculture is promoting organic farming in the country under National Project on Organic Farming, National Horticulture Mission, Technology Mission for North East and Rashtriya Krishi Vikas Yojana (RKVY). Indian organic exports include cereals, pulses, honey, tea, spices, oil seeds, fruits, vegetables, cotton fibre, cosmetics and body care products. During 2008-09, India produced about 18.78 lakh tonnes of certified organic products. Of this, nearly 54,000 tonne food items worth Rs. 591 crore were exported. With more than 77,000 tonnes of organic cotton link production (fibre, textile etc), India became the largest organic cotton grower in the world a year ago.

The Indian organic farming industry is estimated over 100 million dollars and also entirely export oriented. Among Indian States, M.P., Maharashtra, Odisha and NE Hill States are leading States for organic farming.

The Haryana State has also initiated its efforts in the production of Basmati rice, wheat (variety 306) and horticulture and vegetable crops organically. State Department of Horticulture has taken initiatives and allotted a total area of 10180 ha till 2010 to the seven service provider agencies for organic conversion. The expected availability of N, P, K from recycling of organics is about 7.29 lac tonnes in the country (Antil, 2012). However, the major constraints, in this direction are the availability of organics and their recycling for producing quality manure and incorporation of crop residue in soil system. Even to reduce the burning of cowdung, rice and wheat straw (despite of State Govt. ban on burning of straw) is a major problem in the State.

There is a need to encourage farmers by providing alternate sources of energy (cow dung based biogas plants, plantation of multi-purpose trees, use of solar energy etc) to meet the demand of rural households and also incentive to farmers for preparing quality organic manure, better biocontrol measures for disease and pest control, simple certification facilities at door step or producing site and remunerative prices of organic produce, including a separate space or establishment of specific Mandi for organic produce within the State (Singh, 2012).

In long run, organic farming could improve soil health, environment and profitability of small farm holders practicing crops + livestock mixed farming, especially for high value low volume crops, including horticulture and vegetables.

Moreover, the organic agriculture is knowledge based rather than input based and thus, to safeguard the future and make further advancement in the organic farming portfolio, consistent strategic research and development would be utmost important to cover specific area and crops under organic farming in the country/State.

4.2.2.2.3 Value Addition: Productive and Economic Efficiency of Water

Water productivity denotes the output of goods and services derived from the unit volume of water. It demonstrates how per unit volume of water use enhances the productivity and economic efficiency of water at field, farm or basin levels.

In water deficit environment, productivity is a function of:

Y = f (T.W.H),
where
Y = Yield
T = Water passing through crop in transpiration
W = Water use efficiency
H = Harvest Index

Therefore, the various on-farm management practices and breeding efforts should be directed to improve T, W and H for enhancing productivity of water.

In systems perspective, the different management and scientific breeding strategies should be aimed at to reducing unproductive loss of water from soil surface (soil evaporation, water use by weeds, deep percolation below root zone, runoff etc) and to increasing the proportion of water passing through crop in transpiration, and to promoting the genotypes with high water use efficiency (net carbon gain per unit loss of water in transpiration) and harvest index (proportion of biomass translocated to economic yield) to improve productivity (crop per drop of water) in water deficit environment.

The other approaches consider the economic and nutritional value or the quantity of one crop feeds more people than the same quantity of another crop. Thus, there is no single definition of water productivity that suits all situations. However, under all situations the productivity of water could be enhanced either by saving of water use by cutting of non productive water loss or by increasing the productivity per unit process depletion (crop transpiration in agriculture) or other beneficial depletion like allocation of water to higher value uses. Reallocation of water from low value to higher value uses would generally not result in any direct water savings but can directly increase the economic productivity of water. Some of the important genetic, management and other aspects governing the productive and economic efficiency of water and other interlinked resources on-farms are discussed by Singh et al (2011). At farm level, these include: improved water management practices and water saving devices (deficit, supplemental and precision irrigation, changing of crop varieties/crop substitution, pressurized system of irrigation, fertigation, use of plastic etc), and other improved non-water inputs (crop cultivars, soil health, plant nutrition, plant protection etc), including protected cultivation, value addition, processing and marketing. At basin level water productivity spans multiple uses such as crop production, livestock production, tree production, fisheries production, eco-system services, domestic, industrial, power generation, tourism and recreational or integration of crops, livestock or other complementary and supplementary enterprises for maximizing production, profit and employment on sustainable basis (Molden et al., 2003).

The important issues which need consideration are developing location specific models of integrated farming by combining with crops and livestock; one or two location specific complementary agro based enterprises (Nursery raising, seed production, protected cultivation, horticulture, vegetables, floriculture, medicinal plants, mushroom, honey bee, fisheries etc) supported by value addition, processing and marketing. Special efforts are needed to establish processing and value addition centres at strategic places and provide atleast primary processing and cold chain facilities at the production site to the farmers for reducing losses of perishables. Thus, there is a need of creating multipurpose low cost rural based agro-processing complexes through farmers Self Help Groups/cooperatives/ producing companies with provision of needed credit, incentives and rewards following specific area approach with positive government policy support. At the same time providing remunerative prices of value added produce for increasing employment and economic efficiency of water and other resources should also be ensured.

4.2.2.3 Soil Health

The term soil health refers to the state of soil resources in relation to their capacity to perform a range of interconnected and interdependent functions that include as a substrate for crop production and medium which regulates hydrological cycle including retention, storage and regulation of flows within the root zone of crops and in the ecosystem, nutrient cycling at the farm (soil-crop-livestock) and in the landscape ecosystem, a habitat for large variety of biodiversity bringing about transformations fundamental to range of functions, and a regulator of green house gas emissions and carbon sequestration.

In the past, the issues of soil health have been understood and interpreted from the limited and narrow perspective of increasing crop yields by focusing on supply of nutrients through chemical fertilizers, defining and supplying nutrients to meet emerging macro, secondary and micronutrient deficiencies etc. Little attention was given to issues of maintaining and improving hydrological and biological soil properties which are critical and essential processes that impart good soil health. For this reason the critical and more fundamental integrating role of soil organic matter has remained greatly discounted as the key element for enhancing and maintaining soil health. Thus, despite large amount of experimental evidence from several parts of the country to show that application of large amounts of organic matter in the form of FYM and other means was essential to sustain high crop yields; but how to build good soil health based on these finding has been lacking.

Despite its proven benefits, organic matter management and recycling necessarily hinges upon (a) availability of organic matter, (b) economic incentives for generating, conserving and recycling organic matter and (c) awareness and technological backup for alternate source of energy for the rural household.

At the extension level during 11th Five Year Plan under the centrally sponsored initiative 'National Project on Management of Soil Health and Fertility' with the main objectives of setting up soil testing laboratories, strengthening fertilizer quality control, promoting integrated nutrient management and balance use of fertilizers, micronutrients etc., a series of soil testing laboratory have been established. While these efforts are recognition of serious problems, the programs have provided little or no attention to addition of organic matter to soils, a fundamental corrective action required to enhance soil health. The Approach paper to 12th Five Year Plan has emphasized 'addition of bulk organic matter to soil' as a priority need. These imperatives call for developing and promoting agricultural practices which can contribute towards enhancing and maintaining soil organic matter, saving and avoiding burning of cowdung in the households.

Research programs aimed at technology generation in the area of soil health have been guided and funded through ICAR coordinated projects – for this reason, there was little opportunity to understand and find solutions in relation to location specific needs in terms of resource variability and sustained use. Research programs rarely relate to either understanding the problem that the farmers face or the needed solution. *Natural resource management issues are multidimensional and often complex and solutions cut across disciplinary and sectoral boundaries and therefore, call for more comprehensive approaches to identify and find solution to problems of sustainable use and management of soil resource.*

4.2.2.3.1 Technological Focus for Managing Soil Resource and its Health

The focus of technological input to enhance productivity needs to shift from the current focus on chemical fertilizers to one that emphasizes enhancing generation of biomass at farm and landscape level (e.g. in common lands with agro-forestry practices etc.) for generating a bulk which can be returned to the soils. Saving cowdung and leaving crop residues on the soil are other options which should be perused technologically and defining incentives for farmers to adopt practices where cowdung, crop residues are returned to the soil. Efficient use of chemical fertilizers, the primary focus of soil health program, is a major national concern in view of large amounts of subsidies being passed on to fertilizer sector. Improving the organic matter regime of the soils is a single most effective and integrative way to enhance fertilizer use efficiency and must emerge a key focus in integrated approach to soil health management. The following technological interventions need to be pursued with concerted efforts to restore the primary productivity of soil and its health:

- Developing and promoting practices that accelerate build up of organic matter or reduce soil organic matter decomposition by adopting practices such as no or reduced tillage systems.
- Recycling of farm and household wastes through use of intensive nutrient recycling by appropriate composting techniques, phospho-composting, vermicomposting and NADEP (Aerated composting).
- Adopting Natu-ecofarming to improve soil organic matter through the use of cowdung, urine, farm residue, mineral rich soil and green manuring in steps (3, 6, 9 weeks old plants) for soil resource enrichment of small land holders.
- Connecting cowdung based bioenergy with organic product and quality manure by establishing modern biogas plants by using proper biofilters, slurry concentration and additives (Yadvika and Gupta, 2012).
- Adopting agro-forestry practices by planting multipurpose trees for additional biomass, fodder and fuel etc. Associated practices, e.g., installation of night soil based common biogas units and connecting with common Sulabh Sonchalay and Nirmal Village Yojana of GOI.
- Encouraging cropping patterns to include leguminous crops of green manure/pulses and intercrops that keep the soil covered and enrich soils in contrast to increasing emphasis on a couple of cereal crops.
- Pooling existing soil testing data (soil test cards etc) into a 'System of Soil Nutrient Management' which enable much better informed soil nutrition management and quality of extension network.

At the extension level farmers will need to be supported, at least in the initial years, in the form of incentives for adopting agronomic measures and cropping patterns that enrich soils with organic matter (e.g. leaving crop residues on soil surface, adopting no tillage/reduced tillage options, growing crops such as dhaincha and legumes on the farm, organic farming) in a cost effective way. Suitable rewards may be given to farmers for carbon sequestration and reducing emission of GHG.

4.2.2.4 Managing Water Resources

While development of water resources has constituted the core of the strategy adopted by the State to achieve agricultural development goals over the past decades, the challenges of sustaining agricultural production and growth now critically hinges upon our ability to manage the resource in ways which contribute to maintaining and enhancing productivity and profitability levels with declining availability and ensuring that the strategies and agriculture practices which we adopt do not contribute to resource and environment degradation. The dimensions of the challenge, by no means small, assume greater seriousness with growing implications associated with increasing climate variability. While addressing these challenges, there is a need for greater appreciation of a few fundamental elements that will need to guide our technological efforts and solutions. These include:

- Haryana, though a part of arid and semiarid region, receives an annual rainfall ranging from more than 1000mm in the North East to less than 300mm in the south-west adjoining arid Rajasthan. Although rainfall limits the extent of agricultural intensification, any strategy aimed at sustainable intensification must be based on supplemental role of irrigation while maximizing the use of rain water efficiency. This would also imply shift from the current 'maximization of individual crop productivity' to 'improving system productivity, per unit available water resources'. Maintaining this new paradigm into research and extension activities will be at the core of addressing the challenges facing farmer and policy makers.
- On-farm water management has serious implications in term of overall resource degradation but also in terms of efficiency of applied seeds, fertilizers, pesticides and other inputs. Proper application of water and fertilizers improve each other's efficiency. Thus, while improving use efficiency of applied fertilizers is a pressing concern, the solutions cannot be found only in terms of fertilizer management practices. Inappropriate water management practices is the single most important factor affecting use efficiency of applied nutrients through processes which include losses through leaching, pollution of surface and groundwater, gaseous losses

affecting soil environment etc. Water management issues are also at the root of many disease and pest management problems requiring heavy doses of pesticide chemicals for control. Thus, on farm water management needs must be viewed in the context of being pivotal to sustainability of agriculture and overall development.

- As in the case of soil resources, there is high degree of spatial and temporal variability in the amounts, distribution of surface water supplies, groundwater conditions, including quality, availability and subsurface flow condition-all impacting sustainable use and management needs and options. Understanding the nature and dynamics of variability at the farm, watershed and basin levels are important consideration in any strategic planning and management options. At present, Haryana Groundwater Cell of Agricultural Department and Central Groundwater Board are the principal agencies which evaluate and periodically monitor the state of groundwater resources at block, district and State levels. While this has contributed significantly to our broad understanding, there is need for more robust water related studies to guide integrated management decisions at different levels. Haryana Agricultural University has a primary responsibility in this regard. Regretfully while till eighties the University had a strong focus on water related issues, this has gradually been decimated over the years and at present there is inadequate focused efforts at either understanding the issues or to finding solutions there of. A small staff in Soil and Water Engineering Deptartment in the College of Agricultural Engineering is largely engaged in teaching U.G and P.G classes. ICAR sponsored research in the area of water management in the absence of effective multidisciplinary teams of scientists in the present context makes only little difference. There is an urgent need to set up a separate Institute/Department of Natural Resource Management and Environment Sciences with interdisciplinary expertise in the social and biophysical areas to provide a strong scientific underpinning to technological and policy issues relating to water management in the agricultural sector.

- Water management issues are also hardly on the agenda of Department of Agricultural Extension Agencies of the State. The only programs being pursued relate to subsidized availability of drip and sprinkler irrigation systems or to the engineering components of water storage in the watershed projects or transport (underground pipes) water for improved availability. Here again there is little expertise to back up the understanding and fine tuning the knowledge. There are no efforts or programs aimed at understanding constraints or assisting farmers in improved management of their own limited resources. This has to be the main technological focus of the Department of Agriculture through proper coordination with SAU and Irrigation Department.

4.2.2.4.1 Technology Focus for Managing Water Resources

It is clear from foregoing discussing that past efforts aimed at achieving high productivity involving expansion of irrigated area through surface and groundwater development and use have resulted in a variety of problems influenced by the geographic setting and variability in soils, climate, hydro-geological conditions, crops promoted and management methods and policies pursued. From the standpoint of water management a few broad region specific issues are recognized. Addressing these issues will call for region specific strategies and technological interventions. The broad regions include:

4.2.2.4.1.1 Declining Water Table Areas in the North-East

These are the areas (mainly districts of Karnal, Kurukshetra, Panipat, part of Kaithal) which are underlain by good quality ground waters and Rice-wheat is the major cropping system. The region receives mean annual rainfall in the range of 600-700mm. Coping with declining water tables implies higher capital and operating costs to pump water. These are also the regions which use highest doses of fertilizer and groundwater and environmental pollution have emerged as a serious concern. In some areas (eg Distt Karnal) there is evidence of inflow of saline ground water from adjacent areas.

To define and promote appropriate strategies and practices, working group recommends initiation of a research cum development project in an identified watershed aimed at intensive resource characterization and monitoring in relation to selected interventions to address identified problems. The options need to be identified, tested and evaluated for ensuring the farmers participation could centre around alternate cropping systems, use of pressurized irrigation, CA based technologies, including drainage/water recharge needs, impact on natural resources, farmers education on water use related issues, cost: benefit etc. Involving State Department extension staff in project implementation will be important. The primary responsibility for planning and execution must be that of Regional Research Station of CCSHAU at Uchani, Karnal which has a multidisciplinary team of scientists. The weak components at RRS, Uchani are inadequate scientific staff in the area of soil and water management and social science which must be strengthened.

The project should have guidance from the Natural Resource Management Group at the HQ of SAU to be able to take a more comprehensive view at the State level. These projects should provide a basis for continued improvements at the farm level, uptake of knowledge and technologies over a wider area on the one hand while on the other hand they should provide a feedback to scientific community to be able to articulate R&D needs more effectively. These efforts should also be able to highlight policy level issues that would need attention for wider adoption of technologies. These suggestions are only indicative and obviously detailed planning and execution details will have to be worked as will be the technical manpower needs etc.

In the past couple of years promoting groundwater recharge by adopting well injection technique and involving routing of runoff and excess canal water through a recharge filter and then to a tube well type recharge structure under gravity to a sustainable aquifer has been suggested and tested as a way to arrest declining water tables at some sites in Haryana (Karnal, CSSRI). According to these studies the payback period of 30-45m deep recharge structure costing Rs 30,000 to 50,000 would be only 1-2 years. The study further suggests that the recharge structures could also prove useful in areas with high salinity ground waters. Wider adaptability of these approaches however must be seen in the context of rice-wheat dominated areas of Haryana. Thus, while the entire effort in preparation for growing puddled rice in the kharif season is to reduce soils natural capacity to absorb, store and transfer rain water as to retain it on soil surface involving energy intensive soil working etc, in the same season we aim to recharge groundwater at the same site. There is a need to look at natural resource management issues in totality before advocating in large scale intervention for technologies under such conditions.

The other options, i.e. growing of aerobic rice (DSR, SRI) and hybrid maize/maize + soybean/soybean + pigeon pea through CA based technologies also needs consideration while executing research cum development project on NRM by RRS Uchani, Karnal in farmers participatory mode.

4.2.2.4.1.2 Rising and Declining Water Table Areas in the North- West

These are the areas which are underlain by poor quality ground waters where introduction of canal irrigation has enabled double cropping, primarily cotton-wheat rotation in large areas in this region. Rise in ground water levels have caused increasing problem of water logging and soil salinization threatening sustainability of production systems. These are also the areas where use of chemical fertilizers and pesticides is amongst the highest causing serious pollution associated health problems that have been further accentuated due to many farmers opting to grow rice in these areas. As in preceding section, we suggest CCSHAU commissioning an 'on-farm water management research cum development' project in an identified representative area in the zone. The objective of such a project should be to characterize and understand resource use dynamics and related socio-economic factors, identify, test and promote appropriate strategies and practices aimed at improved resource use efficiencies and control of associated degradation processes involving farmer participation and close association with development agencies. The option to be identified with farmer participation must aim at maintaining more favorable salt and water balances through appropriate cropping (eg. intercrops, crop rotation, low water requiring crops etc.) and on farm water management practices.

While pressurized irrigation systems offer significant opportunities for improved use efficiency, their adaptation in canal-irrigated systems will be a more challenging task, although the State is currently promoting pressurized system of irrigation (drip irrigation) for horticultural crops. The interaction of working group with scientists and farmers at Sirsa indicates that the drip irrigation in BT cotton promotes development of shallow roots, lodging and incidence of para wilt. Thus, there is a need to evaluate the comparative performance of drip vs furrow irrigation with paired row planting of crop geometry. The appropriate paired row crop geometry will also help to adjust relay crop of wheat in delayed harvested cotton.

There is also the problem of decline in water table in some parts of Sirsa division and farmers have been benefitted through drip system of irrigation in cotton, and tubewell water recharge by siphoning technology in rice field during rainy season. Past experience and farmers' perception with required scientific backstopping appropriate strategies should be pursued to form a basis for wider adoption of approaches. Monitoring and evaluation must be an integral part of the project. The key responsibility for planning and execution should be that of Regional Research Station (RRS), Sirsa. Involvement of Department of Agriculture and Regional Research Station, Cotton (ICAR) will be important to address NRM related issues of the region.

4.2.2.4.1.3 Inland Basin Areas

These are areas where restricted surface and subsurface drainage limit productivity of large areas. These are also the areas where water logging and soil salinization are increasingly impacting productivity. A number of studies have been carried out to explore the potential of different options to address the problems. We suggest that:

(a) Water management group (which should include social scientists) within CCSHAU should undertake a review of the past studies and field level efforts aimed at finding solution to the water congested areas including the possibility of mixing drainage effluents with irrigation water etc. with the aim of initiating pilot level efforts to build a basis for any large scale effort. This review should be undertaken jointly with the scientists of CSSRI, Karnal. The findings of this review should be shared with principal stakeholders in the State in a workshop with a view to develop a proposal for pilot level studies. Collaboration from outside India should be sought if considered necessary. Appropriate funding should be sought for pilot proposal from State/Centre Government.

(b) There are large areas of salt affected water logged soils where currently no economic production is possible. We suggest that these areas be identified, characterized and at least two sites (Rohtak, Mewat) pilot studies launched by the University in collaboration with CSSRI, Karnal and Department of Forestry to explore the possibility of using such lands for biomass/fuel-food managed plantations. At present many of these areas stand abandoned and support only sporadic vegetation of no economic consequence. Work of CSSRI has brought out the potential of plantations in lowering water table while contributing to fuel wood needs etc. These options are reinforced in view of the potential to sequester carbon, enhancing soil productivity and contribute positively to environment. In Haryana, a sizeable community of rural poor is engaged in small scale activity of producing charcoal from tree biomass which is in high demand. Pilot level studies need to be carried out on a sizeable area and scientifically planned and monitored to be able to feed into policy for larger initiative by the State farmers / communities and they should be well involved at planning and executing these activities.

4.2.2.4.1.4 South Western Region

This region comprised of light textured soils with very low carbon content, harsh arid climate, low and erratic rainfall (300-400 mm) and poor quality groundwater. These are the areas dominated by tubewell irrigation through sprinklers. The water table is declining at an alarming rate, deteriorating both quality of ground water and soil. The farmers are increasingly using gypsum to mitigate the adverse effects of poor quality water on soils. The increase in the depth of water table as well as use of gypsum is also adding to the cost of cultivation. The South-Western highland areas constitute another unique domain in which number of lift irrigation schemes are in operation. In these schemes irrigation water from canals is pumped in stages up to 170 m heights to supply water to different lift canals for irrigation to the farmers. Not much published information is available to understand energy costs and other operational constraints. The presence of Mewat Distt. in the region brings additional specificities (water logged soils, salinity, water scarcity etc.) and the solution of these problems will require specific approaches. The region being highly water scarce, farmers have developed their own ways to use sprinkler and other water saving devices to grow low water requiring crops. This region has got lot of scope for improving resource base and augmenting farmers' income through crop substitution (cluster bean, castor), conservation agriculture, integrated farming, agro-forestry, agro-horticulture by following holistic approach of watershed development and management.

The NRM Working Group recommends undertaking adaptive research by multidisciplinary team of scientists of RRS Bawal in a farmer participatory mode for better understanding of ground realities and developing sound technical approach and supporting policy to address complex and inter linked issues of NRM. Strengthening the scientific support in the area of Soil and Water Management, Water Engineering and Social Sciences including the involvement of the Department of Agriculture and ICAR institute (WTC, IARI) will be essential to achieve short term and long term goals for sustainable resource management in the region.

4.2.2.4.1.5 Shivalik Foot Hills

The northern part of the State forming foot hills of Shivalik consists of high rainfall areas, rolling topography and highly prone to water erosion. This zone also functions as recharge zone of downward area. In the past, good watershed based programmes were carried out jointly by Department of Agriculture, SAU and ICAR Institutes through active involvement of farmers and other stakeholders. The farmers were benefitted immensely in operational areas of the multidisciplinary watershed management project. However, there has been a complete dissipation to continue and repeat this work in other area due to lack of staff and coordination among different agencies. Thus, there is a need to pool all available resources of various Government Departments (Agriculture, Forestry, Rural Development etc.) meant for this purpose and establish proper coordination for adopting system based approaches through scientific planning and implementation of holistic watershed development programmes by involving experts from the State Government, SAUs , ICAR and other stakeholders. There is also a need to intensify aforestation efforts in the catchment area, soil and water conservation activities both in agriculture and non-agriculture areas, desilting of existing water storage structures and making defunct dam functional for better resource conservation and augmentation in the region. The menace of wild animals (blue bulls, monkeys, wild boars) is also one of major constraint as reported by farmers in adopting remunerative cropping system in the Kandi area.

4.2.2.4.2 Other Aspects of Resource Augmentation and Utilization

4.2.2.4.2.1 Augmentation of Water Resource through Reclamation of Problematic Waters

- There is a need to work out the strategies for reclamation of problematic waters i.e. brakish, sewage and industrial effluents for their reuse in irrigation.
- There is a need to complete the mapping of ground water quality in digital form and come out with location specific technology for safe use of brakish water under different agro-ecological conditions by CCS HAU.
- There is a need to conduct more research for monitoring and treatment of sewage and industrial effluent for their reuse in irrigation and improving the environment. A core group consisting of scientists of CCS HAU and CSSRI Karnal by involving the State and Central Pollution Boards should be formulated to work out strategies for their treatment, monitoring and advice the Govt. on this important issue on regular basis.

4.2.2.4.2.2 Water Storage and Recharge Structures

There are main nine Water Bodies/Lakes which are also recharging the aquifer by harvesting the rain water and also mitigating the flood threats in addition to providing direct surface water for irrigation. But at present, these need repair/ renovations/ desiltation for making their full use. The water bodies are: Bhindawas and Dohar (Jhajjar), Bibipur (Kurukshetra), Ottu (Sirsa), Massani (Rewari), Kotla (Mewat), Peer Bhaudi and Nidana (Rohtak) and Uhlana (Sonipat). The total area of these water bodies is more than 6000 hectares. In addition to these water bodies, there are large number of village ponds which are also working as recharge bodies but their capacity has reduced over a period of time due to encroachment and siltation. These are also not adequately documented as well. In addition to above water bodies, some recharge galleries could be constructed in the rivers/ drains so that more rain water can be used for aquifer recharge. In deep drains, some humps at suitable places in the beds can also be useful for recharge purposes.

4.2.2.4.2.3 Water Resources and Fisheries Sector

Of late there has been considerable emphasis on expanding fisheries sector in the State. The major premise is that fisheries enterprise can enhance farmers' income a great deal. A further premise is that fisheries sector has lot of promise in waterlogged and salt affected soils alone as well as alongwith agroforestry. Some good work through soil configuration has been done in water logged area of Sharda Sahay Canal in Uttar Pradesh by CSSRI, Karnal by growing vegetables and tree crops on broad bunds and fish and rice culture in low land water logged broad trenches in canal commands. In 2005-2006 some more than 10,000 ha area was devoted to inland fisheries and this area has further expended to 17094 ha in 2010-11 in Haryana. With limited and fragile resources the implications of such a strategy has never been viewed or evaluated in terms of resource use dynamics, energy and environmental considerations and vis a vis alternate options. There is need to build a regional perspective in different development programs and water resource dynamics is the key to sustainability of resource use under such production systems.

4.2.2.4.2.4 Agroforestry

Currently, Haryana has about 3.52 % area under forestry cover. The State has already formulated forestry policy with an ultimate goal to bring around 20 % area under forestry cover in a phased manner. To meet deficit tree resources for timber, fuel and fodder resources and improving environment in the State, the plantation of multipurpose trees on private lands, waste lands, Panchayat/common lands, road sides and on both sides of railway tracks, field boundaries etc should be given priority. To provide boost to forest sector, there is a need to put in place an effective mechanism to ensure survival and proper establishment of trees, including regular monitoring of forestry cover using remote sensing and GIS technologies. Also forestry research for development of more forestry cover should be greatly strengthened in CCS HAU and HARSAC to help this sector. Agroforestry system could be beneficial to use it as bio-drainage and mitigating the impact of climate change through moderating temperature and reducing the emission of GHG. The farmers could also be benefitted in future due to carbon trading. To help and encourage the farmers for plantation of trees on their own lands, tree should be treated as crop from planting and harvesting point of view for increasing forestry cover in the State.

4.2.2.5 Climate Smart Agriculture

There is a need for strengthening the Department of Agro-meteorology for mainstreaming the climate change related mitigation and adaptation measures into natural resource management research and development to begin with climate smart and weather forecast based agriculture in the State. Increased use of fossil fuel, puddled rice cultivation and large bovine cattle population in the country are major sources of emission of GHG and global warming. The research results suggest that the C3 crops will be benefited from CO2 enrichment, but the elevated temperature will increase water use, reduce maturity duration and productivity due to global warming. The direct seeded rice has less emission of methane gas as compared to puddled rice, but vice versa is true for the emission of nitrous oxide gas in the atmosphere. It will require fine tuning of management strategies to reduce emission of nitrous oxide gas to make DSR technology more ecofriendly. The adoptation of conservation agricultural technologies and good agricultural practices directed to improve resource base and quality and its vegetative cover, commissioning of cattle dung based bio-gas plants and development of cattle breeds and feed to reduce emission of GHG and development of stress tolerant varieties of field, fruit and tree crops could be important climate change related mitigation and adaptation technological interventions for futuristic research for development in the State.

5.0 KEY STRATEGIES

Recognizing that widespread, serious and continuing problems of resource degradation are at the root of achieving sustainable growth rates in agriculture in Haryana and that reversing process contributing to degradation through appropriate conservation and management strategies is fundamental for achieving the objectives of sustainable agriculture. It is important to put in place appropriate strategies to support action aimed at finding solutions of Natural Resource Management problems (Land, soil, water, climate, biodiversity) in the State.

In this regard, it is further recognized that as of now the technologies and management practices and policy regimes promoted have had the net effect of depleting resources while achieving increased productivity. For this reason therefore, both the technology generation and implementation approaches have to undergo a basic shift to find solutions of complex natural resource management problems. This change related to location/region specificity of natural resource base, soil, water, climate, physiographic features etc and the need to find solution to location specific productivity and interlinked natural resource problems should be properly addressed in the present scenario. This change is a fundamental departure from the past where the problems of production agriculture have been largely viewed and solutions found and implemented in terms of inputs needs, availability etc.

Natural resource problems are location specific but also linked spatially hydrologically (Surface and subsurface). Thus, interventions at one point or a location impact the region as a whole. Therefore, understanding these links is important in any long term solution to natural resource problem.

There is also strong interaction between the natural resource base and socioeconomic features of a region which is reflective in the prevailing farming system. Better understanding of the dynamics of the farming system is therefore critical to the success of technologies and approaches to sustainable management. As of now this is serious gap in research for development agenda.

There is ample recognition that addressing natural resource linked productivity problems call for integrated approaches for finding solution to the specific problem.

There is serious gap in planning and execution of research towards this goal. This is at the core of achieving aims of sustainable growth. While it is true that most scientific efforts will be pursued in a disciplinary mode. What is important is to build in farmers' perspective in our research planning and in adopting technologies by interacting and working together with the farmers. Farmer's decision making and adoption of new technologies reflect a deeper understanding of system and can guide in building a system perspective. A system perspective has to guide research and development agenda at all levels-local and regional.

The scientific community has thus far, given little or no attention to research which is designed to influence policy. This will be increasingly important in future. While NRM issues require new approaches and the generation of technologies and linking them to policy will be extremely important and the scientific community has an important role in guiding policy. Finding solution to NRM issues calls for improved decision making at all levels: farmers, communities, policy. Improved decision making calls for enhanced knowledge base and ability to upgrade human resource at all levels. These are some of the tall orders and while suggestive changes and actions are not likely to happen immediately, the need is to put in place initiatives that will contribute to building a strong NRM related program to achieve sustainable agriculture goals through the following strategies:

5.1 STRENGTHENING INSTITUTIONAL NETWORK

5.1.1 Seting up a School of Natural Resource Management and Environmental Sciences in SAU

At present there is hardly any institutionalized way to conceive and plan NRM research for development. A beginning can be made by setting up a Working Group headed by Vice-Chancellor by including Director of Research and Director Extension Education, besides key specialists in the areas of land, soil, water, climate, biodiversity and social science. The broad objectives of this group will be to guide NRM research for development towards sustainable agriculture and generate the required resources to make things happen. It would appear important that a small grant, say 10-15 lacs is made available to be able to hold discussion, invite experts, develop R& D projects and seek funding to develop a comprehensive plan for NRM research/development for the 12th Five Year Plan by SAU. More specifically the group should focus immediately on defining a few priority issues to highlight the policy imperative. Some examples would be:

- Highlight how land use and land cover changes induced resource degradation is impacting sustainably in terms of resource use and diversion of quality land for urbanization, infrastructure, mining, aforestation, industrialization etc.
- Disposal of industrial waste and pollutants in water streams is a serious health and agriculture hazard in many parts of Haryana-mapping these areas, identifying and pinpointing the sources, evaluating how pollution is impacting health, resource quality etc, the available options, needed action etc.

Over the past 3 to 4 decades in our efforts to meet food production goals, there have been profound changes accompanied with spread of irrigation (Canal and groundwater) and agriculture intensification and these have created NRM problems and need immediate attention for their solution.

- There is a need to analyze and understand how socio-economic drivers have impacted resource use and management in the otherwise ecologically fragile region. Thus, changes in soil, water, nutrient imbalances have serious implications in term of sustainability of agriculture and overall resource use. Better understanding of nature and dynamics of these changes and their socio-economic implication is fundamental to evolve strategies for sustained use of resources.
- Amongst other key interventions over the past decades include; transport of water through lift irrigation schemes to higher elevated areas with little possibility of gravity irrigation. What are the lessons that we have learnt in terms of effectiveness and efficiency of the system, energy use, socio-economic impact, resource use.
- Watershed management based approach has been pursued with a view to conserve resources in a limited way. Here again there are hardly any

scientific studies to evaluate to what extent desired objectives were achieved and in what way to build upon these efforts.

- To guide policy and development agenda at State level, the NRM group will have the prime responsibility to view State level problems, prioritize research for development agenda and ensure a coordinated efforts at all levels: State, institutions, farmers.
- As of now there is no institutionalized way to focus on land use studies. The CCS Haryana Agricultural University has obviously a key role. The University could also establish working relations with other universities which have strong departments of geography and interest in land use studies. It will be also important to establish strong GIS and remote sensing facilities/collaborative efforts with the State Remote Sensing Centre (HARSAC) at Hisar.

Thus, there is a need to seting up a "School of Natural Resource Management and Environmental Sciences" at CCSHAU, Hisar to prioritize, undertake and guide education, research and development for sustainable resource management in long run in Haryana. This should consist of multidisciplinary team of scientists drawn from the bio-physical, social and environmental sciences with expertise in areas of modeling, remote sensing-GIS applications, ground water hydrology, watershed management, farming system research, agro-ecology, resource use optimization etc.

5.2 Human Resource Development

Addressing issues of sustainable use of natural resources call for not only sound understanding of the nature and state of resources but also the way socio-economic factors dictate their use. Thus, addressing NRM issues call for inputs from a range of disciplinary sciences both physical and socio-economic. As of now there is very little, if any, involvement of social scientists in natural resource management research and other interlinked areas. Over the decades, there has been a sharp decline in understanding and addressing NRM problems on the part of physical scientists. Further, much is desired by way of quality of available human resource towards addressing complex issues of NRM. Therefore, there is a need to explore all avenues to strengthen human resource base. While, this involves a larger question of agricultural education, we suggest that the CCS Haryana Agricultural University should:

- Explore a long term relationship involving research partnership with an advanced overseas university as a first step in this direction. It is understood that the Department of Horticulture has entered collaborative effort with Israel in developing and promoting technologies in the field of protected cultivation of vegetables and High Tech Horticulture etc. Israel also has strong expertise in the area of managing soil and water resources under resource constraint conditions. Universities in USA would be another options considering our past linkages.
- Initiate a training program to focus on 'On-farm Soil and Water Management' issues for extension workers. The aim of such a program should be to assist farmers better understand and manage their own limited resources. This will call for greatly enhanced capacity of the University and State Department of Agriculture. At present the State Departments have little technical capacity to impart required knowledge to the farmers due to their entire focus on providing subsidized inputs.
- Establish viable units for on-hand training in farming systems perspective with emphasis on intensification, diversification, resource conservation and value addition at the HQ of CCSHAU to train the undergraduate students, rural youths, women farmers and other stakeholders to develop entrepreneurship skills for employment/self employment, profitability and livelihood security of small farm holders. Vocational and certificate courses in the field of secondary agriculture and complementary enterprises (CA based technology, nursery raising, seed production, protected cultivation, floriculture, pressurized system of irrigation, biogas production, honeybee, fisheries, mushroom, medicinal plants, value addition and processing of agricultural produce etc) for rural youths and women will be welcome step.

Similarly location specific efforts, but on small scale, are also required at the different Regional Research Stations of the SAU to help the stakeholders.

- Revisit undergraduate and graduate teaching programmes in consideration of present challenges and needs, especially in the field of modeling, GIS, systems research, resource use optimization, climate change, conservation agriculture etc.
- Need for greatly strengthening Regional Research Stations

Regional Research Stations are currently considered mainly as transfer of technology intermediaries. This must change their primary responsibilities in identifying and prioritizing regional research problems and undertaking adaptive research in the context of location specific needs and production systems. Working together with the farmers, understanding and solving their problems while providing a feed back as what works and what does not work in a particular situation.

Understanding the farming system, the environment in which a farmer works, the resources and the way he uses and takes day to day decisions is fundamental to identify and prioritize possible interventions for improved management. Farming system characterization must become an integral part of research process. Appropriate methodologies have to be developed and research operationalized at the Regional Research Stations as a way to prioritize location specific agenda.

This is a major shift required to focus on NRM research. There is a need to look into manpower needs which go with such a shift. Water science is a particularly neglected science as is the social science field. Adaptive research calls for multidisciplinary team of scientists aiming to find solution to an identified problem by operationalizing adaptive research.

- Strengthen the manpower, infra-structure and training facilities of two training institutes with Govt. of Haryana i.e.

  1. Haryana Agriculture Management and Extension Training Institute (HAMETI) at Jind under Department of Agriculture, and

2. Haryana Irrigation Research and Management Institute (HIRMI) at Kurukshetra under Irrigation Department.

The HIRMI should be headed by high level expert in the field of irrigation management by focusing training capsules on modern technology of high tech irrigation, adaptive research to validate and refine potential High Tech Irrigation technologies and develop their demonstration units on the research farm of the Institute. These facilities will certainly help in better understanding of different aspects of on-farm water management and also to act as a practical guide to field functionaries, extension staff and other stakeholders. The person who normally headed/oblique is heading the institute from Irrigation Department (mostly SE/CE) on transfer basis feels its posting as punishment and does not take full interest to achieve the desired objectives (i.e. research and development) for which the institute was established alongwith good farm facilities. Thus, there is a need to have a high level scientist as its Head with expertise in the field of Soil and Water Management on permanent basis to achieve the desired mandate of the institute.

- Revive of activities of State Land Use Board (SLUB) for monitoring the changes in land use for different purposes in the State. For this purpose formation of Working Group of Scientists from CCS HAU and HARSAC and SLUB is required for monitoring and studying the diversion of agricultural land to non-agriculture, its impact on NRM and agriculture production.
- Strengthen manpower in various Govt. Departments and SAU in the field of NRM for sustained use and development of resources in the State.

5.3 Climate Change constitutes an overarching agenda for agriculture research and development

Mainstreaming climate change related issues into natural resource management research and development is critical to begin with climate smart and weather forecast based agriculture in the State. Better understanding of the imperatives of change and the need for effective response which constitutes a common thread that links different sectors and disciplines towards a common aim. We suggest that Department of Agrometerology at the CCSHAU be further strengthened to be able to work collaboratively to widen and deepen its understanding to enable mainstreaming climate change related mitigation and adaptation issues into research for development.

5.4 Striving for better scientist-farmer connect-Adaptive Research-the Missing Link

The Regional Research Stations of CCSHAU, Hisar were established with the objective of generation and promotion of location specific technologies through proper support from the HQ. Also the current transfer technology programmes are promoted through top-down approach rather than from bottom up approach. We strongly recommend formulation of multidisciplinary team of scientists at different Regional Research Stations and KVKs to undertake adaptive research in a farmers participatory mode by strengthening expertise in the area of water science, social science and farming system research for proper monitoring the status and dynamics of NRM and interlinked socio-economic settings, and come out with location specific need based solutions and training needs of the stakeholders.

Adaptive research projects need to be initiated to address priority issues in following respective regions:

- RRS Uchani, Karnal to address the problem of decline of ground water table and deterioration in the groundwater quality and interlinked issues.
- RRS Rohtak to address the problem of rise in water table of inland basin underlain with poor quality water and irrigated with canal water.
- RRS Bawal to address three different specific problems in the region:
  - a) Semi-arid area of South-west Haryana irrigated with poor quality underground water
  - b) Water logged, saline and water scarcity area of Mewat and
  - c) Lift canal irrigated area with scientific and technical support from HQ

- RRS Sirsa to address problems of rise and decline in water table and interlinked issues in the region

  In these research cum development projects, characterization and monitoring of resources in relation to selected technological intervention, alternate cropping systems/farming systems, use of pressurized system of irrigation, other improved on-farm water management practices, including water recharge needs and impact on natural resources would be important. The involvement of concerned Government Department and other extension agencies in such research cum development projects (R4D) in farmers' participatory mode will be important and critical for better understanding and sustainable development and utilization of resources.

- There is need to develop location specific on-hand training and demonstration facilities of integrated farming system with emphasis on intensification, diversification and resource conservation after their proper validation in farmer participatory mode by combining the major crop production systems and live-stock with one or two need based complementary enterprises (nursery raising, protected cultivation, high-tech irrigation, seed production, fishery, honeybee, mushroom, medicinal plants, value addition etc) by multidisciplinary team of scientists at RRS and KVKs for training and skill development to stakeholders to improve resource base, employment and income under different production systems.

5.5 Scientific Land Use Planning

There is a need for characterization of soil (1: 10-20000 scale) and water resources, cropping pattern, biodiversity, climate, socio-economic and cultural settings over space and time by using modern tools of remote sensing/GIS to develop scientific land use planning and undertaking location specific corrective measures for better utilization and optimization of available resources with the farmers.

- The working group consisting of CCS HAU, HARSAC and State Land Use Board should monitor on regular basis the impact of diversion of land on soil degradation, natural water courses/water bodies, biodiversity, agriculture production and environment and suggest suitable measures to the Department of Agriculture for scientific land use planning and improved resource management of Haryana by using such base information.

- Advances in remote sensing tools are now available to routinely use resource base maps for appropriate intervention on improved soil, water and nutrient management at field, farm and water shed levels. There is a need to initiate pilot level efforts for resource mapping in selected villages in each of the major ecological regions with a view to improve natural resource management at individual farm level.

5.6 Organic Carbon and Soil Health

- Soil organic matter content is the single most important factor to improve hydrological and biological properties of soil and input use efficiency of chemical fertilizers. Thus, there is a need for developing and promoting agricultural practices which can contribute in enhancing and maintaining soil organic matter.
- There is a need to fine tune and adopt the conservation agriculture based technologies, recycle of crop residues, as also the inclusion of green manure and legumes in crop rotation, addition of organic manure (FYM, compost, phospho-compost, vermi-compost, NADEP), biofertilizers and their proper dose of application alongwith chemical fertilizers under different cropping system and adephic conditions.
- There is a need for developing and commissioning efficient cowdung based biogas plants using modern R&D, connecting cowdung based bio-energy with organic product, planting multipurpose trees for additional biomass and meeting energy requirement of rural house hold to avoid burning of cowdung and using it as quality manure to improve organic carbon content in soils.
- Organic farming is knowledge based rather than input based and needs encouragement through consistent strategic research and development for

its adoption under specific production system for improving quality of soil and food products in the State.

- There is a need for quantification of carbon sequestration under different production systems, agroforestry, organic farming and thus help the farmers from benefit of carbon trading in future.
- There should be proper research based corrective measures for modification of existing soil health cards into "System of Soil Nutrient Management" with greater emphasis to maintain soil organic matter and good soil health through integrated nutrient management and good agricultural practices under different production systems.

5.7 Water Management

The working group has already suggested setting up a "School of Natural Resource Management and Environmental Sciences" at HQ to undertake strategic research and adaptive research cum development projects at different Regional Research Stations of CCSHAU to address location specific problems of natural resource management. However, the following specific researchable issues related to better on-farm water management are mentioned here:

- Studies suggest very low irrigation project efficiencies for rice based (<25%) and non-rice based cropping systems (<45%) under flood irrigation. Adoption of sprinkler irrigation in rice-wheat system, especially for rice could be a big departure from the currently cultivated puddled rice under flood irrigation. However, there seem great opportunities to grow aerobic rice (Direct seeded rice, rice cultivation under SRI) under sprinkler irrigation and to assess its impact on soil health, water saving and resource use efficiency with current system of flood irrigation in puddled rice.
- There is a need to complete mapping of water quality of all the districts of State in digital form by involving the scientists of CCS HAU, CSSRI and Department of Agriculture and State Ground Water Cell and update the map prepared by the University in 1976. Testing of water quality of tubewells by having suitable grids and then mapping their quality at

periodical intervals to know dynamics of water quality is also needed.

- There is a need to develop optimum crop plans by proper allocation of land area under different crops (Field crops, fruit & tree crops etc) for efficient use of variable water supply by using modern systems of irrigation in different canal commands (CCA) and also to utilize other water sources (Ground and rain water) for increasing input use efficiency and profitability of different production systems in the CCA.
- Fare amount of information on conjunctive use of water in different modes, combinations, intervals, soils, crops and agroclimatic conditions is available with the university. This is an opportune time to analyze this data by using predictive models available in the country and abroad. Such an exercise will pinpoint the weak links and gaps and save precious time, money and efforts involved, in addition to suggesting new paths for futuristic research.
- There is a need to assess the impact of poor quality water on horticulture and vegetable crops under high tech pressurized system of irrigation/fertigation with and without plasticulture.
- Drains are not only being used for draining out the rain water but also recharging the ground water and farmers are using it for irrigation as well for drinking purposes. Therefore, it is necessary to put some fresh water from canals during post rainy season wherever possible to make them more useful in those areas underlain with poor quality ground water for livelihood security.
- A core group of scientists of CCS HAU, Hisar, CSSRI, Karnal and State and Central Pollution Boards should be formulated to regularly monitor the characteristics and impact of sewage water and industrial effluent on soil health, food chain and environment and advise the Govt. and relevant agencies for their proper treatment and reuse thereafter, for irrigation purposes. As reported by the farmers of the State, the untreated water from different cities in Haryana and NCR in general and from Okhala, Delhi in particular is being diverted in fresh canal systems of Gurgaon.

- Farmers are interested to shift from flood irrigation to sprinkler and drip systems of water application. However, there is need for construction of secondary reservoir in CCA and scientist-farmer connect-adaptive research and proper technical support to guide and help the farmers for adopting pressure system of irrigation under different production systems. As stated earlier, there is a need to formulate functional multi-disciplinary scientists groups at RRSs and KVKs to address location specific issues of NRM under different production systems in the State.
- There is a need to encourage other water saving devices such as laser leveling, water conveyance through underground pipes, raised bed, raised and sunken bed technology, furrow system of irrigation in wide spaced crops, including other resource conservation technologies (Bunding, CA based technologies, short duration cover crops, surface mulching, use of plastic etc), crop diversification, agroforestry, arid-horticulture etc.
- The policy initiatives for shifting of irrigation charges from irrigated area to volumetric basis would encourage the farmers to adopt pressurized system or other water saving devices of irrigation to cover more area under irrigation in canal commands.
- Comparative studies of drip vs furrow irrigation in BT cotton are also needed to better understand their effects on productivity, para-wilt and water saving in Sirsa region.
- Execution of drainage and bio-drainage in water logged areas in farmers' participatory mode need encouragement through financial and technical support by concerned Govt. Departments. How does the continuous removal of poor quality ground water from the waterlogged lands through tube drains affects the spatial and temporal improvement in the ground water quality and how the use of drainage effluent as irrigation water affects the sustainability of natural resources and production system? These are some questions that need answer through long term monitoring of tube drainage projects installed in water logged areas under different agro-hydrological conditions.

- There is a lot of scope of starting pisciculture in water logged saline areas alone and also alongwith agroforestry. However, there is need to assess the impact of saline water pisciculture on NRM related issues alongwith identification of suitable fish spp. with better adaptation and growth under salinity and low temperature stress conditions of cold winters in the State.
- There is a need of proper coordination and accountability among various Govt. Departments for augmentation of water resource through construction of small water harvesting structure (Small dams, plugging of gullies, construction of farm ponds, deepening of village ponds), recharging of abandoned wells, tubewells through water injection technology, construction of recharge galleries in river beds and drains and adoption of holistic measures of watershed management to improve resource conservation, augmentation and utilization under different production systems.

5.8 Intensification and Diversification of Production Systems

- The working group has already suggested undertaking adaptive research cum development projects at RRSs to strengthen need based intensification, diversification and farming system approach in farmer participatory mode for sustainable use of natural resources in the State. However, some of the specific issues are mentioned here.
- There is a need to reorient our research programme and development agenda to conserve water by replacing some area of puddled rice with aerobic rice (DSR, SRI), hybrid maize or soybean as sole or intercrop with pigeon pea on raised beds or maize/soybean and rice respectively on raised and sunken beds; adoption of winter/spring maize alone/maize + vegetables after late harvest of kharif crops, potato and sugarcane ratoon in NE region and cluster bean/cluster bean + castor, bajra + mungbean, chicory + mustard and arid horticulture in South Western Haryana. Intercropping of sugarcane + garlic/other vegetables, agrohorticulture, agroforestry and protected cultivation are other options to increase productivity of water in the State.

Some improved hybrids of maize/HQPM developed at RRS Uchani, Karnal need to be demonstrated in a cluster of villages covering 500-1000 ha area by involving CCSHAU and Department of Agriculture in farmers participatory mode through a research cum development project as a probable substitute for puddled rice in declining water table area in NE region of Haryana.

These studies should be accompanied with regular monitoring of the dynamics and status of natural resources and cost: benefit in farmers participatory mode.

- Terminal heat tolerant genotypes in wheat and other crops need to be developed through scientific breeding and biotechnology means to mitigate moisture stress and global warming effects in field crops.
- There is a need to put in place a pilot cum demonstration project on forestry in Mewat area on 500 to 1000 ha by using *Prosopis juliflora* with value addition and processing in farmers participatory mode by involving CCSHAU and Department of Forestry with full monitoring of its impact on natural resources and cost: benefit for livelihood security of stakeholders.
- Department of Agriculture needs to encourage establishment of agro-service centres and also support self help groups and farmers to purchase CA based equipment and other input on subsidized rates to help small land holders in adopting CA based technologies and crop diversification in the State.
- The State Govt. has spent a lot of money in the recent past to achieve the target of 20% area under forestry cover in the State. Despite all these efforts, there has not been much progress in this regard as the area under forestry cover is still less than 4% in the State. Therefore, concerted efforts are required for intensification of plantation of trees and ensuring their survival with proper monitoring mechanism, for encouraging agro-forestry on common lands, canal banks, road sides, field boundaries by planting multi-purpose trees, and treating the trees as crops for harvesting and plantation purposes to encourage farmers for adopting agroforestry, including helping

them for carbon trading in future through such measures, and ultimately to bring back the glory of the State “Haryalivan”.

- Finally, there is need of developing proper and functional coordination and accountability among different institutions, relevant State Govt. Departments/developmental agencies and stakeholders to address complex and interlinked problems of natural resource management and find solutions to sustain 4% or higher growth of agriculture in the State.

6.0 RECOMMENDATIONS

In order to find solution of location specific complex and interlinked problems of Natural Resource Management (Land, soil, water, biodiversity, climate) for sustainability of agriculture in the State, the Working Group observed that there is an urgent need to undertake the following activities/actions:-

Policy Issues:

- Seting up a school of Natural Resource Management and Environmental Sciences at CCS HAU, Hisar to prioritize, undertake and guide education, research and development for sustainable resource management in the State.
- The school should have multidisciplinary team of scientists drawn from the bio-physical, social and environmental sciences with expertise in areas of remote sensing-GIS applications and modeling of different components of natural resource system inclusive of soil resource, irrigation and drainage systems, watershed management, cropping and farming system, agro-ecology and climatic resources as well as resource use optimization.
- Encouraging use of organic manure, bio-fertilizer, green manure/ legumes in crop sequences, commissioning of bio-gas plants/ plantation of multipurpose trees to save cow dung from burning, promoting CA based technologies for recycling of crop residues and organic farming to improve organic carbon content in soils.
- Undertaking time bound programme to bring at least 50% area in next 10 years under pressurized system of irrigation and other water saving devices.
- Policy initiatives to shift the irrigation charges from irrigated area to volumetric basis to speed up the adoption of pressurized system of irrigation and other water saving devices to cover more area under irrigation by farmers in the canal commands.
- Enforcement of laws banning diversion of untreated sewage water and industrial effluent in fresh water streams.

- Need of policy initiatives for increased allocation of canal water or adequate diversion of excess rainwater to water deficit arid regions but it should precede after scientific studies on salt and water balance, energy cost and socio-economic benefits on long run to the stakeholders.

- Promotion of managed forestry and agro-forestry by treating tree as crop for planting and harvesting purposes and incentive to farmers for undertaking agro-forestry, pisciculture and biodrainage under problematic soils and water conditions.

- Need for effective steps to focus on the large amount of biodiversity, both underground and above ground, for proper preservation and utilization in the State.

- Developing viable units for on-hand training in farming systems perspective with emphasis on intensification, diversification, resource conservation and value addition at the HQ of CCSHAU to train students, farmers and other stakeholders to develop entrepreneurship skills for employment/self employment, profitability and livelihood security of small farm holders.

- Need for establishing better coordination and accountability among different institutions, relevant State Government Departments, Central and other developmental agencies and stakeholders to find solutions of complex and interlinked problems of natural resource management to sustain growth of agriculture in the State.

State of Natural Resources:

- Developing digital data base on status and dynamics of land use, soil, water, climate, vegetative cover and cropping and farming systems by HARSAC and SAU.

- Undertaking regular mapping and characterization of natural resources in digital form (Land, soil, water, climate, vegetative cover) and natural calamities (Drought, flood etc) using modern tools of remote sensing/GIS by HARSAC.

- Undertaking specific land use-cover change studies in relation to resource status/ degradation or other socioeconomic and development issues with a view to understand the nature of the driving forces and option to address the problems.

- Some of the issues which relate critically to sustained agricultural development include; declining farm size and area under prime agricultural lands, contamination of agricultural lands and groundwater systems by industrial and sewage waters, stagnating area under forestry cover and degradation of fragile erosion prone Aravallis and Shivalics.

- Bringing out 'The State of Natural Resources' report in digital form, every five years. The first report should be planned within the next two years.

  The initiative for this must come from CCSHAU and HARSAC.

Strategic, Applied and Adaptive Research:

- Need for greatly strengthened Regional Research Stations of CCS HAU to prioritize location specific research and development agenda in general and striving for better scientist-farmer connect- adaptive research projects in farmers participatory mode in particular to address regional specific issues of NRM in the State.

- Mainstreaming climate change related mitigation and adaptation measures through multidisciplinary strategic and adaptive research for development.

- Developing solutions to hydrological imbalances through integrated approaches involving on-farm water management, conjunctive use of water, pressurized system of irrigation and other water saving devices, surface and subsurface drainage, recharge of aquifers, diversification, intensification, CA based technologies and holistic watershed management approach.

- Amelioration of poor quality groundwater in inland basin through cyclic process of groundwater extraction and recharge with good quality water on pilot scale in farmer participatory mode.

- Developing full scientific package for use of waste water in peri-urban areas of the State, particularly for cultivation of vegetables and fodder crops.
- Undertaking holistic evaluation of selected executed projects in the areas of agricultural drainage, irrigation and watershed management and agro-forestry with a view to assess their effectiveness in achieving the targeted objectives
- Making concerted efforts to substitute puddled rice with alternate crops such as hybrid maize/soybean based cropping systems and adoption of CA based technologies.
- Location specific concerted efforts for fine tuning of different resource conservation technologies (DSR, diversification, intensification, raised bed planting, residue incorporation, brown manuring etc) under different production systems.
- Developing alternate technologies for crop residue management in rice-wheat and cotton-wheat cropping system and use of biochar from crop residue to enhance C-sequestration.
- Mainstreaming farming system research aimed at better understanding of farming system perspectives involving farmers, available resources and economic conditions and the way they interact with natural resources.
- Linking multi-enterprize models of integrated farming system with market, value addition, processing, handling and storage facilities of agriculture produce at production sites for livelihood security of small land holders.

Developmental Issues:

- The clear focus of development efforts should be to help the farmers to manage their own resources in sustainable manner.
- Development of scientific land use planning of the State using modern tools of remote sensing/GIS by HARSAC and CCSHAU, Hisar.
- Promoting integrated agricultural practices and strategies which improve organic carbon content of soils.

- Undertaking special drive for inclusion of legume or green manure crops in cereal-cereal cropping system either as catch or inter/mixed crops.
- Modifying existing soil health cards into system of "Soil Nutrient Management" by Department of Agriculture with greater emphasis to maintain soil organic matter and good soil health.
- Discouraging flood irrigation and encouraging pressurized system of irrigation and other water saving devices (Furrow irrigation, raised and sunken beds, fertigation, protected cultivation, plasticulture etc) through proper incentives to farmers.
- Augmentation of water supplies by conserving rainwater in the fields, aquifers, water bodies, conjunctive use of brackish and fresh waters, treatment of sewage and industrial effluent for use in irrigation and desilting of existing water bodies and construction of new water storage structures to cope up with scarcity of irrigation water.
- Strengthening the capacity of the CCS Haryana Agricultural University, State Department of Agriculture and Irrigation Department to undertake training programmes to focus on improved on-farm water management using modern tools to extension workers, farmers and other stakeholders.
- Exploring all avenues to strengthen human resources base, both in terms of number and quality, through partnership with overseas institutes of repute in the field of Natural Resource Management in CCS Haryana Agricultural University, Hisar.

7.0 SELECTED REFERENCES

Abrol, I. P., Gupta, R. and Malik, R. K. 2005. (Eds.). Conservation Agriculture-Status and prospects, CASA, New Delhi, 154p.

Antil, R. S. 2012. Integrated Nutrient Management for Sustainable Soil Health and Crop Productivity. Presentation in Productivity Enhancement Workshop conducted by Haryana Kisan Ayog, CCSHAU Campus, Hisar (Haryana).

Agarwal, M.C., Roest, C.W.J. 1996. Towards improved Water Management in Haryana State; Final Report of the Indo-Dutch Operational Research Project On Hydrological Studies. CCS Haryana Agricultural University, Hisar, International Institute for Land Reclamation and Improvement, Wageningen, DLO Winand Staring Centre for Integrated Land, Soil and Water Research, now Alterra Green World Research, Wageningen. P 80.

Anonymous , 1998. Management of water logging and salinity problems in Haryana. Master Plan. Govt. of Haryana.

Anonymous , 1991. Waterlogging, Salinity and Alkanity. Government of India, Ministry of Water Resources, New Delhi.

Bhattacharya, A. K. and Michael, A. M. 2003. Land Drainage: Principles, Methods and Applications. Konark Publishers Pvt Ltd, A-149, Main Vikash Marg, Delhi 110092.

Central Soil Salinity Research Institute, Karnal Annual Reports, 2005-06 to 2010-12.

Deora, A. 2012. Utilization of the strength and capacity of microbes in reclamation of problematic waters for irrigation. Abstract in International Seminar on Renewable Energy for Institutes and Communities in Urban and Rural Setting. Organized by Manav Institute of Technology, Hisar from April 27-29, 2012.pp 15-16.

Dhindwal, A. S. and Jhorar, R. K. 2012. Water Resource Management in Haryana. Presentation in Productivity Enhancement Workshop conducted by Haryana Kisan Ayog, CCSHAU Campus, Hisar (Haryana).

Dhindwal, A. S., Phogat, V. K. and Hooda, I. S. 2008. Enhancing Water Productivity in Haryana, Dept. of Soil Science, CCSHAU, Hisar (Haryana).

FAO, 1985. Studies for the use of saline water in command areas of irrigation projects. Haryana (India).

Gupta, R. 2011. Working Group Report on Conservation Agriculture for Sustainable Crop Production in Haryana, Haryana Kisan Ayog. pp 36.

Haryana Operational Pilot Project (HOPP) Inception Report, June,1995

Implementation Completion Report, No.34384,(SCL-44920,IDA-32430), The World Bank, Integrated Watershed Development (Hills-II) Project, December, 2005

Jhorar, R.K., Roest, A.A.M.F.R. Smit, C.W.J. 2009. Assessment of alternative water management options for irrigated agriculture; Agricultural Water Management 96:975-981.

Kamra, S. K.,Singh, S. R., Rao, K. V. G. K. and Genuchten, M. Th. Van. 1991. A semi-discrete model for water and solute movement in tile-drained soils: 2. Field validation and applications. Water Resources Research, vol. 27, No.9, pp.2449-2456.

Kamra, S. K., Anchal, V., Aswal, S. and Lal, K.. 2006. Groundwater recharge through cavity wells in saline groundwater regions. In: Recharge systems for protecting and enhancing groundwater resources. Proc. 5th International Symposium on Management of Aquifer Recharge (ISMAR5), Berlin (Germany), June 11-16, 2005, IHP-VI Series on Groundwater No. 13, 699-704.

Luhach, M.S., Malik, D. P. and Puran, M. 2010. Economic analysis of tubewell driven sprinkler irrigation and furrow irrigation for agriculture in Haryana. Viewed on internet, link http//www. tropentag. de/2010/ abstracts /poster /691.pdf.

Molden, D., Murray-Rust, H., Sakthivadivel, R. and Makin,I. 2003. A water productivity frame work for understanding and action. In-Comprehensive

Assessment of Water Management in Agriculture Series, No. 1. International Water Management Institute, Sri Lanka.

Ram, J., Dagar, J.C., Lal Khajanchi, Singh, G., Toky, O.P., Tanwar, V.S., Dar, S.R., Chauhan M.K. 2011. Biodrainage to combat waterlogging, increase farm productivity and sequester carbon in canal command areas of northwest India. Current Sci 100:1673-1680

Ram, J., Garg, V.K., Toky, O.P., Minhas, P.S, Tomar, O.S. Dagar, J.C. and Kamra, S.K. 2007. Biodrainage potential of *Eucalyptus tereticornis* for reclamation of shallow water table areas in north-west India. Agrofor. Syst. 69: 147-165.

Ramesh, P. and Rao, A. S. 2009. Organic Farming: Status and Research Achievements. Indian Institute of Soil Science, Bhopal, India.

Rao, K. V. G. K., M. C. Agarwal, O. P. Singh, and R. J. Oosterbaan (Eds), (1995). Reclamation and Management of Waterlogged Saline Soils. National Seminar Proceedings, CSSRI, Karnal and HAU Hisar.

Singh, D. P. 2012. Connecting bioenergy and organic input for sustaining eco-friendly agriculture and rural development in India. Abstract in International Seminar on Renewable Energy for Institutes and Communities in Urban and Rural Setting. Organized by Manav Institute of Technology, Hisar from April 27-29, 2012. pp 25-26.

Singh, D. P. and Sharma, H. C. 1993. Important Aspects of On-farm Water Management, Directorate of Research, CCS Haryana Agricultural University, Hisar (Haryana), India.

Singh, D. P., Kumar, A., Gupta, R. and Yadvika. (2011). Genetic and Management Options for Improving Productivity of Water and other Interlinked Resources in Semi-arid and Tropical Regions of Developing Countries. In-Crop Science and Land Use for Food and Bioenergy. pp 275-298.

Tanwar, B.S. and Kruseman G.P. Saline Groundwater Management in Haryana State, India. Haryana State Minor Irrigation (Tubewells) Corporation Ltd., The Mall, Karnal 132001, India. Food and Agricultural Organization of the

United Nations, Rome, Italy; present address: TNO-DGV Institute of Applied Geoscience, P.O. Box 285, 2600 AG DELFT, The Netherlands.

Van Hooran, Jan W., Boumans, Jan H., Kruseman, Gideon P. and Tanwar, B.S. Haryana. Report (FAO 1985).

Yadav, A. 2012. Resource conservation technology for sustainable crop production in Haryana. Presentation in Productivity Enhancement Workshop conducted by Haryana Kisan Ayog, CCSHAU Campus, Hisar (Haryana).

Yadvika and Gupta, R. 2012. Enhancement of biogas production using different techniques. Abstract in International Seminar on Renewable Energy for Institutes and Communities in Urban and Rural Setting. Organized by Manav Institute of Technology, Hisar from April 27-29, 2012. pp 153-154.

Yadvika, Kaur, A., Sreekrishnan, T. R. and Satya, S. 2000. A critical assessment of characteristics of dairy waste waters and their biological treatability. Annals of Agri-BioResearch, 5(1): 23-29.

Web Site – Irrigation Department, Haryana. Irrigationharyana.nic.in

Web site- Agricultural Department ,Haryana agriharyan.nic.in

Website-Haryana Economic Survey, 2010-11.

Annexure I

Working Group And Its Other Details

Considering its objectives and mandate, Haryana Kisan Ayog constituted a Working Group (WG) on "Natural Resource Management (NRM)" in Haryana on March 22, 2011. The WG was requested to analyze and review the complex and interlinked issues and problems of NRM (Land, soil, water, bio-diversity, climate) and suggest suitable measures to overcome them for sustaining growth of agriculture in the State. The WG met and discussed the relevant issues with scientists, field functionaries, policy makers and stakeholders and also visited different water storage structures and delievery systems and ongoing research and development projects on NRM in the State to get necessary input in contextual framework of TOR of WG on NRM. The WG also reviewed and studied relevant literature and recommendations of interactional meetings of HKA with farmers of different divisions to prepare and finalize this report on NRM in Haryana. The composition of WG, TOR and details of various meetings held are given below:

➤ Composition of Working Group

Dr. I.P. Abrol	Ex-DDG (NRM), ICAR, New Delhi	Chairman
Dr. S.R. Singh	Ex – Vice Chancellor, RAU, Pusa-Samastipur, Bihar	Member
Er. H.S. Lohan	Ex-Additional Director Agriculture, Govt. of Haryana	Member
Dr. D.P. Singh	Ex – Vice Chancellor JNKVV Jabalpur and Consultant HKA	Nodal Officer

➤ Terms of Reference (TOR)

- To analyze and review the present strength, weakness, threats and opportunities in the field of soil and water management for increasing crop production in the State of Haryana.
- To study the problems of soil and water management and suggest suitable measures to overcome these problems/constraints for sustaining higher productivity in the State.

- The working group may also suggest suitable measures for mapping of natural resources (Soil, water, vegetative cover) both in terms of space and time using GIS, GPS, remote sensing technology etc. for scientific land use planning and to overcome the ill effects of natural constraints including climate change.
- The working group to examine present status of soil health (Physical, chemical, biological) and suggest suitable management options to overcome nutrient imbalance in the State.
- The working group to also study the current status and availability of water resources (Rain, surface, ground, sewage waters etc.) and their quality and suggest short and long measures for resource mapping, conservation, augmentations, diversion, utilization and optimization for increasing water use efficiency and water productivity.
- To suggest options for increased agriculture productivity, cropping intensity and profitability through technological interventions, diversification, integrated farming system and much needed value addition.
- To improve the effectiveness of service delivery by the Department of Agriculture, Directorate of Extension in the Agricultural University and other Govt. & Non- Govt. Institutions/ Organizations to provide need based services and training programmes to farmers for efficient management and utilization of different inputs (Seeds, fertilizers, chemicals etc.) and available natural resources.
- The working group may also examine and suggest the scope/limitations of organic farming in the State.

➤ Meetings Held

S.No.	Title	Date
1.	Meeting of the Working Group on NRM at Hisar	March 22, 2011
2.	Consultation Meeting of the Working Group on NRM with Vice Chancellor and relevant faculty of the CCSHAU at Hisar	April 19, 2011
3.	Meeting of the Working Group on NRM with the Chairman of Haryana Kisan Ayog at New Delhi	May 16, 2011
4.	Meetings and Visits of Working Group on NRM to different Regional Research Stations of CCSHAU and CSSRI and other ICAR Institutes	August 8-12, 2011
5.	Visit of the Working Group on NRM to Hatini Kund Barrage, Tajewala Dam, Bhakara Nangal Dam and Canal systems in the State	October 2-5, 2011
6.	Meeting of the Working Group on NRM with senior officers of the State Govt. at Chandigarh	November 14, 2011
7.	Meeting of the Chairman Working Group on NRM with the Chairman and Member Secretary of Haryana Kisan Ayog to brief about the issues, progress and preparation of the report on NRM at New Delhi	Jan 11, 2012
8.	Meeting of the NRM Working Group to review and compile the information to prepare the draft on NRM in Haryana at New Delhi	Jan 24-25, 2012
9.	Meeting of the Chairman and Nodal Officer of NRM Working Group to review the Action Agenda in draft report on NRM at New Delhi	March 22, 2012
10.	Meeting of Member (Er. H. S. Lohan) and Nodal Officer of Working Group to revise and finalize the draft report on NRM at Hisar	April 20-21, 2012
11.	Meeting of Chairman and Nodal Officer of Working Group to finalize the recommendations of NRM in Haryana at New Delhi	July, 13, 2012
12.	Meeting of Working Group to discuss and review the draft report on NRM at New Delhi	August 27-28, 2012
13.	Meeting of Chairman and Nodal Officer of Working Group to incorporate appropriate suggestions to revise the NRM draft at New Delhi	September 12, 2012
14.	Meeting of the Chairman and Nodal Officer Working Group to discuss and submit report on NRM in Haryana to the Chairman HKA at New Delhi	Oct 17, 2012

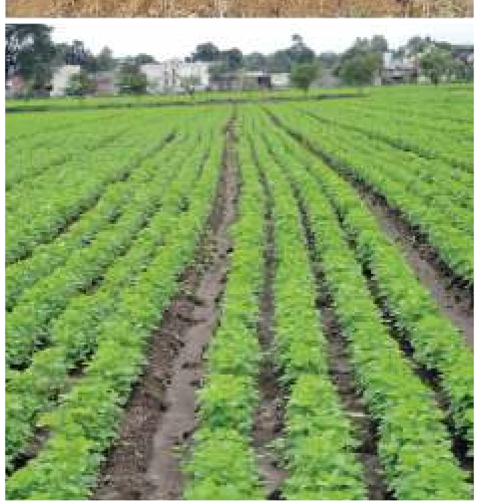
These meetings were intended to get necessary input from policy makers, scientists, field functionaries and farmers. In these meetings, the WG interacted with Dr. R. S. Paroda, Chairman, HKA, Mr. Roshan Lal, FC & PS, Govt. of Haryana, Dr. K. S. Khokhar, VC, CCSHAU, Hisar, Deans and Directors, Incharge of different Regional Research Stations, KVKs and relevant faculty of CCSHAU, Hisar, Mr. Ashok Yadav, DG, Agriculture, Govt. of Haryana and his selected staff, Dr. Satyavir Singh, DG, Horticulture, Govt. of Haryana, Chief Engineer, Govt. of Haryana, Director, State Pollution Board, Govt. of Haryana, Chief Engineer, Bhakra Beas Management Board and their staff, Dr. A. K. Singh, DDG (NRM), HOD, SSLUP, New Delhi, Dr. D. K. Sharma, Director, CSSRI, Karnal and his staff, Director, Regional Cotton Research Station (ICAR), Sirsa and his staff, Dr. R. S. Hooda, Chief Scientist, HARSAC and his staff, Dr. R. S. Dalal, Member Secretary, Dr. M.P. Yadav, Dr. M.L. Chadha, Dr. K.N. Rai, Consultants, Dr. Anupama Deora, Research Fellow, supporting staff of HKA, Hisar, Ms Mamta Mehra and Ms Prachi Kathuria, CASA Office, New Delhi and selected farmers of the State. The report reflects the major outcomes of these consultations and necessary support.












Head Office

Haryana Kisan Ayog
CCSHAU Campus
Hisar-125004

Tel.: +91-1662-289593
Fax: +91-1662-289511

Camp Office

Haryana Kisan Ayog
Kisan Bhawan, Khandsa Mandi,
Gurgaon-122001

Tel.: +91-124+2300784

www.haryanakisanayog.org