Haryana Kisan Ayog
Government of Haryana







Working Group Report on Rainfed Area Development in Haryana

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Working Group Report
on
Rainfed Area Development in Haryana

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Haryana Kisan Ayog

Government of Haryana

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Foreword

Agriculture is the most important setor for redressing rural poverty and accelerating economic growth for livelihood security. The concerted efforts over the years by the policy makers and scientists in Haryana State have resulted in strengthening agriculture sector. Currently, Government continues to promote agricultural intensification in both high and low potential regions. Productivity levels in assured irrigated areas have almost attained a plateau. On the contrary, the low-potential areas in the rainfed ecosystem require concerted efforts to increase productivity. Further, the rainfed regions cannot be neglected because these regions account for about 20 per cent of the total cultivated area in State and support substantial livestock and human population. Harnessing the potential of rainfed regions has further gained attention with the decision to implement "National Food Security Act, 2013". It placed extra responsibility on the State farmers to produce more food grains as well as vegetables, fruits, milk, fish, etc. Obviously, a stimulus to food production system in the rainfed areas is a dire necessity in the present time.

Nevertheless, it is challenging task for the Government to invest more in the low potential regions like rainfed areas, considering low returns on investment. Enhancing water productivity, addressing climate change and managing bio-resources are the daunting tasks for productivity enhancement in rainfed region. Besides, skill development of youth for adoption of improved technologies and options linked to secondary agriculture are currently less attended areas though critical.

I am pleased that the Working Group on "Rainfed Area Development in Haryana" led by Dr. A. K. Sikka, DDG (NRM). ICAR, has done thorough analysis of various factors and issues affecting rainfed agriculture. After wider consultations, the Working Group has suggested a series of policy, institutional and developmental interventions for sustainable development of rainfed agriculture in the State. I am happy that the Working Group has also conceptualized a number of capacity building measures and suggested appropriate research and development related initiatives for resource conservation, augmentation and management, including need based contingent plans, safety nets like livestock development, agri-horticulture & agro-forestry for diversification, farmers participatory holistic watershed development approach, etc.

I sincerely thank Drs. A. K. Sikka, H. P. Singh, K. R. Solanki, G. B. Raturi and D. P. Singh in bringing out this valuable report. I believe that this important publication will be of immense use to the planners, administrators, researchers, farmers and other stakeholders. I do hope that the implementation of various recommendations will accelerate the growth of agriculture in rainfed areas of Haryana.

R. S. Paroda

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Acknowledgement

The expert group consisting of Dr. A. K. Sikka, Chairman, Drs. R. K. Solanki, H. P. Singh, G. B. Raturi members and Dr. D. P. Singh as Nodal Officer & Member was constituted by the Chairman of Haryana Kisan Ayog and requested the working group to complete the assignment on “Rainfed Area Development in Haryana”. This report of working group on Rainfed Area Development in Haryana is an outcome of a series of meetings, field visits and fruitful discussion carried out with policy makers, scientists, field functionaries and selected farmers in the State.

The Ayog is indebted with a deep sense of appreciation for the vision and leadership of its Chairman Padam Bhusan Dr. R. S. Paroda who selected one of the best experts who have not only excellent expertise and leadership in complex and diversified fields of natural resource management, dry land agriculture, agroforestry and arid horticulture but also have good experience of past and present status of Haryana Agriculture.

The Ayog would expresses its sincere thanks to Drs. A. K. Sikka, K. R. Solanki, H. P. Singh, G. B. Raturi and D. P. Singh for completing this important task by thorough analyses of issues and problems of resource poor rainfed farmers and suggesting appropriate starategies for sustainable development of agriculture in fragile rainfed ecosystem of the state. The Ayog also feels highly indebted to Sh. Roshan Lal, IAS, Principal Secretary, Govt of Haryana, Dr. K. S. Khokhar, Vice-Chancellor, CCSHAU, Hisar, Maj Gen Sri Kant Sharma, Vice-Chancellor, LUVAS, Hisar and Deans , Directors, Incharge of Regional Research Stations, KVK’s and other faculty members of two SAUs of the state, Dr. S. B. Mittal, Chief Scientist, Dr. B. S. Jhorar, Senior Scientist and other staff of DLA Research Project, CCSHAU, Hisar, Dr. C. K. Yadav, Dr. Satyavir Yadav, Dr. V. K. Yadav, Dr. Joginder Singh Yadav and Dr. M. A. Khan of RRS, Bawal, Dr. R. S. Hooda, Chief Scientist, Dr. V. S. Arya and Dr. R. P. Dhankar of HARSAC, Dr. O.P.Toky, Ex-Head Forestry and Dean PGS CCSHAU, Hisar, Mr. A. K. Singh, Dr. Sh. Brijendra Singh, D.G, Agriculture, Dr. B. S. Duggal, A.D.G, Agriculture, Dr. Satyavir, D.G Horticulture and his staff, Dr. J. P. Singh, Consultant, Er. H. S. Lohan, Ex-additional Director Agriculture and Consultant, Govt. of Haryana and other field functionaries and farmers for their active participation and keen involvement in the relevant meetings and visits and fruitful discussion and comments and suggestions to improve the draft on Rainfed Area Development in Haryana.

The Ayog is also grateful to Dr. I. P. Abrol, Ex-DDG (NRM,ICAR) and President CASA, New Delhi, Dr. H. S. Gupta, Director, IARI, Dr.(Mrs.) R. Kaur, Director & Dr. A. K. Mishra ,WTC (IARI), New Delhi and other staff for their valuable help for arranging visit of Mewat specific project areas and Dr. Rajvir Singh, P.S (Agronomy),NRM (ICAR) and other NRM staff, Dr. B. Venkateswarlu, Director, CRIDA, Hyderabad, Dr. M. M. Roy, Director, CAZRI, Jodhpur, Dr. A. K. Tiwari, Head, CSWCRTIRC, Chandigarh, Dr. S.K. Dhyani, Director, NRCAF, Jhansi and Dr. G. S. Sidhu, Head NBSSLUP, New Delhi for their valuable help and suggestion to improve the draft on Rainfed Area Development in Haryana.

Finally, Ayog thanks its Consultant, Dr. M. P. Yadav, Dr. K. N. Rai, Dr. M. L. Chadha and Dr. R.B. Srivastava, Our Research Fellows, Dr.(Mrs.) Anupama Deora, Dr. Gajender Singh, Dr. Sandeep Kumar, 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 Rainfed Area Development in Haryana.

Dr. R. S .Dalal

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EXECUTIVE SUMMARY

Haryana is primarily an agricultural state as over 70% of its population is engaged in agriculture. With 1.4% of the total geographical area of the country, Haryana is the second largest contributor of food grains in national food reserves. The irrigation infrastructure has contributed significantly for this stupendous development in agriculture. However, dryland/rainfed region of Haryana is still under transformation and requires investment for its development to improve productivity and profitability. The rainfed agriculture in south western parts and Shivalik in north-eastern region accounts for about 21% (7.72 lac ha) of total cultivable and 16% of net cultivable area in Haryana. Over 91% of the state rainfed area (5.31 lac ha of total net sown area) is confined to 10 districts; 7 in south western and 3 in north eastern regions. Rainfed farmers are resource poor because of frequent crop failures, poor resource base, small land holdings, subsistence farming, non-adoption of improved technologies and low farm income. The soils in rainfed areas are poor in fertility and also suffer from wind erosion in South west and water erosion in the north east parts of Haryana.

Keeping in view of these problems of resource poor farmers in such a fragile environment, the Haryana Kisan Ayog (HKA) had constituted a Working Group on "Rainfed Area Development in Haryana" under the chairmanship of Dr. Alok K Sikka, then Technical Expert (Watershed Development, National Rainfed Area Authority, Planning Commission and presently Deputy Director General (NRM), ICAR with Drs. K R. Solanki, Former ADG(ICAR), H.P. Singh, Former Director CRIDA, G.B. Raturi, Former Director, Central Institute of Arid Horticulture (ICAR) as members and Dr. D.P. Singh former Vice Chancellor, Jawaharlal Nehru Krishi Vishva Vidyalya, Jabalpur as Nodal Officer to suggest Policy, Research, Developmental and Transfer of Technological strategies for rainfed area development in Haryana.

The Working Group Report on Rainfed Area Development in Haryana provides a brief account of status and dynamics of natural resources, identifies important sustainability issues, policy, institutional and implementation gaps and has suggested appropriate strategies and actions to overcome these problems for sustaining growth of agriculture and livelihood security in rainfed area of the state.

The major issues in the south western parts of rainfed areas, include fragile natural resource base, deteriorating soil health, poor germination of small seeded crops due to crust formation, limited irrigation facilities, dominance of brackish ground water and no effective control of *Orabanche* in mustard. In the foothills of Shivalik, undulating topography with moderate to severe soil-water erosion, medium textured soils over ridden with patchy layers of gravels mixed with silt and sand, highly erratic rainfall, and menace of wild animals are some of the major issues. Further, poor socio-economic status and low literacy level of dryland farmers do not encourage them to undertake costly soil and water conservation measures and modern technologies to improve their livelihoods. Farmers in both the regions are undertaking animal husbandry as one of the major safety net. However, the deficiency of green fodder and pasture lands are major problems with rainfed farmers. Even the financial institutions are reluctant to extend credits to rainfed farmers because of high risk proneness and lack of adequate safety nets. Lack of profitable MSP on coarse grains, reluctance of procurement by Govt. agencies, non-inclusion of coarse grains in PDS and their value addition at production site are also matter of concerns to provide adequate financial support to resource poor farmers. Thus, there is a need to address these complex and interlinked issues for attaining sustained growth of agriculture in rainfed areas.

To address the issues and problems of rainfed agriculture, there is an urgent need to build up effective lateral and vertical linkages at all levels; central, state, institutional and also that of stakeholders. The Working Group recommends formulation of flagship scheme/programme exclusively for rainfed areas for augmentation and sustainable use of natural resources in multi-enterprise mode on watershed basis and linking it to the productivity, profitability and livelihood sustainability by optimization of resources available with the farmers.

Augmentation of water supplies by conserving rain water in the field, aquifers, water bodies, conjunctive use of brackish and fresh water, treatment of sewage and other poor quality water for their reuse in life saving/supplemental irrigation, desilting of existing water bodies and construction of new small dams/water storage structures and recharge of ground water through available technologies/subsurface galleries need highest priorities in the development of rainfed farming. Augmentation and restoration of natural assets/infrastructure needs special focus for restoring lost irrigation potential for supplemental and life saving irrigation by involving local communities and reviving local level societies to maintain and use surface and ground water resources on sustainable basis. Further, watershed development and water resource augmentation programmes in convergence with MGNREGA, RKVY, NFSM, NHM, NRLM etc should be used as a policy instrument to augment and effectively use NRM base for sustaining production and betterment of livelihoods of resource poor farmers in rainfed areas.

A Policy for using augmented water resources through micro-irrigation in rainfed areas is suggested. Emphasis should be given for developing collective action plans and preparing water budgets for efficient crop and water use planning. The farmers should be encouraged through proper incentives to use organic manures, biofertilizers, alternate sources of energy and plantation of multi-purpose trees and follow good agriculture practices and organic farming to improve organic carbon content in soils.

The report also encompasses soil and water conservation technologies using well known biological and mechanical measures, including conservation agriculture technologies to control soil and water erosion. The popularization and greater use of ridge seeder in south west Haryana for seeding of both *kharif* and *rabi* season crops could help in-situ harvesting of water. Sunken and raised technologies could be beneficial in high rainfall areas of Shivaliks to grow low and high water requiring crops in the same field through proper soil configuration. There is also a need to strengthen other in-situ soil and water conservation measures, including live fencing for preventing trespass of animals and promoting effective soil and water conservation for higher resource use efficiency in rainfed areas.

The report of Working Group also suggested series of capacity building measures and undertaking appropriate strategic, applied and adaptive research for fine tuning the existing/undertaking innovative research initiatives to improve rainfed farming. These include improvement of resource base, location specific measures to conserve, manage and optimize the use of various resources through holistic watershed management approach, need based diversification and intensification, contingent crop plans, safety nets in the event of aberrant weather conditions, insurance cover for crops and livestock, and improved agromet/agro-advisories, climate smart agriculture, including location specific integrated farming system models through farmer participatory approach.

The Working Group has also suggested development of scientific land use planning and strengthening the research groups at HQ and Regional Research Stations of CCSHAU to undertake appropriate strategic, applied and adaptive research projects by involving concerned State Departments and ICAR institutes in participatory mode. The value addition of coarse grains and niche area crops, providing profitable MSP to coarse grains and bringing them in PDS by branding them as 'nutritious food' need to be addressed properly to benefit the stakeholders.

The report also dwells on appropriate measures to improve livestock breed and feed assets, initiation of Pashu Palak Yojana (PPY) and Pashu Palak Credit Cards (PPCC) similar to RKVY and Kisan Credit Cards and promoting agri-horticulture, agroforestry and silvipastures by establishing nurseries for supply of quality planting material and treating trees as crops for harvesting purposes to support small land holders. Planting of multipurpose trees on both banks of roads, canal banks, field boundaries and through micro-site improvement on problematic soils, need based clusters for protected cultivation of vegetables, flowers and arid horticulture by providing financial assistance upto fruit bearing stage under NHM, scaling up mechanization in seeding/planting and harvesting of field, fruit and tree crops, including value addition, and improving market and institutional linkages have been emphasized in the report.

The public investments for development of dryland areas is far less than irrigated areas. Higher subsidies and public private supports need to be encouraged for fodder banking, fodder seed production, silage making (silo-pits, silo-towers, storage sheds etc), scaling up value addition of coarse grains, guar gum, castor, meat products in Mewat and related machineries need high priority to help stakeholders in dryland areas.

The report also suggests to put in place effective and unified mechanisms for fostering convergence among different programmes, departments/agencies, research institutions, including local level institutions for planning, development and implementation of different programmes, especially at micro level to boost rainfed farming. The convergence of different institutions, including research institutions, CBOS/NGOs etc needs to be addressed through some coordination committee under one umbrella with Chief Secretary as Chair person for unified goal of attaining sustainable development of rainfed areas in the State.

The Working Group strongly recommends the adoption of bottom up approach in farmers participatory mode to guide and implement research and development agenda at all levels. The suggested policy, research and developmental measures once initiated/adopted will certainly improve resource base and help in subsequent augmentation, management and optimization of resources in multi-enterprise mode for attaining eco-friendly progress of rainfed/dryland farming in the State of Haryana.

Abbreviations

AICRPDA	:	All India Coordinated Research Project on Dryland Agriculture
AICRPWM	:	All India Coordinated Research Project on Water Management
BRGF	:	Backward Region Grant Fund
CASA	:	Centre for Advancement of Sustainable Agriculture
CAZRI	:	Central Arid Zone Research Institute
CBOs	:	Community Based Organizations
CCSHAU	:	Chaudhary Charan Singh Haryana Agricultural University
CEV	:	Centre of Excellence in Vegetables
CFP	:	Community Forestry Project
CIAH	:	Central Institute of Arid Horticulture
CPR	:	Common Property Resources
CRIDA	:	Central Research Institute for Dryland Agriculture
CSSRI	:	Central Soil Salinity Research Institute
CSWCRTI RC	:	Central Soil & Water Conservation Research & Training Institute, Research Centre
EUWP	:	European Union Watershed Project
FAO	:	Food and Agriculture Organization
GHG	:	Green House Gases
GIS	:	Geographic Information System
HKA	:	Haryana Kisan Ayog
HARSAC	:	Haryana Space Application Centre
HSDC	:	Haryana Seed Development Corporation
HQ	:	Head Quarter
IARI	:	Indian Agricultural Research Institute
IFS	:	Integrated Farming System
IWMP	:	Integrated Watershed Management Programme
JFM	:	Joint Forest Management

KCC	:	Kisan Credit Card
KVK's	:	Krishi Vigyan Kendras
MGNREGA	:	Mahatama Gandhi National Rural Employment Gaurantee Act
MSP	:	Minimum Support Price
NABARD	:	National Bank for Agriculture and Rural Development
NAIP	:	National Agriculture Innovation Project
NFSM	:	National Food Security Mission
NFWP	:	National Food for Work Programme
NGOs	:	Non-Governmental Organisations
NHM	:	National Horticulture Mission
NRAA	:	National Rainfed Area Authority
NRLM	:	National Rural Livelihoods Mission
NRM	:	Natural Resource Management
NWDPRA	:	National Watershed Development Project for Rainfed Areas
PET	:	Potential Evapotranspiration
PDS	:	Public Distribution System
PPCC	:	Pashu Palak Credit Cards
PPY	:	Pashu Palak Yojana
RIF	:	Rural Innovation Fund
RKVY	:	Rashtriya Krishi Vikas Yojana
RRSs	:	Regional Research Stations
SLSC	:	State Level Sanctioning Committee
TOR	:	Terms of Reference
UNFCC	:	United Nation Framework Convention on Climate Change
WTC	:	Water Technology Centre
WUE	:	Water Use Efficiency

CHAPTER - 1

Introduction

1.1 Background

Rainfed agriculture spanning over several agro-ecologies in the country, has a very important role to play in the inclusive growth, food security, livelihoods and sustainable development. The yield fatigue in major food crops like rice and wheat is already visible in the predominantly irrigated areas of Indo-Gangetic Plains of India, including Haryana. Groundwater now accounts for over 65% of the total irrigated area in the country (56% of net irrigated area in Haryana), and a looming groundwater crisis is evident in most of these areas due to steeply falling groundwater levels as well as degradation of groundwater quality and deteriorating soil health. With the emergence of various resource management related problems in irrigated areas, development of rainfed areas assumes higher priority for contributing to the growing food needs and livelihoods in a State like Haryana which is primarily an agricultural state with 86% of its geographical area being cultivable. South Western part of Haryana with arid climate and Shivalik ranges with relatively humid climate have majority of the rainfed area.

1.2 Scope & Objectives

The TOR of Working Group and other details are given at Annexure I.

Objectives :

- To suggest strategy and road map for increasing overall agricultural productivity, profitability, sustainability and better livelihood opportunities through technological and other rural livelihood based interventions in rainfed areas.
- To suggest suitable policy and institutional interventions, thrust areas of research, and strategies for development of rainfed areas in Haryana.

CHAPTER - 2

Rainfed Agriculture Scenario in Haryana

2.1 Brief About State Agriculture

Haryana is primarily an agricultural state, with over 70 % of its population engaged in agriculture. With just 1.4% (4.42 M ha) of the total geographical area of the country, it is the second largest contributor of food grains (over 17 % between 2010-12) to the national food basket. The cultivable area in Haryana is about 3.8 million hectare (M ha), which is 86 % of the geographical area of the state. Out of this, 3.6 M ha (95%) is net sown area, whereas the gross cropped area is 6.32 M ha, with cropping intensity of 181 %. Haryana receives average annual rainfall of about 545 mm against mean annual evaporative demand of 1550 mm. Extensive cultivation of rice and wheat has led to over exploitation of groundwater and soil nutrient reserves, resulting decline in soil organic carbon content and multiple nutrient deficiencies, decrease in factor productivity and increased production cost. The climate change due to increasing variability in rainfall and temperature regimes is posing a serious threat to sustainability of agriculture. Thus the food security situation is likely to become critical in the changing scenario if urgent actions are not taken to adopt need based soil, water and crop management practices, including appropriate intensification and diversification measures to face the futuristic problems of resource constraints.

2.2 Rainfed Areas and Their Characteristic Features

The analysis of three years of land use data (2007-08 to 2009-10) of Haryana reveals that out of 37.62 lakh ha cultivable area, net irrigated area accounts for 29.90 lakh ha (84% of net sown area) (Table 1). This indicates that 7.72 lakh ha of cultivable area is rainfed which comes out to about 21 % of the total cultivable area of the state and 16 % of the net cultivated area. Over 91% of the State's rainfed area (5.31 lakh ha of net sown area) is confined to 10 districts; 7 in south western and 3 in north eastern parts of Haryana. The SW region accounts for 84 per cent while NE region 7 % of the state's rainfed area and rest 9 % is in the remaining 11 districts of Haryana (Table 2).

State of Agriculture

- Geographical area = 4.42 mha
- Cultivable area = 3.80 mha
- Net sown area = 3.60mha
- Gross cropped area = 6.32 mha
- Rainfed area = 21%
- Net irrigated area = 84%
- Cropping intensity = 184%
- Annual average rainfall = 545 mm

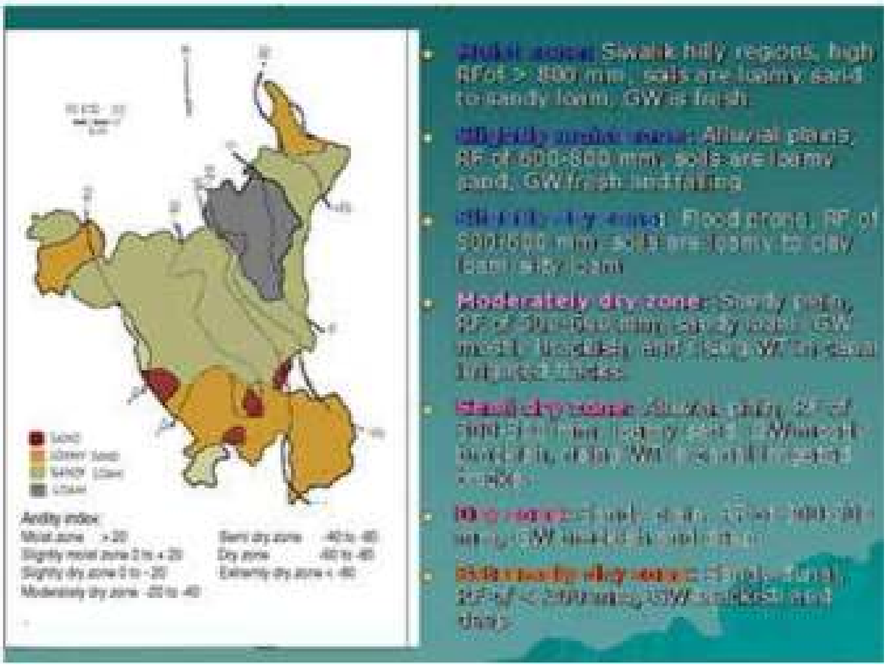


Fig. 1: Agro-ecological zones of Haryanaa

Fig. 2: Rainfed/dryland regions of Haryana

Table 1 : Status of cultivable, net sown, net irrigated and rainfed area in Haryana (000 ha)

Sr. No	District	Geographical Area	Cultivable Area					Net		
			2007-08	2008-09	2009-10	Avg.	%	2007-08	2008-09	2009-10
1	Ambala	154	133	132	133	133	86	131	131	132
2	Panchkula	57	34	34	34	34	60	24	24	24
3	Y. Nagar	172	129	128	127	128	74	129	125	125
4	Mewat	148	147	119	117	128	86	132	107	107
5	Rewari	151	130	132	132	131	87	126	125	126
6	M. Garh	194	157	157	157	157	81	152	151	151
7	Bhiwani	466	419	415	416	417	89	395	387	371
8	Hisar	404	360	360	354	358	89	341	342	332
9	Fatehabad	249	227	225	225	226	91	225	224	224
10	Sirsa	427	404	404	404	404	95	400	400	395
	Total of Districts	**2422**	**2140**	**2106**	**2099**	**2115**	**87**	**2055**	**2016**	**1987**
	Total of State	**4371**	**3772**	**3759**	**3756**	**3762**	**86**	**3594**	**3576**	**3550**

sown Area		Net Irrigated Area							Rainfed Area
Avg.	% of Avg. Cultiva-ble Area	2007-08	2008-09	2009-10	Avg.	As % of Net Sown Area	% of Cul-tivable Area	Rainfed Area (% of NSA)	Net Sown Area – Net Irriga-tion Area
131	99	114	113	113	113	86	85	14	18
24	71	8	8	16	11	44	31	56	13
126	99	114	125	115	118	93	92	7	8
115	90	82	68	67	72	63	57	37	43
126	96	109	94	109	104	83	79	17	22
151	96	85	122	126	111	73	71	27	40
384	92	284	120	202	202	53	48	47	182
338	95	251	240	267	253	75	71	25	85
224	99	215	212	22	150	67	66	33	74
398	99	346	347	371	355	89	88	11	43
2019	**95**	**1608**	**1449**	**1408**	**1488**	**74**	**70**	**26**	**531**
3573	**95**	**3025**	**2877**	**3069**	**2990**	**84**	**79**	**16**	**583**

Table 2: Spread of rainfed area in selected districts of Haryana (2010-11)

S. No.	District	% of NSA	Area (000 ha)
South west districts of Haryana			
1	Bhiwani	47%	185
2	Fatehabad	33%	74
3	Hisar	25%	85
4	Mohindergarh	27%	40
5	Mewat	37%	43
6	Rewari	17%	22
7	Sirsa	11%	43
Sub-total of south west districts (* 84 % of State's rainfed Area)			492*
North East districts of Haryana			
8	Ambala	14%	18
9	Panchkula	45%	13
10	Yamunanagar	7%	8
Sub-total of north east districts			39
Total (91% of State's Rainfed Area)**			531**

Source : Website of Agriculture Department, Haryana

The agro-ecological characteristics of Haryana are depicted in Fig 1. There is great variability in soil types, rainfall and aridity index within the small state of Haryana. The problems of rainfed area in South Western part which has got arid climate are quite different than the rainfed area of Shivaliks in North Eastern Zone (Fig 2).

2.2.1 South Western Zone

This zone comprises parts of Sirsa, Fatehabad, Hisar, Bhiwani, Rewari, Mohindergarh and Mewat districts. This zone represents arid and semi-arid climate with annual rainfall of about 300 to 550 mm (80-85% received in monsoon months in *kharif*) (Fig. 3). The annual potential evapo-transpiration (PET) ranges between 1500 to 1650 mm in these districts. It is characterised with erratic distribution of rainfall which is received in 10-20 rain events with prolonged dry spell and delayed onset and early withdrawal of monsoon. May and June are the hottest months with maximum temperature recorded upto 45-46 ºC and January is the coldest month when minimum temperature some time approaches freezing point. There is a large variation in relative humidity (22 to 96%) and aridity index (20-80). Moisture stress is normally experienced by most of the crops both in *kharif* and *rabi* seasons. The runoff potential is low (< 10%) in the South-Western tract and relatively high in NE Shivalik Foot Hill region (>25%).

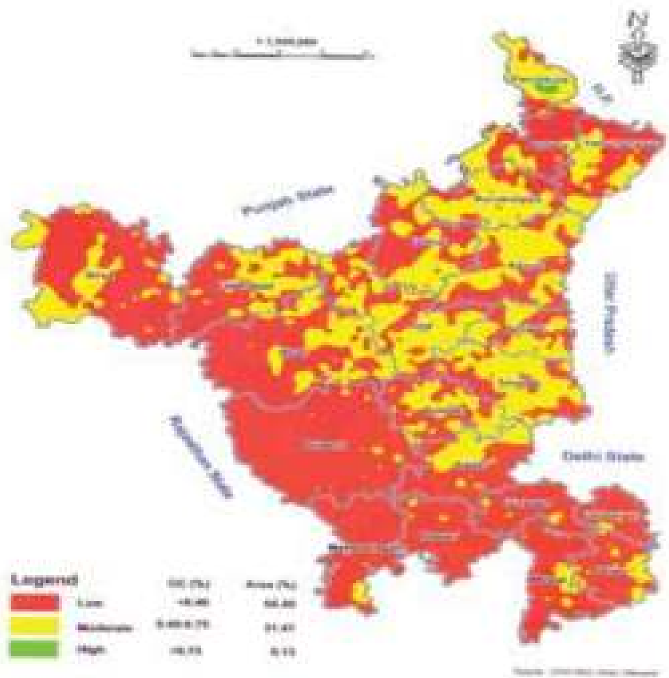
Fig.3: Rainfall variations in Haryana

Soils of rainfed ecosystem in this zone are light to medium textured with low water holding capacity and poor inherent fertility (low in nitrogen, phosphorus and medium to high in potassium). Soils have $CaCO_3$ concentration layer at varying depths (30-60 cm) below the soil surface. The soils are very low in organic carbon (<0.2%) content (Fig. 4). The land is flat, interspersed with undulating topography due to presence of sand dunes of varying heights and magnitudes. Small hillocks of Aravalli ranges are also present in districts like Bhiwani, Mohindergarh, Rewari and Mewat. During summer months, wind erosion is active in some parts of this zone. Soil erosion and inadequate moisture at crucial crop growth phases are major constraints for crop production.

The important crops grown are pearl millet (Bajara), cluster bean (Guar), mung bean, cowpea and castor in *kharif* and mustard, chickpea, barley and *taramira* in *rabi* season. Kikar (*Acacia lotica*), Khejri *(Prosopis cineraria*), Siris (*Albizia lebbek*), wild Ber (*Ziziphus mauritiana*) and Mahaneem (*Ailanthus excelsa*) are pre-dominate trees in this region, apart from pocketed distribution of Marwar Teak (*Tecomella undulate*), whereas Dhaman (*Cenchrus ciliarias*) and Sewan (*Lasirus sindicus*), are common grasses. Termite is a major problem in these areas.

Most of the ground water of NE zone is of good quality while that of SW zone ground water quality varies from marginal to poor quality (saline, sodic and saline sodic). Farmers have installed deep tube wells for protective irrigation. In major parts of SW region, the farmers have adopted sprinkler system of irrigation by using tubewell waters of poor quality. In some pockets, farmers are also adopting life saving irrigation through pressurized system. In some area of Mewat district, where groundwater quality is good, farmers have also laid down underground pipes for drinking purposes as well as for irrigation by transporting water from distances. In some pockets, groundwater is very deep and explored by rock drilling (horizontal and vertical) and blasting.

Fig. 4: Organic carbon status of soils in Haryana



2.2.2 North Eastern Zone

This zone includes parts of Panchkula, Yamunanagar and Ambala districts. The NE zone represents semi-arid and sub humid climate with annual rainfall of 550 to 1100 mm (Fig. 3) and PET of 1250 to 1500 mm. About 80-85% of the annual rainfall is received during monsoon months in *kharif* season while in *rabi* season only 15-20% rainfall is received. The rainfall is highly erratic in magnitude and distribution (received in 40-45 days) and dry spells of more than 3 weeks may occur even during rainy season.

This zone is characterised by medium textured soils which are usually over ridden with patchy layers of gravels mixed with silt and sand. Almost all the soils are low in nitrogen, phosphorus and medium to high in potassium. In Panchkula and Ambala districts, soils have a poor soil structure which leads to soil crusting and water erosion. These soils have gravels in the upper area around 2.5% with organic carbon 0.2 to 0.5 % (Fig. 4). The land is flat except in the upper areas of Panchkula and Ambala districts which fall under Shivalik foot hills consisting of steep slopes with moderate to severe soil erosion and shallow to medium gullies. Upper area is having a number of small and medium seasonal streams which join the main river system of Ghaggar and Yamuna.

In *kharif*, maize, pigeon pea, groundnut, sorghum (jowar), til (sesame) including rice and in rabi chickpea, mustard and wheat are generally grown. Trees like Khair (*Acacia catechu*), Shisham (*Dalbergia sissoo*) and Neem (*Azadirachta indica*), and important fodder trees

Major Features of N-E Zone

- Semi arid and sub – humid climate
- Rainfall 550 – 1100 mm
- Highly erratic rainfall
- Soils are low in N & P
- Poor soils structure
- Low Organic carbon in soils (0.2-0.5 %)
- Soils prone to water erosion

such as kachnar (*Bauhinia variegate*), Khirak (*Celtis australis*), and Biel (*Grevia optiva*), and medicinal trees such as Harar (*Tterminalia chebula*), and Amla (*Phylanthus emblica*) and grasses such as Bhabbar (*Eulaliopsis bianata*), Munja (*Sacharum munja*) and Khas (*Vetivera zizanioides*) are common in this zone. The upper semi-mountain area is also infested with Lantna (Lantana incana). The agriculture near forest area is highly threatened by wild life such as wild boars, monkey, blue bulls etc. As a result of this, the maize cultivation in foothills of Shivaliks has been reduced substantially.

The runoff potential is relatively high (> 25%) in the Shivalik foot hill region. Water harvesting structures have been constructed by the State agencies under different schemes, including Integrated Watershed Development Programmes. As a result of different soil conservation measures, farmers have been encouraged to level their lands.

2.2.3 Socio-economics of Rainfed Areas

Rainfed/dryland farmers in these areas are poor because of frequent crop failures due to moisture stress, subsistence farming and low farm income. Agriculture is the main occupation of the people of the area, as about 60% are the cultivators and agricultural labourers, 30% are other than agricultural labourers and 10% are engaged in service and business. Small farm holdings (< 2 ha) and high population pressure further aggravate the problems of farmers in otherwise high risk prone rainfed areas. Unemployment / under employment is more predominant in these areas. The literacy level of the farming community is generally low (40-50%). Migration is also reported in certain seasons from the districts of Panchkula, Yamuna Nagar, Rewari, Mohindergarh and Bhiwani and part of Hisar largely owing to droughts, lack of water and fodder availability.

The farmers are undertaking animal husbandry as one of the major activities for their livelihood. Rearing of buffaloes, cows, sheep and goats are taken up by farmers along with agriculture as an extra source of income and protection against crop failures due to droughts. However, deficiency of green fodder and pasture lands are matters of concern with rainfed/ dryland farmers. Landless farmers in these dryland areas depend on goat and sheep rearing on community lands. Bullock and camel power is the most popular form of draught power. However, some progressive farmers have resorted to farm mechanization.

The investment for development of infrastructural facilities in rainfed areas is very less compared to irrigated areas and also there is lack of adequate marketing facilities. There is general reluctance on the part of financial institutions to extend credit to rainfed farmers because of high risk proneness and lack of safety nets. Small and marginal absentee land holders also lease out their land. This tenancy system creates many socio-economic and technological adoption problems. Farmers have low purchasing power for cash inputs in general and costly agrochemicals (fertilizers, pesticides etc), and farm implements in particular, hence adoption of improved package of practices is also very poor.

2.2.4 River Basins and Water Resources

Major part of area in Haryana is part of the Indo-Gangetic Plains, except Shivalik belt in the north east and Aravallis in the southern part of Haryana. The Haryana state forms a water divide between Indus and Ganges basin, with majority of area falling in Ghaghar and Yamuna river basins and very small portion in Satluj basin. Sources and amount of available surface water from different rivers in Haryana is shown in Fig. 5. Dangri, a tributary of Ghaghar river originates in the Morni region of Shiwalik hills and is a seasonal river. In southern Haryana, a number of rainy season streams namely Sahibi, Krishnawati, Indori and Dohan rise in Rajasthan and drain to southern districts of Haryana, including Bhiwani, Mohindergarh, Jhajjar and Gurgaon. However, the construction of dam on Sahibi and other rivers does not allow the rain water towards Rewari and Mohindergarh districts to recharge ground water supply for supplemental irrigation. But during very high rainfall season, some water in the rivers flows and up to some distance sub-surface flow also takes place.

The total surface and ground water potential of Haryana is estimated at 1.51 and 1.24 M ha m respectively, amounting to 2.75 Mha m including ground water of marginal quality (Abrol *et al.*, 2012). The north eastern part of the state is extensively underlain by fresh ground water, while the remaining 65% area of the state is underlain by brackish to very saline groundwater combined with semi-arid or arid climate (Fig. 6). Considering urban and industrial needs of water resources, existing available water resources can meet hardly 60% of the irrigation requirements of the state.

Over the past decades, the State has witnessed extensive use of groundwater through tube well irrigation. The number of tube wells in the state has increased from less than 40,000 in sixties to 6.97 lakhs as on April 1, 2011. Of these, while 4.62 lakhs are electrically operated

Status of Water Availability

- Surface water = 1.51 Mha m
- Ground water = 1.24 Mha m
- 65% area of the state is underlain with brackish to saline water
- Of the 119 blocks, 70 are over exploited

while the remaining 2.35 lakhs are diesel sets. As a result of these efforts, ground water now accounts for about 55% and canal water with a vast network cover only 45% of the net irrigated area.

The pattern of groundwater dynamics in the state varies according to the geo-hydrological setting, cropping pattern evolved over time, prevailing water management practices and 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%) and 9 blocks are semi critical (70-90%). Out of the remaining 18 blocks that are safe (<70%), 10 are in major rainfed districts (Table 3). Groundwater

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

Fig.5: Sources of available surface water from different rivers in Haryana

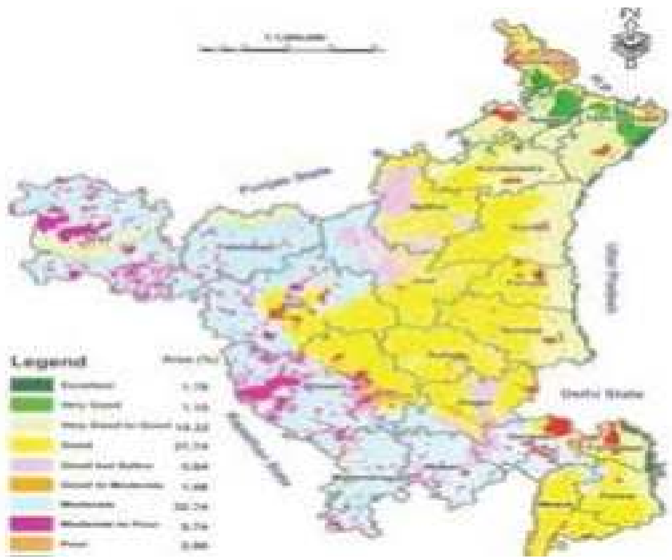


Fig.6: Availability of different qualities of ground water in Haryana

Table 3: 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 KheraTosham, Bhiwani
Hisar	`Narnaund	Adampur	Agroha Uklana, Hansi-II	Barwala, Hansi-I Hisar-I, Hisar-II
Mewat	Tauru, Ferozepur Zhirka	Punhana		Nagina, Nuh
Mohindergarh	Ateli, Kanina Mohindergarh, NarnaulNangal Chaudary			
Rewari	Nahar, Rewari Bawal, Khol	Jatusana		
Sirsa	Ellenabad, RaniaSir-sa, Ns Chopta	Baraguda	Odhan	Dabwali
Yamunanagar	Jagadhri, Radour Mustafabad Sad-huara,Chachrauli	Bilaspur		
Total	**70**	**22**	**09**	**18**

*** :** not accessed

(**Source** : Department of Agriculture, Haryana) availability in major parts of rainfed districts of south west Haryana is between moderate to poor category (Fig. 6)

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 was drastic decline in water table depth (Abrol *et. al.*, 2012). Amongst the rainfed districts, over exploitation of ground water is higher in districts of Mohindergarh (43.6 m), Bhiwani (21.5 m), Rewari (21.0 m), Fatehabad (21.0 m), and Sirsa (17.0 m). Declining water tables entail higher energy requirement as well as increased pumping costs besides having long term implications for climate change. Pumping from deeper layers is also reported to be having indications of water quality decline due to possible intrusion of brackish water from adjoining saline groundwater regions.

2.3 Growth in Area and Yield of Major Rainfed Crops

Significant shift has been witnessed in the growth of area as well as yield with steep increase in area under rice, wheat and cotton after Green Revolution and with the introduction of Canal as well as ground water irrigation and intensive use of fertilisers in the State of Haryana. This has largely happened at the cost of replacing area under traditional low water requiring rainfed crops, including pearl millet, maize, sorghum, cluster bean, gram, etc. The area under maize, pearl millet, sorghum and gram has reduced drastically by 86%, 25%, 73% and 89% respectively from 1966-67 to 2010-11 (Table 4). Increasing trend of area under rice and wheat and steeply decreasing trend in area under rainfed crops is clearly evident in Table 4 and Fig. 7. In rainfed areas, there has been increase in the area and productivity of rapeseed mustard.

Trends in productivity of rice and wheat, and major rainfed crops are shown in Figure 8 and 9 for the period 1966-67 to 2009-10. This clearly indicates plateauing or only slight increase in the yield of rice and wheat over the past few years. Among the rainfed crops, there has been a significant increase in productivity of maize and bajra as a result of improved varieties and management practices besides occasional supplemental irrigation.

Up-coming Crops in S-W Rainfed Areas

- Cluster bean (guar) is upcoming rainfed crop in S-W part.
- Mustard crop suffers from *Orobanche*
- Guar, castor & mustard+ chicory could be remunerative crop if market and policy support are provided

Table 4: Change in area and yield of major rainfed crops in Haryana

Crops		1966-67	2010-11
Rice	A Y	192 1166	1245 2789
Wheat	A Y	743 1425	2512 4624
Cotton	A Y	183 283	492 603
Maize	A Y	87 988	122 167
Bajra	A Y	893 418	661 1793
Sorghum	A Y	270 181	72 475
Gram	A Y	1062 500	112 735
Guar	A Y	196 (2001-02) 644	219 (2011-12) 1123
Oilseed (Rapeseed/ mustard) A Y		211 435	504 1869
Rabi Pulses (other than gram) A Y		50 (-)	9 (-)
Area (A: 000 ha) & yield (Y: kg/ha)			

Source : Website of Agriculture Department, Haryana

Analysis of the district-wise area under major rainfed crops has revealed that about 87%, 68%, 32% and 80% of the area sown under maize, jowar, bajra and gram is largely rainfed in the predominantly rainfed districts of Haryana. District-wise analysis of the productivity levels of major rainfed crops in the rainfed districts indicate that under predominantly rainfed condition, yields of maize, jowar, bajra and gram are about 2085, 475, 1500 and 735 kg ha^{-1} respectively (Fig. 10).

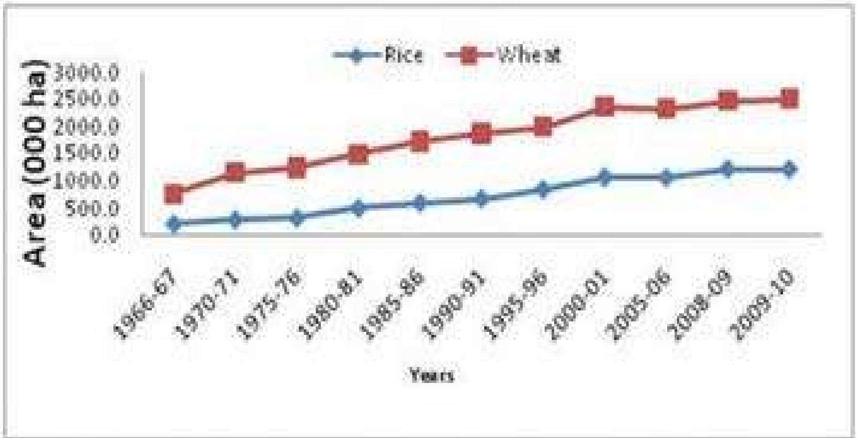


Fig 7: Trends in acreage under rice and wheat in Haryana

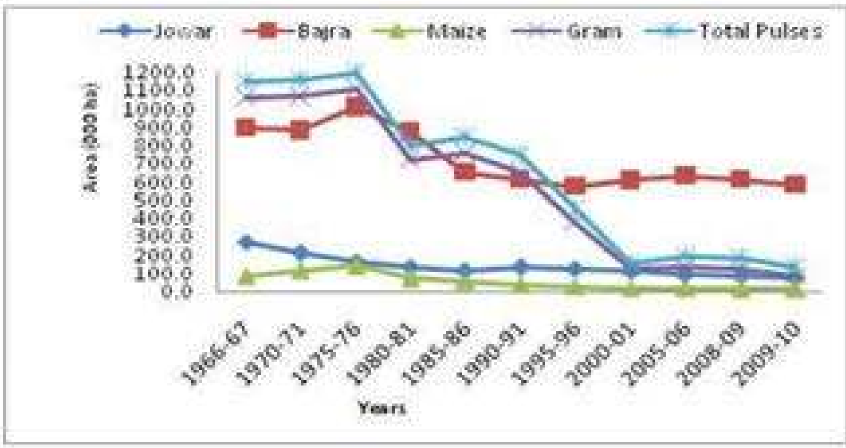


Fig 8 : Trends in acreage under coarse food grain and pulse crops in Haryana

Cluster bean (Guar) is one of the upcoming rainfed crop in the south western districts of Haryana. Districts of Hisar, Fatehabad, Sirsa, Bhiwani, Mohindergarh and Rewari are accounting for 2.12 lakh ha under guar out of total of 2.19 lakh ha for state as a whole. Haryana is the second contributor of guar production (24%) after Rajasthan from just about 9% of the total area under guar in the country (Fig. 11). The yield levels of guar seed are reported to be highest in Haryana (1130 kg/ha) as evident from the productivity trend as shown in Figure 12.

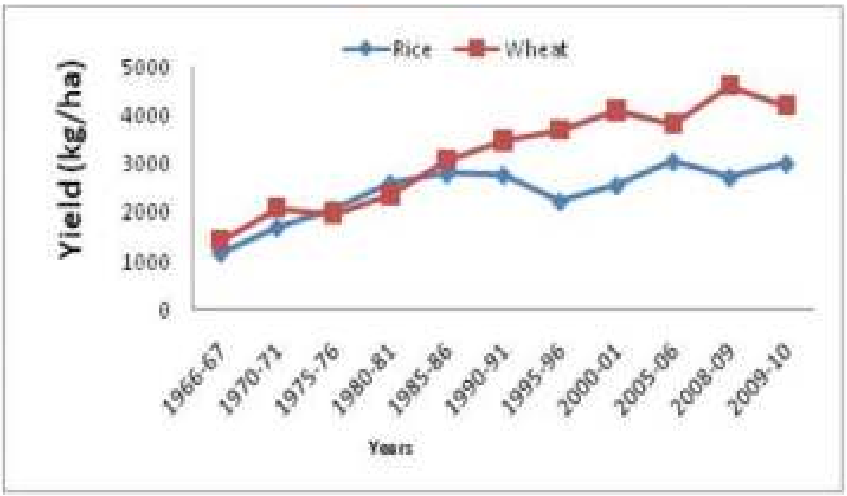


Fig. 9 Trends in productivity of rice and wheat in Haryana

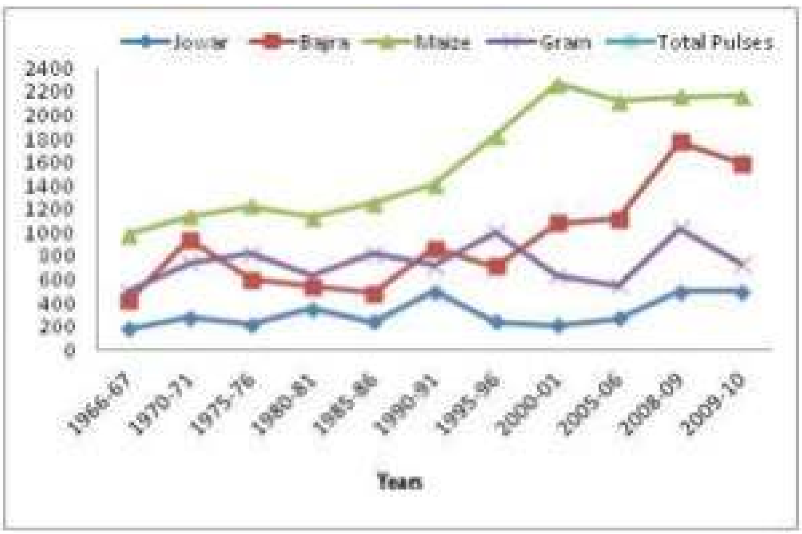


Fig. 10 Trend in productivity of coarse food grain and pulse crops in Haryana

District wise trends in area and yield of guar for rainfed districts of Haryana are shown in Figure 13 and 14. However, wide fluctuations in area as well as yield of guar are noticed which primarily could be attributed to market forces and rainfall deficit. The guar crop has variety of value added products but both specialized Mandies for marketing and factories for value addition are still inadequate for providing to support the farmers in Haryana.

Another important low water requiring crop like mustard has again shown increase in area and productivity due to remunerative prices and low input requirements, mainly in rainfed districts of South West Haryana (Table 4). The crop is infested by *Orobanche* parasitic weed which needs special attention of researchers for its better control. In such hot spots of parasite infestation, the cultivation of castor or mixed crop of chicory + mustard with supplemental irrigation could fetch better remuneration to the farmers. However, there is a need to provide adequate technical and policy support for marketing and value addition of castor in Haryana. The crop chicory (*Cichorium intybus*) has multiple uses and specialized Mandi available in Distt. Gurgaon for purchasing the produce from Haryana and Rajasthan.

The total fertilizer consumption in Haryana has increased by about 9-10 times between 1966-67 to 2007-08, whereas total cropped area has gone up by 1.4 times and production of food grains (cereals & pulses) and oil seeds by about 5-6 times over the same time period. The total fertilizer consumption per hectare of gross cropped area is lowest (64 kg/ha of gross cropped area) in Bhiwani having maximum rainfed area of 1.85 lakh ha, while it is highest (315 kg/ha) in Yamunanagar with only about 8000 ha

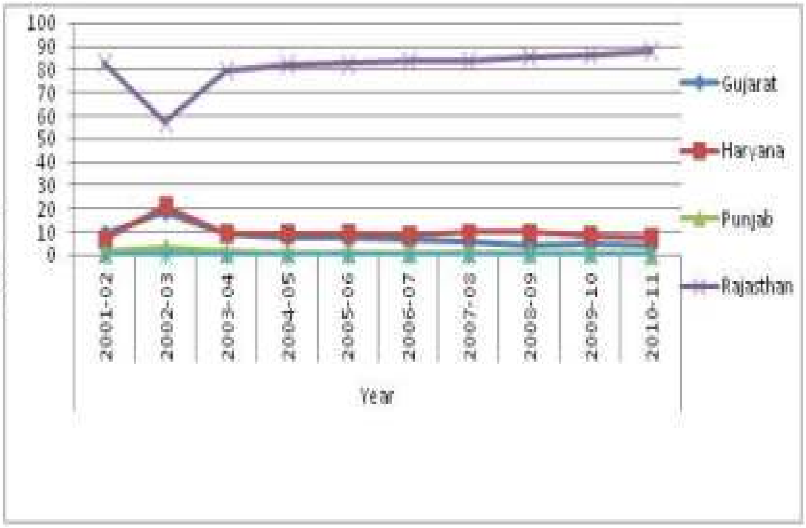


Fig. 11 Trend in acreage of guar in major guar growing states of India

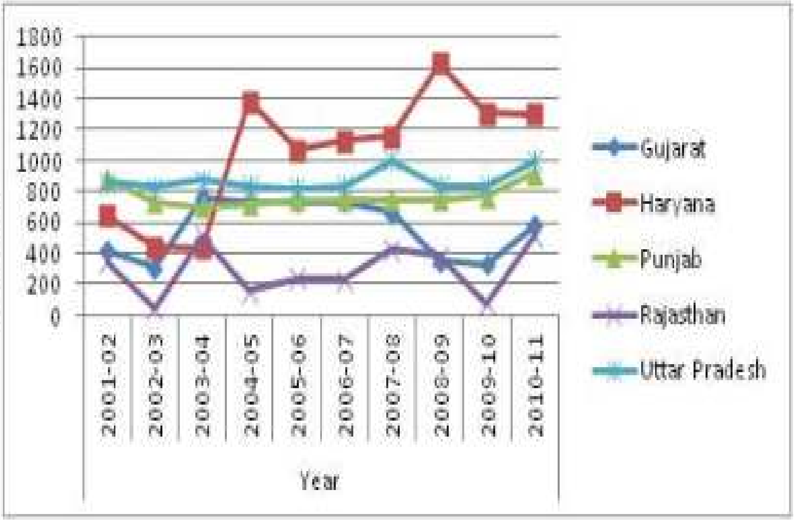


Fig. 12 Status of yields of major cluster bean (Guar) states in India

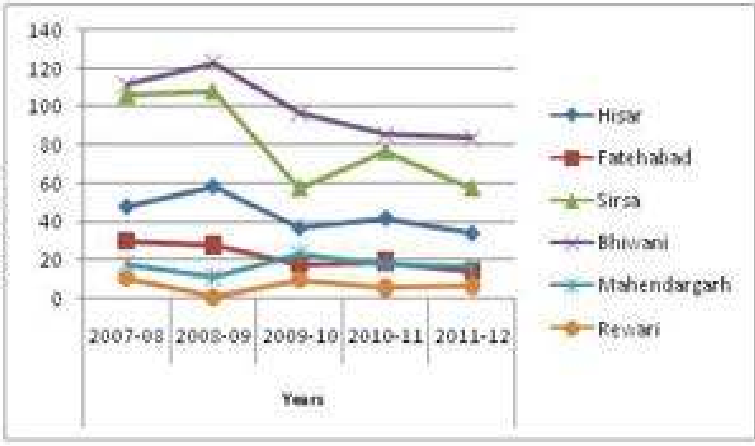


Fig. 13 Trends in acreage of guar in major guar growing districts in Haryana

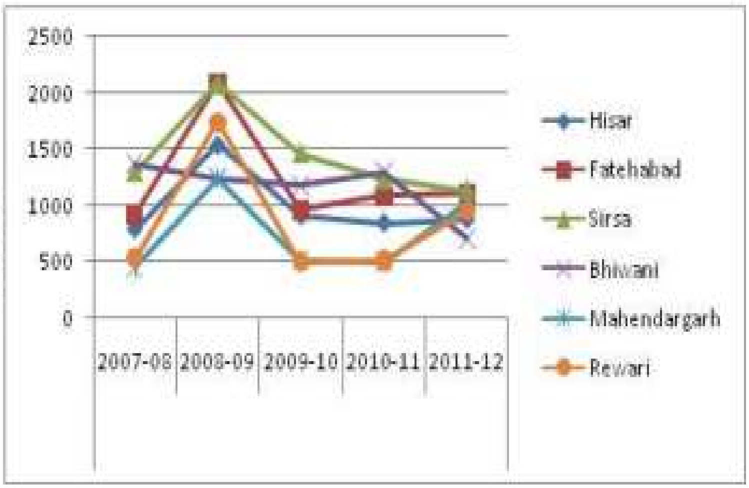


Fig. 14 Trends in productivity of guar in major guar growing districts of Haryana

rainfed area amongst the rainfed districts.

The productivity in traditional rainfed area is still low and there is enough scope for improving productivity and production in such areas by adoption of improved varieties of seeds and proven soil and water conservation and other dryland technologies. Inhospitable climate and poor soil resource base (poor carbon content, multiple nutrient deficiencies) and water scarcity are the major factors attributed to low and unstable crop production and productivity in these rainfed areas. With agriculture productivity growth slowing down in irrigated areas consequent upon natural resource degradation and decline in factor productivity, the rainfed areas have still potential to bridge the gap through increased productivity of field, fruit and tree crops.

2.4 Climate Change and Rainfed Agriculture

The GCM models predicted that the Indian Sub-continent will be warmer by about 1.5^{0}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 CO_2 and other green house gases in the Indian sub-continent. According to the emission inventories that different Governments submitted to the United Nations Framework Convention on Climate Change, agriculture accounts for around 15% of global GHG emission. The increase in deforestation in developing countries for agricultural purpose could raise its contribution between 26-35%.

Rainfed areas are relatively more vulnerable to climatic variability and climate change as a result of poor capacity to cope with extreme water and weather shocks on account of degraded natural resources, poor socio-economic condition, and lack of irrigation water and inadequate forest cover to moderate or insulate the adverse impact of climate change in these areas. Climate change and climatic variability, especially extreme weather events, are further compounding risks and investment decisions of policy makers and farmers in the rainfed areas. This clearly suggests the need for greater emphasis on research and development in the field of climate resilient agriculture, besides shift at the policy level as well as investment decisions in favour of need based adaptive and mitigation measures to sustain agriculture growth in the rainfed areas under changing scenario of climate in Haryana.

A network project on "National Initiative on Climate Resilient Agriculture" (NICRA) was initiated in 2011 aiming at enhancing resilience of Indian agriculture through Strategic Research, Technology Demonstration, Capacity Building and Sponsored/Competitive Grant Projects. Improved practices like water harvesting, direct seeded rice, alternate wetting and drying, green manuring, deep placement of fertilizers and feed supplements for livestock have been demonstrated on farmers' fields in 130 districts to cope up with various climatic aberrations. Contingent plans for 500 districts have been completed out of targeted 572 districts in the country. Automatic weather stations have been established in 100 Krishi Vigyan Kendras (KVKs) located in vulnerable districts to improve the agro-advisory services to the farmers. Besides, 100 Village Climate Risk Management Committees (VCRMCs) and Custom Hiring Centers (CHCs) are being established. AICRP-DA centre at CCSHAU, Hisar is one of the centre for NICRA activities. Three villages named Ghangala and Budhaselly (both in Bhiwani district) and Balawas (Hisar district) have been selected as Climate Smart Village for demonstration of technologies to mitigate the adverse impact of climate aberrations.

2.5 Major Issues, Opportunities and Challenges

Major issues of concern in these rainfed areas include low rainfall with erratic distribution, undulating topography with moderate to severe soil erosion, light textured soils, less retention of water due to poor soil health i. e. low carbon content, poor fertility and multiple nutrients deficiency, low germination of small seeded crops due to crust formation, limited irrigation facilities, depleting good quality groundwater and dominance of brackish ground water in rainfed areas. Institution of MSP, value addition and marketing of rainfed crops, timely availability of quality input and planting material and shortage of skilled manpower and poor mechanization for small holders are some other concerns.

The public investment rate of Rs.12,000-15,000/ha under watershed development schemes in rainfed areas is 13 to 16 times less than Rs.2.0 to 2.5 lakh/ha under canal command development schemes. It is highly under-invested, being more fragile, risky and distress prone. However, greater potential and strength of diversified crops, horticulture, agroforestry / other commodities and livelihood options provide ample opportunities and scope for niche crops/commodities such as guar, pearl millets, rapeseed/ mustard, castor, chicory, medicinal plants, spices, arid fruits, livestock, dairy, value addition and processing of these commodities to help the resource poor farmers in the state.

The major challenges before researchers, implementers and policy planners are issues of conserving and augmenting rain water, arresting declining groundwater and deteriorating water quality, restoring soil health and fertility, development and aggressive promotion of efficient water use management practices, promoting less water demanding field-, fruit- and tree

Major Issues in Rainfed Areas

- Low rainfall and erratic distribution
- Poor soil health
- Low retention of water in soil
- Depleting good quality ground water
- Low germination of small seeded crops
- Marketing problems of rainfed crops
- Low investment under watershed development
- Rainfed areas are more vulnerable to climate change

crops and livestock in the rainfed areas.

There is a need for development of scientific land use planning with greater emphasis on multi-commodity-enterprize based location specific diversification and intensification, climate resilient agriculture, value addition and market linkages, alternative institutions, enabling policies and bringing convergence for sustainable development of these rainfed areas in Haryana. The real challenge is to develop and demonstrate holistic and integrated approach focussed at management of natural resources together with its linkage with location specific and farmers' centric production, productivity and livelihood interventions.

CHAPTER – 3

EFFORTS/SCHEMES/ INITIATIVES IN RAIN-FED AREA DEVELOP-MENT

3.1 Research Initiatives and Achieve ments

Major R&D activities in development of rainfed areas in the region are being carried out by the Dryland Centre under ACRIPDA and basic research project of drought tolerance in field crops under NARP at CCS Haryana Agricultural University, Hisar and its Regional Research Station, Bawal, and CSWCRTI Research Centre, Chandigarh. Major focus of CCS HAU has been on identification of potential drought tolerance traits, their simplified measurements, inheritance and their relations to productivity, selection of crops and varieties, crop geometry, in-situ moisture conservation, contingent crop plans, nutrient management and farm mechanization; while CSWCRTI RC pioneered in developing and demonstrating various soil and moisture conservation practices, water harvesting and watershed management in rainfed areas. Water Technology Centre of IARI, New Delhi, CCSHAU, Hisar and CASA, New Delhi have also undertaken research programmes in cluster of villages for efficient use of natural resources and other inputs including conservation agricultural technologies in water deficit area of Mewat. Some of the important research achievements for development of rainfed agriculture are briefly discussed here.

3.1.1 Rain Water Management

(a) Surface Water Harvesting

Water being the most limiting and important resource, the most efficient and cost effective approach for rain water management is *in-situ* conservation of rainfall. Runoff must be arrested to recharge the ground water reservoir or diverted into basins, furrows, pits, dugouts, ponds, recharge wells and tanks. Some important research achievements in this field are described as below:

Tillage

Deep ploughing in every 3rd year helps in retention of rain water for longer duration by reducing runoff and facilitating better water infiltration and conservation in soil profile. Shallow off season tillage with pre-monsoon showers ensures better moisture conservation and lesser weed intensity. Tillage and seeding across the slope and ridge furrow configuration should be practiced for higher and uniform soil moisture conservation.

Contour Bunding and Terracing

Contour bunding for medium textured soils receiving <600 mm rains and graded bunds with a slope of 0.1-0.5% for heavy textured soils getting >600 mm rain is recommended. For slopes greater than 6%, bench terracing need to be adopted. *In-situ* conservation of rain water as much as possible by levelling and bunding of field and timely planking is recommended.

Inter Plot Rain Water Harvesting

Under low rainfall, it is appropriate to cultivate the crops in 2/3rd part and leaving remaining 1/3rd area fallow as catchment for rainwater harvesting. This has resulted in 50-60% yield improvement in pearl-millet, mustard and taramira (*Eruca sativa*) under water deficit season.

Inter Row Rainwater Harvesting

The harvested rainwater on inter row basis (30/60 cm paired row planting in ridge and furrow system by ridger seeder) improved the yield of pearl millet, chickpea and mustard crops remarkably. It also helped in mitigating the adverse effect of crusting on germination and seedling damage (burying) due to rains in monsoon season. It is recommended to seed the different crops on the shoulder of ridge during rainy season and at the bottom of furrow in paired rows (30+60 cm) during *rabi* season.

Rainwater Harvesting in Farm Ponds

Under above normal and extended rainfall conditions, runoff could be collected in a suitably designed dugout farm ponds. For South

Major Efforts for Rainfed Area Development

- Development of drought tolerant crop varieties
- Promotion of soil moisture conservation and water use efficient technologies
- Technology demonstration for water harvesting and watershed management
- Selection of suitable crops and crop rotations as per availability of water
- Promotion of machine and tool suitable for rainfed agriculture
- Integrated nutrient management and farming system
- Comprehensive Mewat specific programe
- Promotion of Livestock, Agri-horticulture and agroforestry as safety nets
- Promotion of silvipasture and fodder production
- Organic farming

Western region 199-250 m^3 and for Shivalik foothills, 400-600 m^3 pond sizes have been found to be ideal for rain water harvesting.

(b) Watershed Management

The technology of participatory watershed management with water harvesting as an 'entry point' in Shivalik foothills at Sukhomajri, Bunga and Nadah and in Aravalis at Bazar Ganiar in Rewari District (earlier in Mohindergarh) was developed and demonstrated by CSWCRTI RC, Chandigarh in the late seventies and early eighties. Under these programmes many water harvesting structures were constructed in different places. Some of them are still irrigating the fields in their command. These structures helped in increasing the productivity of the land on down side but also recharged the aquifer, brought large chunk of land under plough, reduced the flooding of the area and also benefitted landless farmers through better livelihood opportunities in the villages thus reducing migration.

Various studies conducted by different organisations established that with such projects, the catchment area can be enriched with vegetative cover and the soil erosion could be reduced, besides improving socio-economic conditions of the people. Harvesting, storage and recycling of rainwater for supplemental irrigation enabled the villagers to increase the cropping intensity and production in arable land, besides higher milk production through enhanced fodder availability. The cropping pattern shifted in favour of more remunerative and quality crops such as wheat, mustard, berseem, fruit and vegetable crops etc. The area under wheat increased substantially. The concept of social fencing came up from Sukhomajri watershed, which has been instrumental in increasing vegetative cover in the catchments. Over the years, CSWCRTI has demonstrated many more such Projects and conducted a number of evaluation studies.

In a study conducted by the CSWCRTI (Arya and Samra, 2001), it was found that wherever watershed management projects have been successful, both the farmers and implementing agencies have overcome a series of collective action/problems to govern, maintain and manage the system over a period of time. However, in some cases water harvesting structures have not served the purpose because of technical difficulties faced by implementing agencies, besides the social conflicts among the beneficiaries and village level institutions. This suggests scope for improving institutional and policy issues for sustenance of watershed projects.

(c) Rainwater Harvesting and Recycling for Sustainable Production

The technology of rainwater harvesting and recycling can be successfully replicated in the entire area of Shivaliks and other rainfed region. The type of structure for rainwater harvesting and its capacity will depend upon the physiography, soil and land use. An earthen embankment can be constructed in hilly watershed adjoining the cultivated area. Pond construction needs to be taken up at the bottom of foothills or in depressions in gently sloping agricultural watersheds.

- More than hundred Water Harvesting Structures (WHS) in Haryana were constructed on Sukhomajri pattern.
- Apart from the suitable technology of rainwater harvesting by making earthen dams in Shivalik foothills demonstrated by the CSWCRTI Research Centre, another milestone was created by involving the communities in the management of rainwater harvesting for supplemental irrigation and protection of hilly areas contributing the rainwater to the reservoir.
- The technology developed on supplemental irrigation from harvested rain water can be very useful for areas having no assured source of irrigation and having possibilities for rain water harvesting and its recycling. The farmers can plan cropping and irrigation schedule according to the quantity of water available for irrigation. Almost entire rainfed region falls under this category where there are no assured / reliable water sources for irrigation.
- There is a need to divert excess rain/flood water to water deficit arid regions of south western parts, but it should follow after scientific studies on salt and water balance, energy cost and socio-economic benefits on long run to the stakeholders.

(d) Sub-Surface Harvesting: Infiltration Gallery as Sub Surface Dams

Soil Conservation Department of Haryana has successfully demonstrated subsurface water harvesting in different watersheds of Shivaliks in north-east Haryana by tapping the water of perennial and ephemeral streams emanating from the higher reaches by constructing vertical infiltration galleries (subsurface dam) across the channel or stream or rivulets from bed level of the stream down to the level of the impervious layer below. A typical design of RCC Infiltration Gallery and a view of its operation are given in Fig. 15(a) & 15 (b.c,d) of a few villages in the foot hills of Shivaliks.

This water is then conveyed to the drinking water supply system and/or the agriculture fields through pipelines for irrigation. This source is very good as the water gets filtered automatically while crossing the various layers of earth through which it passes. Further, there is no risk of silting or drying up, though the volume may reduce during off-season. It can be utilized downstream under gravity by using UPVC, HDP and RCC pipelines.

The post-project impacts are clearly visible in the area through increased irrigation in the command area, crop yield and production. The agriculture which was earlier solely dependent on the erratic occurrence of rainfall has now become sustainable and profitable. The Working Group visited this oject area in the Foot Hills of Shivaliks and had fruitful discussion with the farmers of Mallah, Kedar Pur and Jabrot villages. The most important crops currently grown by farmers are ginger, tomato, basmati paddy, wheat, green fodder, marrygold and seasonal vegetables. There is significant improvement in the cropped area, yield and production, especially during *rabi* season (Fig. 16).

In the foothills of Shivaliks, the ginger intermixed with turmeric (haldi), *colocasia spp.* (arbi, kachaloo), chillies, lady finger and marigold has been adopted by majority of the farmers as the most remunerative mixed cropping system. The area under ginger has increased by 5 times (3.5 acre to 18.5 acre) during the post-project period. The average yield of ginger is varying from 35 q/acre to 45 q/acre. Instead of selling fresh ginger in nearby markets, the farmers have taken up to process the fresh ginger by fabricating the machine on their own for shaping the fresh ginger and making saunth (dry sliced ginger) which is a highly remunerative product. About 25 % *saunth* is produced from raw ginger as per information recorded through interaction of Working Group with local farmers in this area. Besides, supplemental irrigation in crops, the water needs of livestock and households in these villages is also being met from the subsurface water harvesting system.

3.1.2 Agronomic Interventions

(a) Selection of Rabi Crops

- Long term rain water harvesting suggests that it is possible to conserve about 1/3rd

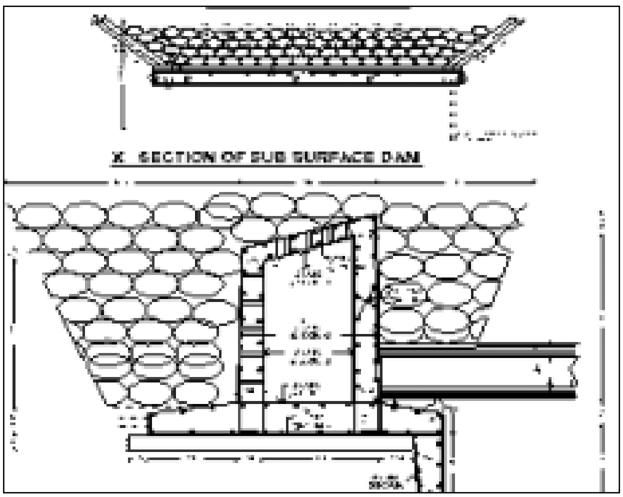


Fig. 15 (a) Typical design of RCC Infiltration gallery

Fig. 15 (b) Infiltration gallery in village

Fig. 15 (c) Water storage tank in a village

Fig. 15 (d) RCC pipeline outlet of SSD

rain water in the soil profile at the time of sowing of *rabi* season crops out of the total rainfall received during the preceding monsoon months.

- Taramira (*Eruca sativa*) has been found to be an appropriate crop for moisture regime of 100 to 125 mm m^{-1} in the soil profile at the seeding time, and if moisture in the soil profile is in the range of 125-200 mm $m^{-1,}$ mustard and chickpea are the most suitable *rabi* crops.
- Strip cropping of pearl millet and moong bean in 8:4 or 6:3 ratios (row to row 30 cm) has been found more productive and economical as compared to sole crop or other inter-cropping system. This ensures some harvest in case of drought situations. However, better mung bean varieties with high shade tolerance need to be developed for inter and mixed cropping of mung bean with pearl millet.
- Intercropping in chickpea with raya in 6:1 or 8:1 showed good promise.

(b) Seeding Technology and Intercultural Operations Through Mechanization

Ridger seeder has been proved very effective to control ill effects of crusting and improving germination of small seeded crops. With this implement, pearl millet is sown on the shoulder of the ridge in paired rows (30:60 cm). On the contrary, in mustard and chickpea under poor soil moisture, sowing may be done in the paired rows (60+30 cm) at the bottom of furrow. However, under extreme drought condition (as in 1987-88) only one row of mustard at the centre of furrow performed better than chickpea. Existing heavy ridger seeder has been modified

Fig. 16 (a) View of command area in Village Kedarpur before project and (b) after the project

by reducing its weight by 20-25% which was operated successfully on 187 ha in 15 villages for seeding of pearl millet, mustard and chick-pea crops. The ridger seeder can perform three operations in a single run i.e making ridge and furrow, seeding and placement of fertilizers at desired depth. However, there is a need to popularize this machine through custom hiring to help small holders in water deficit areas of Haryana.

Wheel hand hoe has been found successful for weed control and soil mulching.This implement needs to be popularized even by conducting more demonstrations, its multiplication and distribution to the resource poor farmers on subsidized basis.

(c) Integrated Nutrient Management

As it is rightly said that the rainfed areas are not only thirsty but also hungry. Integrated use of inorganic, organic and bio-fertilizers to meet the nutrients needs of various crops is essential feature of arable rainfed farming.

- Application of 40 kg N through FYM in

Table 5 Effect of life saving irrigation with harvested water on crop yields (t ha^{-1})

Crops	Without irrigation	With 7 cm irrigation
Pearlmillet	1.32	2.24
Green gram	0.83	1.30
Chickpea	0.58	1.96
Mustard	0.75	1.65

pearl millet gave comparable yield to 40 kg N (through urea) + 25 kg P_2O_5 ha^{-1}. Also half of the recommended dose of inorganic fertilizers could be saved by addition of 4 t FYM ha^{-1} along with seed inoculation with appropriate bio-fertilizers. It improves soil organic C and soil moisture retention.

- Green manuring of *Dhaincha* in *Kharif* has been found to save 15 kg N and 7.5 kg P_2O_5 ha^{-1}.
- For rainfed cereals and oilseeds, application of 40 kg N+ 20 kg P_2O_5 ha^{-1} and 20 kg N + 40 kg P_2O_5 ha^{-1} in pulses is most economical.
- Advance application of fertilizer by the end of monsoon season increased mustard seed yield by 1.5 q/ha over basal application at the time of sowing.
- Placement of 20 kg P_2O_5 ha^{-1} at 20-25 cm depth is equally effective to 40 kg P_2O_5 ha^{-1} placed against conventional practice.

(d) Life Saving Irrigation

In most of the dryland areas in North India, the ground water is generally brackish and not suitable for irrigation. However, the sulphate dominated brackish water could be exploited for life saving irrigation to enhance the productivity of dryland crops during water deficit seasons. Also, harvested rainwater in farm ponds, wherever feasible, should be used at earliest opportunity as a pre-sowing/life saving irrigation in rainfed crops (Table 5). The pressurized system of irrigation such as sprinkler and drip will further ensure high water use efficiency and water economy under such situations.

(e) Synergies Between Soil Water and Fertilizers

Water and fertilizers increase each other's efficiency. Application of fertilizers could improve grain yield with no or only slight increase in water use. Dryland soils are generally poor in fertility. These hungry soils can not withstand the water stress in the event of drought. Deep placement of 40-50 Kg N + 20-25 Kg P_2O_5 ha^{-1} in oilseed brassicas and 20 Kg N + 40-60

Kg P_2O_5 ha^{-1} in chickpea has been found quite useful to boost their grain yield. Ridger seeder could be utilized for deep placement of fertilizer in the moist zone below seed along with seeding of dryland crops. These crops also responded favourably to zinc application upto 10-15 kg $ZnSO_4$ ha^{-1} in zinc deficit light textured soils of dryland areas. Advance application of fertilizers by the end of monsoon season could also be practised profitably in the winter season crops. Supply of adequate plant nutrients helps in early development of crop cover and thereby reducing evaporation from soil surface. Also more vigorous shoot growth as a result of nutrient application stimulates deeper root development and greater extraction of water from deeper layers, if these layers contain adequate moisture. Nutrient application, therefore, increases water use and better partitioning of ET in favour of transpiration. A proper combination of water, fertilizers (organic, inorganic, bio-fertilizers) and genotypes is required both for low and high input systems of agriculture. Water and fertilizers up to optimum level improved plant water status, physiological functions and crop productivity under different situations of water availability.

(f) Recommended Crop Rotations Under Different Situations

i. Mono cropping

Kharif crops – Fallow

Kharif Fallow – *Rabi* crops (on conserved moisture)

ii. Double cropping : (in case of above normal rainfall years)

Pearlmillet – Chickpea; Moongbean – Mustard; Cowpea-Mustard

Pearlmillet + cowpea (fodder)- Mustard/chickpea

(g) Drought Management

Dry Spells and Drought

A dry spell is considered if the rainfall received is less than 50% of normal for a consecutive period of more than 20 days during a season and that if the deficiency occurs for 21 to 28 days, it is mild, 29 to 42 days it is moderate and beyond 43 days, it is considered as severe drought.

Early Season Drought

It generally occurs either due to delayed onset of monsoon or due to prolonged dry spell soon after the onset of rainy season resulting in seedling mortality. Water availability duration for crop growth is reduced and the crops suffer from acute shortage of water during reproductive stage on account of early withdrawal of monsoon. Under these situations, pearl millet is the first causality, so the area sown in Kharif may be divided in the ratio of 1:1 for pearl millet and pulses.

Mid Season Drought

This occurs due to inadequate soil moisture between two successive rainfall events. Its effect varies with the crop growth stage and the appropriate plant population, top dressing or spray of fertilizer, interculture (mulching), and supplemental irrigation by harvested rain water, are the practices which are recommended to mitigate the effect of mid season drought.

Terminal/Late Drought

This occurs as a result of early cessation of monsoon rains and for mitigating its effects, soil water conservation, interculture and supplemental irrigation by harvested rain water should be adopted.

3.1.3 Agro - physiological Aspects of Crop Improvement for Drought Tolerance

An understanding of constraint of water on yield and adaptation of plants to water deficits challenges the breeders to develop crop cultivars that will give a greater yield under water deficit conditions and the agronomists/water management experts to ensure that the most efficient use is made of the available water. It has been argued that to improve grain yield of crops in a dryland area, one must increase the water passing through the crop in transpiration (T), increase the water use efficiency (W) and /or increase the proportion of total dry matter going to grain (H). The crop productivity depends on the development of leaf area to intercept radiant energy and the role of photosynthesis to convert it into dry matter. However, the distribution of assimilate within the plant will determine the proportion of the total biomass that is harvested as economic yield.

In order to endure the period of water deficit, higher plants should use one of the three main drought resistance mechanisms: drought escape, drought postponement or avoidance, drought resistance, i.e. the determinants of survival. Regardless of the assumption of independence or inter linkages between the determinants of plant survival or determinants of yield (T, W, H), the integration of these conceptual frameworks is useful to tailor various management practices and breeding programmes for sustaining higher productivity of field crops in drought prone environments. Multidisciplinary team of scientists of CCSHAU has conducted detailed studies in well designed drought plots covered

Contingent plans for varied situations of monsoon rains are given below for Pearlmillet / Cluster bean and pulses:

Pearlmillet

		Monsoon Situation	Measures Suggested
A.		Normal monsoon	Grow all the recommended varieties of pearlmillet with normal package of practices. The sowing of crop should be initiated as and when 20-30 mm rains are received.
B.	**1.**	**Delayed onset of monsoon**	
	a)	Two weeks delay	Follow the practices as described in A.
	b)	Three-five weeks delay	Cultivate short duration varieties (HHB 67 and HHB-197). Pearlmillet sowing can be done latest by 1st week of August, Transplant 3-4 weeks old nursery on rainy day. Use wheel hand hoe to weed control and moisture conservation. Thinning to reduce 1/3rd plant population.
	c)	Six-seven weeks delay	Apply N through foliar application of urea. Harvest every third row of pearlmillet for green fodder after 45 days of sowing and make furrow in space so vacated for in-situ rain water harvesting.
	2.	**Long dry spell after sowing**	
	a)	Two-three weeks	Use wheel hand hoe for weed control and moisture conservation. Thinning to reduce 1/3rd plant population.
	b)	Four-six weeks	Follow 1 (c)
	3.	**Early withdrawal of monsoon**	
			Remove third row and make ridge and furrow for in situ rain water harvesting and follow foliar spray of urea under rainfed condition.
	4.	**Heavy monsoon causing flood**	
	a)	At initial stage	Sow pearlmillet by ridger seeder. Drain out the stagnated water to field pond. Use wheel hand hoe to weed control and moisture conservation. Apply N fertilizers just before vattar (workable field conditions) to compensate N leached. In case of crop failure, resow early maturing varieties.
	b)	At mid stage of crop growth	Drain out stagnant water. Apply N fertilizers just before vattar (workable field conditions) to compensate N leached. If the crop fails, go for green manuring before Rabi and conserve the moisture for rainfed Rabi crops.

Cluster bean and pulses

	Monsoon Situation	Measures Suggested	
A.	Normal monsoon	Sow recommended varieties and follow package of practices	
B.	**1.**	**Delayed onset of monsoon**	
	a)	Two weeks delay	Sow recommended varieties and follow recommended package of practices.
	b)	Three-five weeks' delay	Sowing of clusterbean may be ensured by end of July or by 1st week of August using early maturity varieties. For delayed sowing, seed rate may be increased by 20% and follow recommended package of practices. Some area may be used for fodder/moongbean/moth/pulses.
	c)	Six-seven weeks' delay	Avoid clusterbean sowing and conserve moisture for Rabi season.
	2.	**Long dry spell after sowing**	
	a)	Two-three weeks	Prefer weeding by wheel hand hoe to keep the crop weed free and conserve soil moisture. Maintain optimum plant population.
	b)	Four-six weeks	Repeat one hoeing with kasola/wheel hoe to keep the crop weed free and to conserve soil moisture. Harvest third row and use it for mulching.
	3.	**Early withdrawal of monsoon**	Apply light irrigation, if available, at pod formation stage.
	4.	**Heavy monsoon causing flood**	
	a)	At initial stage	Drain out the stagnated water to field pond. Crop should be hoed immediately after vattar condition.
	b)	At mid stage of crop growth	Drain out stagnant water and if field comes in vattar condition in September, plough up the remnant crop as green manure and conserve the moisture for Rabi season.

with rain out shelters and micro plots connected with washing tanks on different agro-physiological aspects of resource management and crop improvement of rainfed crops in drought prone areas.

(a) Characterization of Environment

The first requirement for improving crop productivity in water deficit environment is to identify the timing and the length of stress likely to be encountered. These depend on the soil water storage at the beginning of the season in relation to rooting depth, the incidence of rainfall/availability of irrigation water, and the rate of crop evaporation (ET) during the growing season. There are several ways to characterize the environment with regard to availability and utilization of scarce water resource by the crops in dryland areas. In certain situation, the estimation of available water at the time of seeding and crop water use in relation to weather data could be adequate to select crops/varieties for attaining higher productivity under progressive moisture stress in dryland areas. Analysis of 62 years rainfall data at the Dryland Research Center, Hisar (India) has revealed that in a 10 years cycle, 3 years received above normal rainfall (> 400 mm), 5 years normal rainfall (200-400 mm) and 2 years received below normal (< 200 mm) rainfall. With proper soil and water conservation practices under North Indian conditions (Hisar), the amount of water available during the first fortnight of October (i.e. at the time of seeding of winter season dryland crops) is about 30% of the total rainfall of the preceding monsoon months of July, August and September. Based on such estimation of available water in the soil profile, the farmers could be advised to choose the suitable crops/varieties for obtaining higher productivity in winter season dryland crops.

(b) Crop Water Use

Crops and varieties differ not only for total water use, but also for soil water extraction pattern under water deficit conditions. Among summer cereals, maize had more water uptake from top soil (0-45 cm) and sorghum from sub-soil (45-135 cm), while pearl millet had low water extraction from the whole soil profile. Stomatal conductance under severe moisture stress in pearl millet exceeded that in sorghum and maize, indicating maintenance of normal physiological functions in pearl millet. In addition, pearl millet had greater water use efficiency (WUE) than sorghum under severe water deficit conditions. These studies thus confirmed the superiority of maize over sorghum under adequate water supply conditions and that of pearl millet over sorghum under ex-

Table 6: Rainfall, water storage in the soil profile and water absorption by oil-seed brassicas and chickpea in three contrasting seasons.

Parameters	Crop Growing seasons		
	1983-84	1984-85	1987-88
Monsoon season rainfall (mm)	391	330	49
Winter season rainfall (mm)	20	12	31
Total rainfall (mm)	411	342	80
Usable water* in 1.8 m top soil (mm)	242	207	96
Water extraction(mm) by			
** Oilseed brassica	185	164	65
Chickpea	138	125	50

*between -0.01 and -1.5 Mpa soil water potential, ** Averaged across genotypes

tremely dry conditions. There is a need to select proper crops/varieties for rational use of available water during monsoon season for high crop productivity in dry lands.

The case studies carried out at Hisar on oilseed brassica and chickpea for three contrasting seasons: 1983-84 [normal rainfall (411 mm) year], 1984-85 [slightly rainfall deficit (342 mm) year] and 1987-88 [extremely dry (80 mm rainfall) year]. In general, oilseed brassicas and chickpea grown on sandy loam soil extracted water down to 200 cm soil depth. However, the major proportion of water was absorbed from 30 to 150 cm soil depth (> 80 %), while 0-30 and 150-180 cm soil layers contributed 7 to 10 % of total water use each during different seasons. The oilseed brassica extracted more water from all soil depths than chickpea. For a given value of soil water potential, oilseed brassica had lower value of leaf water potential, but higher degree of osmotic adjustment. The high degree of osmotic adjustment facilitated a greater extraction of water from all layers of soil profile by oilseed brassica than chickpea. However, a moderate degree of osmotic adjustment provided better seasonal water extraction pattern and improved productivity in long duration dryland chickpeas.

It is interesting to note that the soil water in deeper layers of profile was not fully exhausted in any growing season either by oilseed brassicas or chickpea (Table 6). Even in extreme drought year 1987-88, some soil water remained available below 90 cm soil depth after maturity of these crops in dryland areas. There was significant genetic variation for soil water use, particularly from sub-soil layers, both in oilseed brassicas and chickpea. Grain yield was proportional to the amount of water extracted from deeper layers of soil profile (90-180 cm soil depth) during reproductive phase of growth in oilseed brassica and chickpea. Thus, there is a need to select proper crops/varieties with proper rooting characteristics for rational use of available soil water during Rabi season for high crop productivity in dry lands.

(c) Plant Adaptations to Drought

The successful colonization of terrestrial environments by higher plants has occurred largely as a result of the evolution of wide range of phenological, morphological, physiological and biochemical changes/adaptations associated with water deficit conditions in a water limited environment. Characteristics that impose a limitation on crop productivity should be reversible if the stress is likely to be relieved. This suggests that if the rainfall probability increases during a crop's life cycle, radiation shedding and stomatal closure could be of greater benefit than a reduction in leaf area from leaf senescence or shedding. If a particular physiological or morphological character can be identified and shown to improve the drought resistance of the crop and if the character and yield are separately inherited, incorporation of the character into a high yielding line should improve the crop's yield under drought. This has been the basis of a scientific breeding programme for crop improvement of dryland crops by several workers in different countries. Also, the understanding of potential drought tolerant traits, their genetics and internal physiological consistency is essential for genetic improvement of drought tolerance in field crops.

Potential drought tolerant traits which could be beneficial over a long time scale in dry environment should include: crop phenology, osmotic adjustment, rooting characteristics, and assimilate transfer from vegetative plant parts to grains. There is good evidence that the traits are linked in strategies that vary from extreme dehydration avoidance to dehydration tolerance. Osmotic adjustment is a good example in this context. Osmotic adjustment behaves like a system and has its reflection and manifestation in the form of several measurable characteristics such as root growth, soil water extraction, leaf conductance, canopy temperature, continued photosynthesis/ growth and assimilate transfer to grains. The inheritance of osmotic adjustment in oilseed brassicas, chickpea and wheat suggests that this character seems to be under the control of few genes. The identification of QTLs for rooting characteristics and osmotic adjustment in rice will further aid the selection process and breeding for improving drought tolerance in field crops.

The moisture and heat stress are compounded in water deficit dry environment in rainfed eco-system. Same is true for susceptibility of dryland crops to frost. However, accumulation of sugar and other osmoles within the cells help the plants to tolerate low and high temperature stresses. The common manifestation of several stresses (drought, temperature, air, radiation) is linked to maintenance of water uptake and cooler canopy. Thus, the complex traits such as osmotic adjustment and root activity could be indirectly assessed by measurement of leaf water retention or through the non-destructive measurement of air minus canopy temperature difference (Ta-Tc) by infra-red thermometry in field crops (Singh *et al.*, 2011). The list of genotypes identified for potential morphophysiological characteristics in oilseed brassica, chickpea and wheat is detailed elsewhere (Singh *et al.*, 2003; c.f. Sanwal *et al.*, 2003). This information could be valuable in tailoring appropriate management and breeding strategies for further yield improvement under different situations of water availability in drought prone areas.

Fig 17: Interaction of Working Group with scientists and farmers in Mewat area

3.1.4 Other Efforts

- A comprehensive Mewat specific programme has been undertaken by Water Technology Centre of IARI in a cluster of villages through need based diversification and intensification for efficient use of water and other resources available with farmers. A similar programme has been operated by CCSHAU, Hisar and CASA, New Delhi for validation and adoption of conservation agriculture technologies through adaptive research project under

NAIP in farmer participatory mode.

- The Working Group visited operation areas of these projects and interacted with scientists and farmers (Fig 17). These efforts brought remarkable changes in diversification of area from field crops to horticulture and vegetable crops using micro-system of irrigation and adopting zero-tillage based conservation technology in wheat and other crops. Farmers also adopted preparation of quality vermi-compost, balanced use of fertilizers and TATA C Krishi –IT Module for on spot advice through mobile phones displaying photographs of crops for undertaking appropriate plant protection and other measures quickly for attaining higher productivity. Scientists also helped the farmers in livestock production to small land holders and land less farmers. Farmers have been benefited immensely through such direct interaction of scientists by improving the resource base and efficient use of water and other resources available with themof farmers. However, such programmes need replication to other areas of Mewat and south-west Haryana through active involvement of Departments of Agriculture and Horticulture.
- The scientists of RRS Bawal of CCSHAU have done good work on crop diversification, including resource conservation technology on mustard based cropping system. The mustard crop often suffers by infestation of *Orobanche* parasitic weed in this area. However, there is no effective control of this weed in mustard and other solanaceous crops. The research results suggest that such hot spots need a shift from mustard crop to castor or castor+ cluster bean or chicory (*Chicorium intibus*)+ mustard intercropping systems. Arid zone fruit crops such as bael and guava also suffer from wilt disease in this zone. Thus, there is a need of focussed research to control *Orobanche* and wilt disease in fruit crops, including development of frost tolerant varieties of castor to help the farmers.

View of Orobanche Parasitic Weed and a closed view

- The Woking Group also visited some villages around Hisar and interacted with scientists and farmers of water deficit dunal sandy areas. The farmers around Shyadwa village are growing strawberry successfully using fertigation and drip system of irrigation under plasticulture. Similarly, farmers around Bhalawas have diversified some area of rainfed field crops to ber cultivation under drip system through stored water in farm pond. They are also using roof harvested water to recharge their hand pumps for drinking purposes. Framers in these dunal areas are of the opinion that the installation of deep tubewell and their recharge through land shaping is far better option to conserve rain water and its reuse in life saving/protected irrigation in such harsher environment. They also demanded establishment of more units of processing of cluster bean, castor, strawberry and arid zone fruits supply of quality planting material and better linkages with marketing in south-west Haryana.

3.2 Diversification and Intensification of Production System

There is a need not only to increase the productivity of field crops in rainfed areas, but also to go for location specific diversification and intensification of production system in the arid ecosystem. The agri-horticulture, agroforestry and livestock production need special emphasis in this regard to sustain higher agriculture growth and livelihood security in rainfed areas. Inclusion of tree component with arable crops has been found to be remunerative. Arid fruit trees e.g. Ber, Aonla, Karonda, Phalsa and trees like Khejari (*Prosopis cineraria*) and Mahaneem (*Alianthua exclxa*) have been found very promising. Harvested rain water from 'kund/tanka/farm pond' can be used for establishment of agri-horticulture and agroforestry through drip irrigation during initial years of tree establishment. Even low cost dripers connected with the water tank on the back of camel have been found very useful in establishing saplings on the dunal sands at Balsamand (Hisar), Dry land Research Centre of CCSHAU, Hisar.

In addition to the availability of arable agriculture lands in rainfed eco-system, there is substantial area in the waste land category for utilization in multi-enterprize based agricultural activities in the state. The wastelands occupy 2.34 lakh ha which is about 5.3% of the geographical area in state. These lands are not being used to their optimum potential owing to adverse conditions like salinity, alkalinity, water logging, sand deposits, mining and industrial dumps. The districts of Mohindergarh, Jhajjar, Bhiwani and Hisar have sandy area of about 41 km^2, besides about 1.8 km^2 in Karnal, Palwal and Sonipat under waste lands. About 72 km^2 area is under waterlogged lands in Jhajjar, Mewat, Bhiwani, Sonipat and Rohtak districts, 93 km^2 area is under rocky wastelands in Mohindergarh, Rewari, Bhiwani and Mewat districts. These marginal areas can be put to productive use by appropriate policy framework followed by suitable conservation measures and planting of selected stress tolerant varieties of hardy fruit/tree species suiting different types

of wastelands. The need based diversification of horticulture, agroforestry and livestock in rainfed areas, including waste lands is briefly discussed in the following sections.

3.2.1 Horticultural crops

Horticulture crops have significant role in diversification, risk moderation, value addition and enhancing farm income in rainfed areas, especially in low productive land use system. Hardy fruit crops have better choice in these areas because of their perennial nature, deep root system and synchronization of fruit development period with rainy season. Large opportunities for expansion exist in rehabilitation of vast degraded and waste lands, common property resources etc in rainfed areas. Ample scope is also there to integrate horticulture with existing land use and cropping /farming systems, and especially where subsistence agriculture is practised owing to number of productivity and other constraints. Fruit tree based production system has several adaptation mechanisms to cope with rainfall uncertainties.

The area and production under horticultural crops has increased significantly over the last two decades (1990–2010) in Haryana, i.e. from 68,050 ha to 4, 15,930 ha (511%), and from 9, 02,040 MT to 51,41,271 MT (470%). However, to meet the increasing demand, the area coverage has to be stepped up. Haryana Government envisages increasing the area from 6.4% to 10% by the end of the next two plans. This projected growth is proposed to be achieved by area expansion in non-traditional waste lands and rainfed areas and by adopting suitable cropping systems and location specific cluster approach for value addition and better market linkages.

The rainfed arid zone conditions greatly favour development of high quality production in a number of fruits such as date palm, ber, pomegranate, citrus, fig (anjir), aonla, bael, grapes, tamarind and in vegetables such as cucurbitaceous crops and some medicinal plants. Khejri is a multipurpose tree for vegetable (sangri), fodder and fuelwood. In arid ecosystem of South West Haryana where rainfall is very low and climate, is very fragile, drought hardy fruit crops like aonla, ber, bael, pomegranate, anona, fig, phalsa, datepalm (khajoor), etc. can be a major component of farming system. The fodder from ber, khejri, ker (*Capparis decidua*) etc. can also be used as feed for small ruminant.

New clusters should be developed in areas which are unutilized, barren and undulating in south west Haryana for citrus, guava, bael and ber. The State's integrated model that encompasses orchard plantation, micro-irrigation (drip irrigation) along with fertigation, plasticulture and farm ponds is quite praiseworthy.

Table 7: Potential fruit crops suitable for arid regions in Haryana.

Climate zone	Districts	Potential crops
Arid	Rohtak, Jhajjar, Mewat, Bhiwani, Fatehbad, Sirsa	Lasoda (*Cordia dichotoma*), Ber (*Ziziphus mauritiana*), Ker (*Capparis decidua*), Khejri (*Prosopis cineraria*), Phalsa (*Grewia asiatica), Pillu (Salvadora oleoides), Karonda* (*Carissa carandas*), Datepalm (*Phoenix dactylifera*), Aonla (*Phyllanthus emblica*), Custard apple (*Annona reticulata*), photo/ kachari(*Cucumis pubescens*).
Dry Sub-humid	Panchkula, Ambala, Yamunanagar, Kurukshetra, Karnal	Loquat (*Eriobotrya japonica*), cape gooseberry (*Physalis peruviana*), cow pea (*Vigna unguiculata*), cluster bean *(Cyamopsis tetragonoloba*)
Moist Sub-humid	Panchkula, Ambala, Yamunanagar	Loquat (*Eriobotrya japonica*), cape gooseberry (*Physalis peruviana*), jamun (*Syzygium cumini*), dolichos bean (*Dolichos lablab*), cow pea (*Cyamopsis tetragonoloba)*
Semi Arid	Panipat, Sonipat, Palwal, Kaithal, Jind, Hisar	Bael *(Aegle marmelos)*, Jamun(*Syzygium cumini)*, Mahua (*Madhuca longifolia*), wood apple (*Limonia acidissima*), pomegranate (*Punica granatum*), aonla (*Phyllanthus emblica*), custard apple (*Annona reticulata*), drumstick (*Moringa oleifera*), Indian almond (*Terminalia catappa*), Khirni(*Maricara hexandra*), guar (*Cyamopsis tetragonoloba*), faba bean (*Vicia faba*)

Source: Chadha *et al.,* (2012)

The clusters should ensure integrated development of horticulture by providing common facilities and for supply of quality planting material, value addition of produce and post harvest management, including marketing linkages. Some of the potential horticulture crops suitable for different parts of Haryana are listed in Table 7 (Chadha *et al.*, 2012).

The utilization of plastic mulch along with drip line underneath has been very successful in reducing soil evaporation and water use by weeds. High value crops like strawberry followed by another crop of chillies under the same plastic cover used as soil mulch has been found very remunerative in water scarce areas of Haryana with almost total control on soil evaporation which is about 60-65% of total ET in this region. The high degree of water economy can also be achieved by fitting drip lines under plastic mulch for growing several fruit and vegetable crops. The farmers in water deficit Mewat area are transporting conserved water through underground pipes from Aravali hills to grow fruits and vegetable crops by drip and plasticulture.

3.2.2 Microsite Improvement of Soil Profile

The soil of dry lands are generally characterized with low level of organic matter, weak to moderate profile development, gravels, coarse to medium texture with shallow soil depth, poor fertility status and poor biological activity. Better survival and establishment of fruit trees in rainfed and dry lands requires proper microsite improvement in the pits apart from providing life saving irrigation in summer season during initial years. Microsite improvement consists of soil profile modification by way of increasing volume of pit with good rooting medium such as filling pits with pond silt, FYM etc for better establishment of fruit plants under adverse growing condition. *In-situ* moisture conservation with the profile modifications, mulching, trenching, inter-terrace land treatments and *in-situ* run-off harvesting through micro-catchments, catch pit, V-ditch, etc are best for growing fruit trees. The *ex-situ* rainwater harvesting technologies including jalkunda, dugout ponds, tanks, nala bunding, subsurface dams/ barriers, etc help in providing life saving irrigation.

The growers should be trained in land reclamation practices and choice of suitable field/fruit/tree crops to be grown as sole or in agri-horticulture/agroforestry systems in the region. Pocket planting should be adopted for perennial fruit crops. Only early maturing summer dormant fruit crops need to be selected for extreme environmental conditions. Use of drought tolerant rootstocks needs to be promoted for grafting purposes. Subsidies should be provided to farmers for growing horticultural crops in marginal lands. There should be provision for replanting and gap filling so as to have a proper plant population over a three to four year package, instead of one time subsidy as practised under NHM. Research institutes like CSSRI, Karnal, CSWCRTIRC, Chandigarh and CCS HAU, Hisar should be involved for developing technologies to mitigate edaphic problems and develop location specific crop varieties suited for different areas. Agriculture and Horticulture Departments should be involved to make provision for procuring soil amendment for its supply to growers at subsidized rates. More emphasis should be laid on proper soil configuration and on-farm preparation of compost using rock phosphate and effective microbial consortia developed at CCSHAU, Hisar and IARI, New Delhi. During initial years of plantation, suitable intercropping of legumes, spices and medicinal plants should be promoted to help the resource poor farmers.

To promote fruit crops in rainfed areas of Haryana, the following suggestions have also been made:

- *In–situ* water harvesting should be encouraged in micro-catchment for individual tree by proper soil configuration.
- Pitcher irrigation or use of double walled pots needs to be adopted to establish fruit plants under dry/harsh conditions.
- Facility for life saving irrigation should be provided by strengthening the scheme on construction of community ponds/jalkund in dry and drought prone areas. Jalkund using plastic has proved very useful in central India for life saving irrigation which can also be validated and adopted in Haryana.
- In perennial fruit crops, where feasible, *in-situ* grafting should be encouraged.
- For inter cropping in orchards, suitable varieties of annual vegetables or short duration legumes/fodder crops and medicinal crops should be selected based on their ability to endure the dry period and utilize available rain/irrigation water more efficiently.
- Planting windbreaks around field boundaries should be encouraged in areas frequented by strong windstorms to control soil erosion and moderate the micro-climate.
- There is also need to provide subsidy for fencing/live fencing to control trespass of animals under NHM for promoting agri-horticulture in rainfed areas.

3.2.3 Vegetable Crops

Emphasis should be laid on studies to identify/develop vegetable genotypes that can profitably perform under moisture, temperature and other stress conditions. Cultivation of vegetable crops like cluster bean, cowpea, pea and cucurbitaceous vegetables (water melon, phoot, kakari (*Cucumus setivus*)) needs to be encouraged in water deficit areas. Brinjal, Sugarbeet, spinach, bakala (*Vicia faba*) have been found suitable under mild saline water conditions. The addition of organic matter, gypsum and use of micro-irrigation have shown better performance of vegetable crops grown in salt affected areas or irrigated with brackish water (Phogat *et al.*, 2010). The sulphate dominating salinity is less damaging than chloride dominating salinity to vegetable crops. Several varieties of vegetable crops like brinjal, spinach, sugarbeet, cabbage, carrot, cauliflower, radish, tomato and turnip suitable for growing under high/low temperature and salinity conditions are listed by Phogat *et al.,* (2010) and Chadha *et al.,* (2012).

Protected cultivation structures are also useful for combating both biotic and abiotic stresses that limit the productivity and quality of vegetable crops. The low cost, medium cost semi-automated or high cost automated polyhouses can be used depending upon the need, besides the plastic low tunnels or shade-net houses. Low cost transparent plastic tunnels could also be used directly in the fields to protect young seedlings of cucurbits from frost for early crop promotion. These structures have several uses such as producing off-season vegetables, flower and vegetable nursery, early crop of vegetables, extending growing season and production in cold season. Different hi-tech interventions like micro-irrigation, fertigation, plasticulture, soilless culture, automation and intelligent computer programming can also be integrated with this system depending upon requirements. Proper rain water harvesting and storage structures, water saving devices and selection of proper vegetable crops alone or in combination with fruit trees would be of utmost importance. Pitcher farming has been found promising for growing cucurbitaceous vegetables in rainfed areas. Well designed polyhouses can also be used for rainwater harvesting in storage structures and using it for irrigation purposes. Farmers in Mewat and other areas have developed their own devices for carrying conserved water through underground pipes from 3-4 km distances for irrigation to grow high value vegetables and fruit crops in poor quality lands.

Large scale motivation and training to educated unemployed youths and farm women in the field of protected cultivation need to be launched in the State. Centre of Excellence in Vegetables (CEV), Gharaunda should have hostel/accommodation facilities for trainers and visiting farmers. Similar facilities are being developed at Centre of Excellence for Fruit Crops in Sirsa district to help farmers of the state.

3.2.4 Agroforestry

Haryana being predominantly agricultural state was having only 2.86% forests until 1960s. However, despite enormous investments and efforts by the State Government, the forestry cover has increased to only 3.52% of total geographical area. Per capita forest area in the State is 0.007 ha against the national average of 0.08 ha. The State has already formulated forestry policy with an ultimate goal to bring 20 % area under forest 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, canals, drains, field boundaries etc should be given priority. To give a 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 forest cover using remote sensing and GIS technologies. Also forestry research and education should be greatly strengthened in the 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.

(a) Agroforestry for Southwest Haryana

The Western zone of Haryana mainly consists of the arid-tract of the State and is full of sand dunes. Permanent vegetation is essential for its stabilization. There is huge scope of introduction of agroforestry component for sustainable production of food, feed, timber, fodder etc. in this area. Some multi-purpose trees like Khejari (*Prosopis cineraria*), Ber *(Zizyphus spp*), Neem (*Azadirachta indica*) and Senjan (*Moringa species*) can do very well even during drought years. Provisioning of fuel, fodder and other minor tree produce are also very important for farmers, especially the small and marginal ones. Based on research results, ardu/ Mahaneem (*Ailanthus excels*) is a good choice for inclusion into plantation programmes on account of highly nutritious leaf fodder, short rotation (9-10 years) and yields of several minor forest produce like particle boards besides firewood. Hingota (*Hardwickia binata*) is another excellent choice on account of leaf fodder as well as timber value on a longer rotation (20+

Table 8: List of suitable tree species having fodder value and may be incorporated in various agroforestry systems in rain fed regions of Haryana

Name/Species	Product			Area/ region of the state where species can be used
	Leaf Fodder	Fuel	Timber	
Kala siris (*Albizia amara*)	8	7	4	Semi arid Sandy Plains of South and South West Haryana
Kardhai (*Anogissus latifolia*)	6	7	3	Semi arid Sandy Plains of South and South West Haryana
Salai guggul (*Boswellia serrata*)	7	4	3	River Plains of Haryana
White crossberry, Phalsa cheery (*Grewia optivia*)	8	6	0	Southern most part of Haryana
Indian Elm, Papri *(Holoptelea integrifolia*)	7	4	3	Foot hills of Aravallis and Siwalikas
Ber (*Ziziphus mauritiana*)	8	8	4	Semi-arid Sandy Plains of South and South West Haryana and southern arid part
Jharberi (*Ziziphus nummularia*)	9	8	3	
Desi ber				
(*Ziziphus rotundifolia*)	9	8	3	

(*on a scale of 1-10; higher the value, better is the utility)

years). Both these trees species may be planted on farm bunds, farm land with arable crops/ fodder crops, forest lands under JFM as a component of silvipastures.

The important tree species grown naturally in rainfed zone of the State are: Babul (*Acacia nilotica*), Rohida (*Tecomela undulate*), Israeli Babul (*Acacia. tortilis*), Bael (*Aegle marmelos*), Desi siris (*Albizia lebbek*), Ardu (*Ailanthus excels*), Neem (*Azadirachta indica*), Kair (*Capparis decidua*), Phog (*Colligonum polygonoides*), Vilayti babul (*Prosopis juliflora)*, Khejri (*P. cineraria*), Jamun (*Syzygium cuminii*), Bada Peelu or Jal (*Salvadora oleoides*), Ber (*Zizyphus mauritiana*), Jujube (*Z.jujuba*). A list of other suitable tree species having fodder value and also as agroforestry species both for southwestern and northeastern Haryana is presented in Table 8.

(b) Agroforestry for Salt-affected Lands

Salinity and sodicity are very common and occur in pockets in south western parts of Haryana. The choice of species for sodic soils is determined by the ability of trees to survive and withstand adverse high excess sodicity. There are very few wild species which are able to grow on highly sodic soils (pH>10). In order to rehabilitate salt affected soils, appropriate tree planting techniques and choices of trees are very much essential. In sodic soils, a hard pan of Kanker layer of calcium carbonate is generally found at a depth of 1.25 to 1.5 m. This layer acts as a barrier for root penetration and makes tree plant roots to coil. The hard layer, therefore, needs to be broken before the plantation of suitable tree species is done. Auger holes technique is suitable method of making plantation in sodic soils. Generally, 15-20 cm dia. and 150 to 180 cm deep digging is done in sodic soils with the help of auger. The auger hole is filled with original soil, 3 kg gypsum, 8 kg FYM and a small quantity of $ZnSO_4$ and insecticide to take care of termites. Sodic soil tolerant tree species with 6-9 months old sapling may be planted in the auger hole followed by irrigation. For making plantations in saline soils, ridge-furrow method is found to improve growth and survival of plant species. This method reduces salts and creates favourable low zone of salinity below the root zone soil in furrow owing to upward and lateral movement of salts. Creation of such niches favours the establishment of young seedlings of trees. Moreover, such a system is suitable for undertaking large-scale plantations. The agroforestry section of CSSRI, Karnal has identified suitable tree species for salt affected areas.

There are areas in south western Haryana (Mewat, Bhiwani) which are entirely rainfed with very high saline groundwater. This area should be covered with block plantation of *Prosopis juliflora* by undertaking a pilot project by Department of Forestry of CCSHAU, Hisar through holistic approach from plantation, harvesting and value addition (pods for fodder, lac production, charcoal making, electricity generation through gasification, inoculation with lac insects etc). CSSRI, Karnal has developed 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.

(c) Agroforestry for Combating Water Logging Through Bio-Drainage

In waterlogged areas near canals, the planting of cloned Eucalyptus on bunds (one meter height) on farmer's field have proved very useful. This not only controlled rise in water table but also helped in substantial revenue generation. Farmers harvested 34 t/ha fresh aerial biomass and 12.3 tones root biomass per ha from 5 years and 4 months old plantation. The strip-plantations sequestered 15.5 t/ha carbon (Jeet et al., 2011). Benefit-cost ratio of the first rotation of strip plantations (excluding crop yield) was 3.5 : 1 and it would be manifolds for next 3 to 4 rotations due to negligible cost of coppiced Eucalyptus. Wheat yield in the interspaces of strip-plantations was 3.4 times than that in adjacent waterlogged areas without plantation. It was mainly because of lowering of the water table and improvement in soil properties. High density plantation has been one of the main reasons for failure of Eucalyptus in Haryana, which is found to affect crops adversely. However, new clones of Eucalyptus available now are being preferred by the farmers in water logged inland basin of Haryana.

(d) Agroforestry for Northeast Haryana

In North east zone, Ambala, Yamunanagar, Panchkula, part of Sonipat, Gurgaon, Faridabad and Rohtak experience rainfall of 500-1000mm. District Yamunanagar is a bowl of Poplar in Haryana, where 18.8% cultivated area is under boundary plantation and only 4.8% under block plantation. Under this practice trees are planted on field boundaries or along irrigated channels either on one side or on both sides of the channel. The farmers generally plant trees at a very close spacing.

Due to leaf fall in winter, there is relatively less shade over winter crops in such boundary plantation. Such plantations need further promotion by selecting shade tolerant suitable field crops for agroforestry to further benefit the farmers.

(e) Agroforestry for Eroded Lands

Woody species found growing in eroded habitats may find priority in afforestation program. Following species viz., Desi babul (*Acacia nilotica*), Reonja (*A. leucophloea*), Neem (*Azadirachta indica*), Desi siris (*Albizzia lebbeck*), Desert date (*Balanites roxburghii*), Shisham (*Dalbergia sissoo*), Bamboo, Bans (*Dendrocalamus strictus*), Nutan (*Dichrostachys cineria*), Safeda. (*Eucalyptus spp*), Wood apple or Kaitha (*Feronia limonia*), Karanj (*Pongamia pinnata*), Vilayti babul (*Prosopis julifiora*) and Ber (*Ziziphus mauritiana*) have been found to adapt easily in the eroded soils of Shivaliks. Among

Table 9: Livestock population of Haryana (in millions)

Species	Years			
	1992	1997	2003	2007
Buffalo	4.37	4.82	6.04	5.95
Indigenous Cattle	1.72	1.55	0.97	0.99
Crossbred Cattle	0.42	0.85	0.57	0.57
Goat	0.80	0.97	0.46	0.54
Sheep	1.04	1.28	0.63	0.60
Poultry	8.58	9.23	13.62	28.79

grasses, Marvel grass (*Dichanthium annulatum*), Buffel grass or Anjan grass (*Cenchrus ciliaris*), Rattail grass (*Sehima nervosum*), Indian Bur grass (*Tragus biflorus*), Musal grass or Machuri (*Iseilema laxum)*, Dhoob grass (*Cynodon dactylon*) and Munj grass (*Saccharum munja*) flourish well in such highly eroded lands. After protecting from grazing, silvi-pastoral system involving the above-mentioned tree and grass species and introducing legumes such as Clover (*Stylosanthes, Alysicarpus*), Ban methi or sweet clover (*Melilotus*), etc may be developed with great success. High value medicinal species such as Aloe or Ghritkumari, or Korphad (*Aloe vera*), chandrasoor (*Lipidium sativum*) and drumstick can easily be blended in these habitats. These may be promoted through Integrated Watershed Management Programmes being implemented on a large scale in the state.

3.2.5 Livestock

Haryana is endowed with rich livestock genetic resources. The State is well known for the best "Murrah" breed of buffalo and cattle breeds, namely Hariana and Sahiwal. It serves as source of on-farm employment to women, landless and small holder farmers. For achieving ever green revolution, livestock, poultry and fisheries having potential for higher growth, need more focus including funding and policy support. In livestock rearing, about 70% expenditure is on feeding alone. Hence, balanced nutrition, both quantitatively and qualitatively is of paramount importance. There is a need to start Live Stock Mission, Pashu Palak Yojana (PPY) similar to RKVV and Pashu Palak Credit Cards (PPCC) similar to Kisan Credit Cards through appropriate institutional and policy intervention to

further support the livestock farmers (Madan *et al.,* 2013).

The Livestock Mission should lay down programs for the small ruminants (goats, sheep, rabbits), pigs and poultry to keep those farmers whose livelihood options are better served through these species. The Mission should also facilitate the meat industry through promoting the meat of small ruminants, pigs and poultry in a hygienic and safe mode. Such Mission should also examine the issue of including the benefit of micro finance loans, insurance, input allocations (energy, water, machinery, fodder seed etc.) to livestock holders at par with agriculture sector for increasing the total agriculture and GDP growth of the state.

(a) Meeting the Feed and Fodder Requirements

There is a huge gap between demand and availability in fodder and feed requirement. At national level there is a deficit of about 40%, 36% and 57% between demand and supply of dry fodder, green fodder and concentrate, respectively (Madan *et al.,* 2013).

Unfortunately, fodder seed production and supply is a grey area between the Department of Animal husbandry and the Department of Agriculture. Also fodder seed is a low priority for Haryana Seed Development Corporation (HSDC). Another unfortunate concern is that fodder seed is invariably not entering in to seed production chain. Hence, it is proposed that either HSDC should undertake defined responsibility or establish on priority a Fodder Seed Development Corporation by involving the State Agricultural University / Veterinary University and Government Livestock Farms for the production of breeder and foundation seeds. At the same time, there is an urgent need to involve progressive farmers and the private seed sector to produce certified seeds of improved varieties/ hybrids of fodder crops, which must be linked with specified indents confirmed in advance by the Department of Animal Husbandry through a Seed Rolling Plan. In such cases, subsidy for seed production should also be made available to the fodder seed producing farmers and the private seed companies.

In rainfed areas the fodder production during post-rainy season is possible only through supplemental irrigation by water harvesting in rainy season in farm ponds or water recharge in shallow tubewells. However, on conserved soil moisture in the soil profile it is possible to grow *rabi* season fodder / fodder cum grain crops of *Brassica napus* and *Brassica carinata,* oats, thornless safflower and barley through proper inter cropping and cutting management. The productivity of these crops could be increased if supported by minimum supplemental/life saving irrigation through water harvesting in farm ponds. The crop of chandrasoor *(Lipidium sativum)* could also be tested and validated for its adoption in Haryana as this crop requires less watering but its seeds are very useful to increase milk production in cattle. There is also a need to promote multipurpose trees, silvipastoral system and cactus to supplement fodder requirement of cattle, camel and small ruminants as described in the following section.

(b) Promotion of Silvipasture System

The fodder production may be increased through silvipasture development under joint forest management schemes. Incorporation of suitable range grasses and legumes in association with trees / shrubs having fodder value will be of much value in rainfed areas of the state. A list of such suitable grass and legume species is given below in the table :

(c) Introduction of Non-conventional Forages

Some of the non-conventional trees/shrubs can also be promoted for forage option in central and southern Haryana.

***Prosopis juliflora* pod as Fodder:** *Prosopis juliflora* (*Vilayati Kikar*) is distributed in entire central and south west Haryana and reports suggest its ingression in foot hills of Shivaliks. Studies have indicated that *Prosopis juliflora* can serve as a very good source of fodder on account of its pods if managed properly. The pods are very rich in protein and carbohydrate, thus a very good fodder for cattle and small ruminants. The need is to organize the pod collection, its threshing and value addition. A simple technology of cheaper and balanced concentrate feed mixture has been developed by CAZRI utilizing *Prosopis juliflora* pods along with other locally available ingredients. This balanced ration has significantly increased

Grasses	Legumes
Buffelgrass (*Cenchrus ciliaris*), Dhamangrass (*Cenchrus setigerus*), Sewan grass (*Laisurus sindicus*), Sudan grass (*Panicum antidotale*)	Butterfly bean or Gokarni (*Clitoria ternatea*), *Stylosanthes hamata*, Cow pea (*Vigna unguiculata)*

milk yield and also lactation length at a cheaper cost. In Haryana, there is very good scope of dissemination of this technology in 15 districts of south western part of the state viz., Bhiwani, Faridabad, Fatehabad , Gurgaon, Hisar, Jhajjar, Jind, Mohindergarh, Mewat, Palwal, Panipat, Rewari, Rohtak, Sirsa and Sonipat.

In Shiwalik region important fodder trees which should be promoted are, Bael (*Grewia optiva*), Khirak *(Celtis saustralis)* and Kachnar (*Bauhinia variegate*). These trees are highly adaptive to grow on the bunds of the fields as they have high ability for coppicing and can stay as shrubs.

(d) Promotion of Cactus as Fodder

Cactus (*Opuntia ficus indica*) is effectively being used in several countries as a useful fodder supplement. Although, these materials were introduced in India in 1970 under Indo-US collaborative research program, the interest on its use as fodder and fruit has grown in the last couple of years. At CAZRI animal feeding trials of chaffed thorn less cactus pear pads have shown good acceptability and palatability, by small ruminants and cattle. Cactus could also improve rumen fermentation and consequently enhance intake and or digestion of low quality roughages. However, it must be combined with other foods to complete the diet, because they are rich in carbohydrates and calcium, but poor in proteins. The combination of cactus and urea represents a viable option because it provides adequate energy and sufficient nitrogen for the microorganisms in the rumen. The high concentration of soluble carbohydrates in cactus facilitates the incorporation of nitrogen into microbial protein, which is the main source of metabolizable protein for the host animal. In this manner, the protein content of cactus, which is normally insufficient for adequate animal performance, may be supplemented with protein rich ingredient. Cactus cladodes could be used to replace partially concentrate feeds without causing detrimental effects on digestion, production and reproduction of ruminants. The use of cactus as an animal feed substantially reduces water consumption as a result of its high water content. Thus, the introduction of Opuntia spp. in wasteland development projects, agroforestry schemes, farm bunds etc. will benefit the farming communities in the arid zone of the state on account of reduced feed costs.

(e) Generating Income from Unproductive Farm Animals

Mewat region of the State can be notified as "Meat Development Zone" supported well by institutional infrastructure and programs aiming at meat production, especially from male buffaloes, goats, sheep and poultry. The existing slaughter house near village Parigaon can be converted into a modern abattoir. Once meat processing is undertaken on modern lines, Haryana can target for meat exports to Middle-East and adjoining countries for fetching higher income to the livestock farmers. It will also ensure inclusive growth in Mewat region.

3.2.6 Organic Farming

The indiscriminate use of agro-chemicals without organics or recycling crop residues in cereal based cropping system has resulted in deterioration of hydrological and biological properties of soils, poor carbon content, multiple nutrient deficiency and inturn poor soil health, decline in factor productivity and increase in cost of cultivation. Organic agriculture has a high potential to arrest soil degradation and counter climate change damages by higher carbon sequestration and increase the agro ecosystem's resilience to moisture stress under unpredictable rainfall patterns. Despite proven benefits of application of organic matter to sustain high crop yields and improve biological and hydrological properties of soils, organic matter management and recycling has been lacking, especially in rainfed areas.

Studies of CSWCRTIRC, Chandigarh have shown that organic farming using appropriate bio-fertilizers with compost/ vermi-compost under different cropping sequence resulted in not only equivalent crop yields and net returns but also better soil health as compared to conventional farming. A survey of the organic farms in the region also showed a higher crop diversification, productivity and improved soil health as compared to conventional farms. However, the major problems faced by organic farmers were identified as lack of proper technical knowledge, poor incentives and certification and marketing of organic products.

The Govt. of Haryana has initiated massive programme of solid waste management for generation of biogas, organic manure and providing clean environment even in small towns. Department of Horticulture, Govt. of Haryana has also appointed service providers for conversion of soils for organic horticulture using micro-irrigation system. NABARD is also helping organic farming under Rural Innovation Fund (RIF).

During the 11th Five Year Plan under the centrally sponsored initiative 'National Project on Management of Soil Health and Fertility', a series of soil testing laboratories have been established. However, addition of organic matter to soils has not received required attention 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 for enhancing and maintaining soil organic matter.

The following aspects need to be addressed in order to enhance the efficiency and productivity of organic farming systems:

- Soil organic matter content is the single most important factor to improve hydrological, physico-chemical and biological properties of soils. Thus, there is a need for developing and promoting agricultural practices which can contribute for enhancing and maintaining soil organic matter.
- There is a need for fine tuning and adopting the conservation agriculture based technologies, recycling of crop residues, inclusion of green manure and legumes in crop rotation, addition of organic manure (FYM, compost, phospho-compost, Safal-Compost, vermi-compost, NADEP etc), biofertilizers and their proper dose of application under different cropping system and adaphic conditions.
- Organic farming is knowledge based rather than input based and need encouragement through consistent strategic research and development for its adoption under specific production system for improving quality of soil and food products.
- There is a need for quantification of carbon sequestration under different production systems, agroforestry, organic farming and to help the farmers from benefit of carbon trading in future.
- Natu-ecofarming also needs proper testing and validation to enrich soil with high organic matter and micro-flora for helping small land holders.
- The potential of MGNREGA could be utilized for the preparation of various types of compost and other formulations of organic manures, biopesticides etc at Panchayat or community levels in PP mode.
- Organic manure/composts are complete fertilizers which improve organic carbon content, hydraulic and biological properties of soils and thus can save foreign exchange on imported chemical fertilizers. Therefore, farmers should be provided enough subsidies on organic manure to support organic movement.
- Improvement of certification procedures and marketing of organic produce to make them farmer friendly.
- Providing suitable incentives to farmers during initial years for adopting eco-friendly farming methods.

The development and implementation of technology must be aimed at making farmer self- reliant with minimum dependence on external resources, especially in rainfed areas. The development of efficient organic farming technologies and their successful implementation in rainfed areas are the sustainable solutions to restore and enhance productivity while promising higher resilience to moisture stress caused by unpredictable rains under changing climatic conditions.

3.2.7 Integrated Farming System

Traditionally, Indian farmers are adopting integrated farming system approach for their livelihood. With industrialization, farmers were forced to become commodity farmers depending on their location. The marketing forces and agro-climatic conditions are primarily responsible for the existence of particular crops and cropping pattern in certain areas. The industrialization and procurement of certain crops with MSP for PDS and mechanization have also played a major role in farmers' decision making for growing particular crop or adopting a particular farming system. Integrated approach, however, has several distinct advantages like:

- Security against complete failure of the crop based system.
- Minimization of dependence on external inputs.
- Optimum utilization of farm resources and family labour in multi-enterprized based system.
- Efficient use of natural resources i.e. land, water, organic waste, vegetative cover and climate.

There is a lack of research work in developing rainfed farming system models for different agro-ecosystem in the state.

Support Strategic Crosscutting Research and Feed into Production Systems Research

Strengthening location specific research is fundamental for 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 are also the key factors for better understanding of the extension domain of technologies. Both social and biophysical scientists will need to be involved in Farming System adaptive research in farmer participatory mode. Social science research will need to be strengthened to enhance capacity for farming system research at the HQ, regional research stations and KVKs of CCSHAU.

There is a need to develop functional units of secondary agriculture and agrobased enterprizes using holistic approach of watershed alongwith value addition and processing of produce at the HQ, RRSs and KVKs of CCS HAU to train the agricultural graduates, field functionaries and rural women and youth on regular basis for more employment and income generation activities. Some of the farmers have also developed successful models of IFS on their own with some scientific support by combining crops with livestock, agri-horticulture, agro-forestry, silvipastoral system in different water sheds (Bunga, Sukhomajari etc) along with value addition of produce for better utilization of resources and generating higher employment and income. However, more systematic adaptive research work is required by involving the RRSs and KVK's to develop location specific models of IFS to help the stakeholders in the rainfed areas of the state.

CHAPTER - 4

PRESENT STATUS OF DEVELOPMENTAL PROJECTS

4. 1 Current Efforts

A number of government initiatives, policies and programmes directly and/or indirectly address management of natural resources and development of rainfed areas. A variety of programmes/schemes have been initiated by different Ministries/Departments ranging from single component/commodity based sectoral scheme to integrated approach of watershed development. Some important programmes like flagship programme of Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), Rashtriya Krishi Vikas Yojana (RKVY), National Horticulture Mission (NHM), Artificial Ground Water Recharge, Artificial Recharge to Ground water through Dug wells, Repair, Renovation and Restoration of Water Bodies, and Backward Region Grant Fund (BRGF) are directly linked to agriculture for benefiting the stakeholders in rainfed areas.

4.1.1 Watershed Management - A Vehicle for Rainfed Area Development

Initially started as soil and water conservation programme, watershed management has undergone many paradigm shifts over the years. This process of agricultural and rural development for enhancing productivity and livelihood has travelled a long way from initial protection and conservation oriented piecemeal/sectoral approach of soil and water conservation to restoration of degraded areas for biomass production, eco-restoration, farming system and income generating activities. Earlier generation of watershed programmes were mostly confined to biophysical aspects, viz. contour bunding, check dams, afforestation etc. but subsequently, participatory empowerment of communities, transparency, the social and innovative institutional issues came into prominence. Of late, the focus is shifting towards convergence, livelihood security and income generation through watershed development.

Watershed programme in Haryana is being implemented mainly by three agencies/departments; Forest Department in the forest area, Rural Development and Panchayati Raj Department in the wastelands of Panchayat & Community lands and Agricultural Department on cultivable waste lands. Many programmes/

projects have been implemented in the past by these agencies. Some of the programmes implemented in the state during the last more than four decades include DPAP, DDP, Flood Prone River (Sahibi), Sub-mountaneus schemes of Soil & Water Conservation, Food for Work Programme (FAO), European Union Watershed Project in Arravalli & Community Forestry Project in Shivalik, Social Forestry, Integrated Watershed Development Projects (World Bank Aided), Integrated Wasteland Development Projects (IWDP), Flood Prone River, (Ghaghar) Schemes of Shivalik, Mewat Development Board, Shiwalik Development Board, National Watershed Development Project for Rainfed Area (NWDPRA) etc. Besides, national flagship program like MGNREGA is spending its funds on rainwater harvesting and Natural Resource Management (NRM) related activities for creating durable assets to build production and livelihood system for sustained income and employment.

In rainfed areas, different soil and water conservation structures were adopted on the slopes namely, crate wire structures, earthen gully plugs, masonry cement structures, small stone check dams, sub-surface dams, village tanks/ponds and water harvesting structures (large and small) under different sponsored schemes. The State Govt. also replicated a number of these measures, which were further adopted by the farmers. Rainfed crops demonstrations were also laid out. These demonstrations included use of improved variety seeds, balanced fertilization, *in-situ* moisture conservation, line sowing and other improved agronomic practices, including plantation of mango, guava, citrus, ber, plum, peach, aonla etc. Silvipasture land use system was adopted in private, non-arable and community waste lands.

All these projects have shown positive results inspite of a few failures. This programme addresses all the 5 Js issues related to Rainfed farming like land (*Jamin)*, Forest (*Jungle)*, Water(*Jal)*, Climate (*Jalvayu)* and living beings (*Jan)*. Watershed works not only to reduce soil loss, increase water conservation, enhance recharging but also reduce the flood damage be-

Status of coverage under the watershed programmes in Haryana	
Total geographical area	44.21 lakh ha
Area available for watershed development	19.41 lakh ha
Area treated or sanctioned so far	10.17 lakh ha
Area yet to be treated	9.24 lakh ha

sides increasing the productivity of the area. Comprehensive assessment of watershed programmes in India has shown increase in agricultural productivity by about 35% based on the findings of Meta analysis. Impact evaluation studies of watershed programmes undertaken by a number of agencies have shown several benefits of watershed development approach, the important ones are:

- Increase in cultivated area
- Increase in surface storages, and recharge of ground water aquifers
- Reduction in runoff and soil erosion
- Increase in cropping intensity
- Change in cropping pattern leading to higher value crops
- Increase in agriculture productivity, including milk yield of livestock
- Rise in overall bio-mass production in the watershed
- Improved employment & livelihood security and
- Reduction in rural and urban migration of cattle and human beings

However, during the interaction of working group with farmers around Hisar, it emerged that the farmers are demanding recharge of the ground water through community borewell rather than storing the same on soil surface ponds to minimize evaporation and use it in life saving irrigation.

Drivers for Rainfed Area Development

- Enhanced investment required for research and development
- Convergence across the programmes and departments
- Introduction of location specific cropping and farming system
- Improvement and value addition of coarse grain cereals
- Special attention on guar, castor, mustard, tree and livestock based production system
- Strengthening of adoptive research
- Development of market and institutional linkage
- Farm mechanization

The Integrated Watershed Management Programme (IWMP) was started in the country in 2009-10 in accordance with the Common Guidelines for Watershed Development Projects, after merging erstwhile DDP, DPAP and IWDP. However, its implementation in Haryana started only in 2011-12 onwards. Under this programme, the area of only those watersheds are selected where rainfed area is predominant. So far in Haryana IWMP has started in the thirteen Districts of the State as per details given in the Table 10.

4.2 Need for a Paradigm Shift

It has been observed that even with the cumulative policy neglect and low investments, rain-fed agriculture contributes significantly to the state/national economy. Meeting the future demand for food grains and other agro based products would require a step up to boost the growth of food production and need based diversification and intensification where rain-fed agriculture has to play a major role. Therefore, a breakthrough in research and development of rain-fed agriculture is essential for poverty alleviation, livelihood promotion and food security in Haryana.

4.2.1 Addressing Integrated Approach for Livelihood Security

A paradigm shift is required for addressing the rainfed livelihoods because livelihood strategies in rain-fed areas are dependent on a mix of agriculture, livestock, horticulture, agroforestry, and alternate income generating activities. The livelihoods of the rural poor in rain-fed areas are based on a complex interplay between humans, rainwater, common- public-private lands . This calls for combining natural resource conservation and management goals with productivity, carrying capacity and livelihood augmentation by using a holistic and integrated approach.

Natural resource conservation and management and its sustainable use for enhanced productivity and livelihood is to be seen in unison. Programmes and policies for rainfed farming should therefore address the issues related to convergence and integration, multiple livelihood options, equity and equality (from gender perspective), and vulnerability to climate change, besides more location specific intensive research efforts in rainfed crops and livelihoods. Water management in rainfed areas, be it *in-situ* soil moisture or surface water or recharged groundwater, assumes highest priority to increase rain water productivity. Convergence across the programmes and departments is a matter of priority for reviving rain-fed areas. Shift is also required from the present approach of single commodity to location specific mixed cropping and farming systems intensification approach, besides improvement and value addition of coarse cereals and cash commodities like guar, mustard, castor, including trees and

Table 10: Integrated watershed management programmes in rainfed dominated districts of Haryana.

S. No.	District	No. of Projects Sanctioned	Project Area (ha)	Estimated Cost (Rs. In Crores)
1.	Bhiwani	6	23766	28.52
2.	Hisar	7	24944	29.93
3.	M/garh	7	27898	33.48
4.	Rewari	6	25100	30.12
5.	Ambala	7	26482	31.78
6.	Panchkula	7	26020	31.22
7.	Yamuna Nagar	7	25321	30.38
8.	Rohtak	2	10061	12.07
9.	Sonepat	1	5660	6.79
10.	Jhajjar	3	14819	17.78
11.	Gurgaon	3	10921	13.11
12	Mewat	2	9056	10.87
13.	Palwal	2	11352	13.62
Total		**60**	**241400**	**289.67**

Source : IWMP Haryana

livestock based produce in rainfed areas.

4.2.2 Location Specific Solutions/Interventions

Focus of research should be on finding technological interventions/solutions to the problems specific to a given situation and location in view of large variability in natural resource base. Better understanding of natural resource variability, their potential, limitations and associated use and management issues including socio-economic base are fundamental to define technological needs and options for sustainable use of resources available with the farmers in rainfed areas.

4.2.3 Need for Strengthening Adaptive Research

Defining and promoting integrated solutions calls for scientists from a range of disciplinary background to work together with farmers, adopting and refining resource management and connected productivity issues in participatory mode. Adaptive research at present is the most critical systemic gap in understanding and finding solutions in rainfed areas. There is an urgent need to put in place a strong program of adaptive research involving natural resources management and production system specialists, including socio-economists at the Zonal/Regional Research Stations of CCSHAU. The involvement of LLRUVAS and KVKs in such research strategies will be a welcome step. This will also provide an opportunity to upscale the agro-technological packages with indigenous knowledge base accumulated by farmers in the local context.

4.2.4 Integrated Approach to Commodity/Technology and Area Development

Fragmented approach of research and development based on specific components/commodity and/or area has to change. In rainfed areas, location and farmer centric commodity approach has to be integrated with the area based IFS approach for holistic development as well as promotion of technologies. Therefore, the future R & D programmes and policies of rainfed areas must consider natural resource management measures as "means" and the production, productivity and livelihood support systems compatible to resource base, ecology and market as the "ends". In this context, both "means" as well as "ends" are equally important as both serve each other, and their disconnect could lead to inefficient use of resources and poor outcome from investments both in research as well as development. This calls for a well coordinated and interdisciplinary research programs with multi-disciplinary teams to address the complex NRM, livestock, need based diversification, intensification and livelihood related issues in rainfed areas.

4.2.5 Systems Approach for Research in Rainfed Area Development

There is a need to shift from the current largely crop focused technological approach to one that addresses the needs of the farmers in the context of rainfed farming systems. Issues of sustainable use and management of natural resources at the local level (farm, watershed, farming system) are deeply embeded in overall use and management issues. System approaches will call for greatly enhanced efforts towards adopting modern scientific tools and methods (remote sensing, GIS, modeling etc) as also to strengthen technical capacity by adopting system based approaches of scientific land and resource use planning for optimization of available resources with the rainfed farmers.

4.2.6 Profitability and Productivity Enhancement

Profitability to the farmer besides productivity enhancement has become crucial as the market has become very competitive. This calls for more research in technology development specific to small and marginal farmers suiting to their resources and needs. This would also require careful examination and promotion of interventions that have high efficiency and reduce cost of inputs specially the external ones and should focus more on methods of *in-situ* like moisture conservation, use of bio-resources (organic manure, organic wastes, green manure, bio-energy etc.) and bio pesticides so that the farmers reliance on external inputs is reduced. Conservation agriculture, including zero/minimum tillage, contour/terrace farming, strip/cover crops, residue management, agroforestry and integrated farming system approach should be promoted for reducing the cost of cultivation and increasing the profitability in rainfed areas. Incentivization through MGNREGA and input subsidies for these interventions should form part of policy and programmes in rainfed areas.

The potential of special attribute crops like coarse cereals, guar gum, moth bean, castor, seed spices, medicinal plants and horticulture etc., which are home to rainfed areas through value addition, has remained unexploited. Processing, value addition, knowledge transfer and credit and market linkages etc. should be emphasised. Models of aggregation, processing and efficient marketing may be scaled up in rainfed areas. Developing organised processing, value addition and market linkages in meat sector, especially in Mewat region need special attention.

Minimum Profitable Support Price (MSP) and procurement enforcement in rainfed crops is nearly non-existent. MSP for rainfed crops needs to be declared and assured to the farmers well before the sowing time itself. Well structured system for procurement of food grains, even better than rice and wheat, needs to be operationalized. Inclusion of coarse cereals and millets into food security as "nutritious food" is a forward step in right direction. Innovative products, branding and efficient marketing of rainfed crops based products should be given high priority in research and development.

4.2.7 Safety Nets for Rainfed Region

Livestock production systems in dryland agriculture play a significant role as traditional safety net against droughts. Infact, livestock provides best coping mechanism and insurance against droughts and crop failures in arid and semi-arid drylands, but this component has not received due priority in development of such areas. Tree farming is another safety net in rainfed farming systems. There is need to develop efficient tree based models for supply of quality planting materials with proper market linkages with wood and energy industry. The plantation of multipurpose fodder trees should also be encouraged. There is a need to integrate effective crop-livestock-tree components and such models should be developed and supported. Appropriate policy measures should be taken to treat the tree as crops for harvesting purposes. Similarly, feed and fodder development, small ruminant and livestock insurance need to be prioritized in the rainfed area development programmes. Arid horticulture, spices and medicinal plants are also important for better income generation in rainfed areas. Weather based insurance is picking up in cash crops and is not affordable in coarse and other cereals in rainfed areas, including livestock. Mutual insurance system at village and panchayat level with least transaction cost and deciding claims mutually at local level may be promoted as a viable alternate option especially for low value crops and commodities.

4.2.8 Market and Institutional Linkages

For scaling up the aggregation of farmers, several alternate models like cooperatives, self help groups, water user associations, joint liability groups, and Primary Producers Companies exist in the country and each of them have their own advantages and disadvantages. However, these institutions need nurturing and initial hand holding for their success. An efficient mechanism for capacity building of these institutions, providing easy access to credit, start-up and working capital requirement are some of the issues which need attention. Provisions must be made and/or Byelaws amended to provide initial hand holding and financial support in the form of start-up and working capital to Primary Producers Companies.

4.2.9 Farm Mechanization

Mechanization in rainfed areas has become more relevant due to narrow time window of farm operations. Promoting mechanization through innovative models like small tools, ridger seeders, multiplanter, threshers for cash crops (castor, guar etc) and other implements, custom hiring of costly farm machinery, micro enterprises, agri-business, agro-service centre etc. need priority focus. There is also a need to develop and popularize mechanical harvesting and chaffing, charcoal making, gasification and value addition of *P. juliflora*, mechanical harvesting and value addition of arid fruits, including development of women friendly implements to remove drudgery of women in farm operations.

CHAPTER – 5

WAY FORWARD / RECOMMENDATIONS

It has been observed that even with relatively low investments in rainfed area development than irrigated agriculture, it significantly contributes towards poverty alleviation, livelihood promotion and food security of resource poor communities and small holders. In order to find solution of location specific complex and interlinked problems of resource management of farmers in rainfed areas, the Working Group observed some important policy, institutional and implementation gaps and suggested following necessary actions/activities for sustaining growth of agriculture and livelihood security in the rainfed areas of the state.

Policy Issues

- There is an urgent need to start flagship scheme/programme exclusive for rainfed areas of the State for sustainable use of natural resources and linking this to the components of productivity and livelihood sustainability that depends on multiple resources, assets and commodities.
- The key to successful farming in water deficit rainfed areas is not only land farming but very importantly water farming to enhance productivity of water. Therefore, effective policy initiatives for enabling restoration of natural resource assets/ infrastructures created under different developmental schemes/programs such as water harvesting structures/dams including their repair, de-silting to restore storage capacity, repairs of distribution network, decongesting feeder channels, etc in rainfed villages/watersheds needs higher priority to restore lost irrigation potential for supplemental and life saving irrigation and win confidence of local community. Policy initiatives to revive local level societies and Water Users Associations are also required.
- A policy need be put in place to divert flood water to water deficit rainfed areas and use augmented surface and ground water sources through micro-irrigation in rainfed areas. Focus should also be on developing '**collective action'** with water literacy and participatory monitoring of surface and ground water resources in preparing water budgets, to educate and train local people for planning location specific cropping/ farming systems and other uses of water as per water availability and local needs.
- Watershed development programme in convergence with MGNREGA may serve as the foundation for providing sustainable natural resource base to support productive and

profitable farming and livelihood support system. It is, therefore, recommended that MGNREGA be implemented on watershed principles and converged with IWMP to develop more productive natural resource assets to help resource poor small land holders. Convergence of production and livelihood related programmes such as RKVY, NFSM, NHM, NRLM, etc should also be used as a policy instrument to effectively use NRM base for sustained production and livelihood.

- Livestock and tree farming are safety nets to support rainfed farming. Appropriate policy initiatives need to be in place to conserve and improve livestock breed and strengthen feed assets promotion of agri-horticulture and agroforestry by establishing nursery for supply of quality planting material and treating trees as crops for harvesting purposes is required.
- The training of women and rural youths would be welcome steps as part of the policy initiatives for up-scaling and out-scaling such programmes.
- A comprehensive agricultural insurance scheme to cover all major crops and livestock should be put in place by addressing the drawbacks of the existing livestock and crop insurance schemes. The scheme need to ensure easy and timely implementation to help the stakeholders. There is a need to strengthen weather index based crop insurance using weather data (rainfall, frost, drought, heat stresses, wind storms etc) as trigger events to compensate the farmers for loss of their livelihoods.
- Organic manures and composts are complete fertilizers, and their promotion through appropriate subsidy will not only save foreign exchange on imported chemical fertilizers but also help in improving soil, human and ecosystem health and thus this issue needs proper consideration by the GOI/State Govt. to support organic farming.
- Policy initiatives for setting up of infrastructure and institutional mechanism for timely procurement of coarse grains, pearlmillet, mustard, guar, pulses, castor and other rainfed crops with profitable MSP and branding coarse grains as nutritious food for inclusion in PDS have to be made.
- Policy support for promoting processing and value addition of niche (Guar) and other crops (pearlmillet, mustard, castor), livestock products, arid fruits, vegetables, spices, minor forest produce, market linkages and income generating activities is recommended. This may also be linked with watershed programmes by promoting farming system based approach.
- MSP for timber of poplar and eucalyptus must be there .This will benefit the farmer as these are industrial material for plywood, paper and packaging material and huge transaction is involved around these species.

- There is a need of providing superior clonal material to the farmers at reasonable cost for poplar, eucalyptus and maharukh.

Institutional Issues

- Institutionalization of convergence process requires evolving an effective and unified mechanism for fostering convergence amongst different programs and departments/agencies targeting rainfed/dryland areas in the State. SLNA of watershed programme (IWMP), SLSC of RKVY and state level mechanism of MGNREGA may be brought together under one umbrella, with Chief Secretary as Chair to promote convergence at the planning level itself by spelling out clear cut roles and responsibilities of various actors at district level. Convergence of institutions, including research institutions, CBOs/NGOs, etc may also be addressed through some arrangement in the form of Coordination Committee or any other innovative form.
- There is a need to develop local level dedicated institutions for planning and implementation of rainfed area development programmes (district to block levels) and build their capacity. For sustainable planning and implementation, optimal combination of formal government institutions (GOs) and alternative institutions (involving local groups), especially at the micro level, should be prioritized in rainfed areas to improve delivery efficiency.
- Institutional mechanism like marketing of

Major Recommendations

- Policy for sustainable use of natural resources
- Procurement of rainfed produce and inclusion of course grains in PDS system
- Watershed programmes need to be in convergence with MGNREGA and also with IWMP, RKVY, NFSM, NHM, NRLM
- Comprehensive agricultural insurance scheme
- Rainfed area development programmes at block levels
- Promotion of mechanization
- Improvement of livestock, agri-horticulture , agroforestry in arid areas
- Infrastructure for processing and value addition industries
- Strategic research for soil and water management, crop improvement/ production/ protection and integrated farming system

ground water, community bore-wells, etc needs to be promoted for efficient use of collective resources (forest, grazing land, water). There is an urgent need to have a holistic strategy to use and manage such resources judiciously and prudently with people's participation.

- Due to poor maintenance of natural resource assets and common property resources (CPRs), there is a need to change the pattern of benefit sharing from CPRs by the Forest Department, as most of the Societies in villages/watersheds have become non-functional. Necessary alternate institutional arrangements are required to revive these societies by restoring their lost potential through bottoms up approach.
- Pashu Palak Yojana (PPY) similar to RKVY and Pashu Palak Credit Cards (PPCC) similar to Kisan Credit Cards may be initiated through appropriate institutional and policy intervention at the State/Central levels.

Developmental issues

- Augmentation of water supplies by conserving rain water in the field, aquifers, water bodies, conjunctive use of brackish and fresh waters, treatment of sewage and industrial effluent for use in irrigation and de-silting of existing water bodies and construction of new water storage structures need highest priority for development of rainfed areas in the State.
- Construction of sub-surface dams/galleries, wherever possible, must be encouraged, supported and scaled up in the Shivalik area with community participation at a large scale.
- There is an urgent need to further strengthen measures to recharge groundwater using technologies developed by the CSSRI, Karnal and CCHAU under the AICRP on Water Management and AICRPDA.
- Water budget based crop planning and water use management need to be prioritized in rainfed areas. In case of over exploited ground water regions, re-charging and promoting less water demanding crops / varieties, diversification and farming system approach should be encouraged.
- The ridger seeder is one of the most important intervention for *in-situ* moisture conservation in dryland of Haryana which helps in applying seed and fertilizers in the moist zone in a single operation. This technology should be popularized by a special mission on '**Mechanization of rainfed crops in South-West Haryana**'. This may be incentivised and promoted through village level custom hiring centres etc.
- The district contingency plans prepared for the rainfed districts should be regularly revised and operationalized on pilot basis under the proposed mission. The capacity building of the district level agricultural officers should be built in this mission to encourage and help the stakeholders.

- The dryland soils are not only thirsty but also hungry and thus conservation agriculture, seed priming, seed treatment, use of organic manures and biofertilizers and need based advance/split and spray application of fertilizers should be promoted in rainfed crops.
- There is a need for raising location specific nursery for promoting arid horticulture and agroforestry for block-, field- and bund plantation. Arable lands with subsistence agriculture, waste and problematic lands should be utilized for tree based production system for income generation and livelihood sustainability.
- Concerted effort should be made to focus on arid horticulture in South-West Haryana. Several operations in horticulture plantation can be realized by converging National Horticulture Mission (NHM) and MGNREGA as done in Andhra Pradesh.
- Adoption of *in-situ* moisture conservation practices and micro-site improvement of problematic soils should be made mandatory as part of financial assistance provided under NHM for planting fruits. This should be strictly adhered to and financial assistance (protection and production) should be provided up to fruit bearing stage.
- For promoting protected cultivation, clusters of villages should be identified and devel oped, and these clusters must be mandatorily clubbed with rain water harvesting infrastructures and facilities. A special cluster club of protected cultivation growers may be established to promote scientist and farmer interface. Practical demonstration units at each cluster may be established for ensuring demonstrations of all low cost protected cultivation structures along with the production and pest management strategies.
- Capacity building should be taken up in mission mode to train trainers, extension personnel and farmers, both in terms of number and quality.
- Live fencing with Karonda, *Agave sisilana, Euphorbia tirucalli* could be adopted in arid and semi-arid region of Haryana for preventing the trespass of animals (stray and wild), and promoting soil and water conservation.
- Conservation and improvement of livestock in arid areas should be given priority. Incentives may be considered to the farmers who are engaged in round the year forage production, making of silage and silos, establishment of fodder banks etc.
- There is a need for promoting 'silvi-pasture and rangeland management systems' for optimum livestock production at selected sites. Emphasis should be laid on planting of multipurpose fodder trees. Popularization of animal feed block making machines and economic formulation of supplementary and complete feeds for animals need to be focussed on.
- Fodder banking, fodder seed production and

silage making need to be popularized. The subsidy already available under various state/ national programmes for silo-pits, silo-towers, storage sheds and related machinery / equipment etc., may be further increased by at least 25%.

- Processing industry for guar gum should be established in South-West Haryana since cluster bean area is fluctuating due to unstable market. The state may take up this as a priority rural industry by inviting prospective entrepreneurs.
- Scaling up models of aggregation, processing, value addition and efficient marketing of agro-based produce, including meat products and non edible parts of meat need to be promoted in Mewat for higher income generation of farmers and farm women in rainfed region of Haryana.
- Drought proofing mechanism should be strengthened by developing weather index based insurance module for rainfed crops and other agricultural sectors.
- There is a need of strengthening the capacity of the CCSHAU, Watershed Development Agency and State Department of Agriculture to focus on water harvesting, natural resources and improved on-farm water management using modern tools to extension workers, farmers and other stakeholders.
- There is strong need for strengthening of Regional Research Station, Bawal, Dryland Research Project of CCS HAU in terms of 'state of art' laboratory facilities, and scientific manpower for conducting exclusive research catering to the need of dryland/rainfed areas in Haryana. Strong linkage should be developed with institutes of ICAR, particularly Regional Centre of CSWC&RTI, Chandigarh, CAZARI, Jodhpur and Central Institute of Arid Horticulture, Bikaner to prioritize location specific strategic and adaptive research for rainfed areas.
- There is a need to establish knowledge and

experience sharing platforms in a structured manner using modern advances in informa tion technology. Rainfed Portal as a knowledge platform to share data, technologies and experiences need to be developed.

Researchable Issues

Strategic Research

- Deteriorating soil health is a serious concern. Strategic research for developing knowledge base in organic farming should be encouraged for its adoption under specific production system for improving quality of soil and food products in the State. Traditional practices/wisdom must be blended with scientific tools/techniques for perfection of organic package of various crops.
- There is a need for quantification of carbon sequestration under different production system, agroforestry, organic farming so as to help the farmers from benefit of carbon trading in future. Similarly, there is need for scientific studies on nutrient budgeting and soil quality improvement indicators (carbon sequestration, dehydrogenase activity, microbial biomass, C and N).
- Research on enhancing rain water productivity should be emphasized following interdisciplinary approach by including location specific NRM research in rainfed areas.
- There is a need to strengthen research in the use of new generation polymers to enhance moisture water holding capacity of soils in rainfed water deficient areas.
- Improvements in indigenous trees/shrubs/grasses/crops for earliness and stress/drought /heat/frost/salt etc tolerance through conventional and modern tools of genetic improvement need to be made.
- High priority should be given for harnessing of renewable energy (cow dung based bio-energy/solar/wind/geothermal) for developing gadgets at affordable price for different farm and domestic operations. Close association with other institutes (particularly CAZRI, Jodhpur, IIT, Delhi) who have already developed small gadgets in this direction may be established.

- With a view to catering futuristic demands, efforts should be made to conserve, collect, evaluate and exploit genetic potential of under-utilized species, including new crops (date palm, chandrashoor, chicory, month bean, fodder cactus etc). Close linkage should be developed with research institutes like CIAH, Bikaner, CAZRI, Jodhpur, etc.
- Development of strategies for improved agromet/agro advisories and contingency plans at micro level and their dissemination at grass-root level in case of drought conditions need to be prioritized.
- There is a need to prioritize research to design a crop and/or area specific proxy weather risk triggers (index) with predictive capability to realistically measure crop losses, with well researched and calibrated threshold levels of triggers by considering critical crop growth stages for rainfed crops.
- Mechanized harvesting and chaffing of *P. juliflora* and threshing of castor and harvesting its needs to be developed.

Applied and Adaptive Research

- Standardization of mulching technologies (organic and plastic) for moisture conservation suitable for different regions of rainfed areas of Haryana.
- Standardization and popularization of raised and sunken bed technique, auger pit technique for large scale trees plantation on waste and unproductive areas (rocky, deep and hard pan etc) of the region in participatory mode.
- Need to develop solutions to hydrological imbalances through integrated approaches involving on-farm water management, conjunctive use of water, recharge options, pressurized system of irrigation and other water saving devices/techniques in a holistic watershed management approach.
- High priority to multiple use of water needs in saline/sodic groundwater areas through bio-saline agriculture.
- Identification of compatible crops and their varieties for mixed/intercropping with optimization of planting techniques for better risk cover for aberrant weather condition in rainfed areas.
- Location specific concerted efforts for fine tuning of different conservation agriculture and resource conservation technologies (diversification, intensification, soil configuration, residue incorporation etc) to mitigate ill effects of climate change under rainfed production systems.
- Research programme on foliar application of water soluble fertilizer mixtures having NPK and important micro-nutrients to be undertaken for drought mitigation to boost plant vigor for withstanding drought and mitigating yield losses in rainfed crops.
- Development of biopesticides to promote organic farming of different crops in rainfed areas for effective control of insect-pests and

diseases. CAZRI has developed technologies for IPM (neem pallets for control of termites, Bio-phos, a native phosphorus mobilizing organism, bio-pesticides like Maru Sena-1, Maru Sena 2, Maru Sena 3 and Kali Sena for wilt control) which can further be refined for dryland areas and can be replicated extensively for distribution among farmers of Haryana.

- Mainstreaming climate change related adaptation measures, including demonstrating the concept of 'Climate Smart Villages 'to meet the challenges of climate change in fragile rainfed ecosystem.
- Need for strengthening research efforts for improvement of indigenous grasses like *Cenchrus cilliaris, C. setigerus, Lasiurus sindicus,* etc., trees like *Prosopis cineraria, Tecomella undulata, Acacia senegal,* etc. and shrubs like kair, henna, senna and guggal in close association with ICAR institutes.
- Design and development of efficient and low-cost tools and implements for various agricultural operations, including tillage and post-harvest to reduce drudgery in field operations, especially to farm women.
- Bridge research gap in post harvest processing of coarse grains, guar, castor, arid-horticulture fruits for benefitting the stakeholders.
- Greater emphasis on the effective control of Orobanche in mustard and wilting of bael and guava trees and other diseases and insects in arid fruits in arid ecosystem.
- Development of multi-enterprise based farming systems models (arable crops/ horticultural crops/ trees/ shrubs/ grasses/ medicinal plants/ livestock, etc.) and alternate land use strategies, suitable for upliftment of socio-economic conditions of resource poor farmers. Need to link multi-enterprize models with market, value addition, processing, handling and storage facilities of agriculture produce at production sites for livelihood security of small land holders.

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Website of Agriculture Department, Haryana

ANNEXURE-I

Haryana Kisan Ayog as per its mandate and objectives constituted a Working Group (WG) on "Rainfed Area Development in Haryana". The WG was requested to analyse and review the important issues and problems of rainfed areas of Haryana and suggest suitable strategies and measures to overcome them for sustainable development and growth of rainfed areas in Haryana. The WG met and discussed the relevant issues with scientists, field functionaries, policy makers and stakeholders and visited different types of ongoing research and development work being carried out by various institutions, agencies and stakeholders for getting necessary input in contextual frame work of TOR on Rainfed Area Development. The WG also reviewed and studied relevant literature, recommendations of interactional meetings of HKA with farmers including working group reports on NRM, Horticulture, Livestock Production etc available in the Ayog to prepare and finalize this report.The composition of WG, TOR and details of various meetings held are given below:

Composition

1.	Dr. Alok K. Sikka, Technical Officer (WD), National Rainfed Area Authority and DDG(NRM), ICAR, New Delhi	**Chairman**
2.	Dr. K. R. Solanki, Former ADG, (ICAR), New Delhi	**Member**
3.	Dr. H. P. Singh, Former Director CRIDA, Hyderabad (ICAR)	**Member**
4.	Dr. G. B. Raturi, Former Director, Central Institute for Arid Horticulture(CIAH), Bikaner	**Member**
5.	Dr. D. P. Singh, Consultant, HKA & Former VC, JNKVV, Jabalpur	**Nodal Officer & Member**

Terms of Reference

1) To have an in depth SWOT analysis of rainfed agriculture in Haryana.
2) To examine the present status of soil health (physical, chemical, biological) and suggest measures to improve the same, including efforts to overcome the nutrient imbalance and water retention capacity.
3) To suggest suitable measures for increasing agricultural production and productivity of existing cropping systems in the rainfed areas of Haryana.
4) To assess the current status and quality of existing water resources and suggest measures for their conservation, augmentation, diversion, utilization and optimization, including increase in water use efficiency (WUE) in rainfed areas.
5) To examine the role of live stock, fodder production in the existing mixed farming systems and suggest measures to improve agriculture production through livestock, poultry, fishery and other sectors for needed diversification in dryland areas.
6) To review the current status of dry land horticulture and silvipastoral activities and suggest suitable measures to improve their role in mitigating the impact of drought/water deficit seasons/climate change so as to have improved livelihood security of resource poor farmers of arid region.
7) To examine available research support and effectiveness of service delivery system by the State Agricultural Universities, Department of Agriculture and other Allied Departments of Govt. of Haryana and relevant Institutions/Organizations to ensure needed research backup, advisory services and training programmes for the efficient utilization of natural resources, livestock and human resource in dry land areas.
8) To suggest strategy and the Road Map for increasing overall agriculture productivity, profitability, sustainability and better livelihood opportunities through technological interventions, agricultural diversification, integrated farming systems, rural based agro-processing, value addition and marketing.

S.No	Meetings Held	Date
1.	Meeting of WG with the Chairman, HKA to brief and discuss about the TOR of Rainfed Area Development at New Delhi	Jan11, 2012
2.	Meeting and discussion with Deans, Director, HODs and Chief Scientist of DLA and other staff in COA, CCSHAU, visit to field experiments, NICRA and other programmes of DLA in villages near Hisar	March 19-20, 2012
3.	Visit of WG to RRS Bawal of CCAHAU and interaction with scientists	March 21, 2012
4.	Meeting and interaction of Chairman and Nodal Officer of WG with the Scientists of WTC, IARI and CASA about Mewat Specific Programme in Haryana at New Delhi	Oct 17, 2012
5.	Meeting with the Chairman and Nodal Officer of WG at New Delhi to prepare outline for report writing	Nov 26, 2012
6.	Visit to Chandigarh and interaction with the scientists (CSWCRTI, Chandigarh), field functionaries and farmers in the foot hills of Shivalik	Dec 10-12, 2012
7.	Visit of WG of Mewat specific programmes and interaction with the scientists of WTC, CASA and CCSHAU, Hisar and farmers in Mewat area.	March19-20, 2013
8.	Meeting with the Chairman and Nodal Officer of WG to discuss the relevant information available from ICAR Institutes for preparation of draft of Rainfed Area Development at New Delhi	April 29, 2013
9.	Meeting of Chairman and Nodal Officer of WG to review the draft of Rainfed Area Development at New Delhi	June 2, 2013
10.	Meeting of WG to improve the draft of Rainfed Area Development for its circulation to different quarters for comments/suggestions	July 11-12, 2013
11.	Meeting of Chairman and Nodal Officer of WG to incorporate the suggestions of institutions and experts to improve the draft at New Delhi.	Sept 18, 2013
12.	Meeting of Member of WG and Experts to finalize the draft of Rainfed Area Development at Hisar	Sept 24-25, 2013
13.	Finalization of Report of Rainfed Area Development for its submission to Haryana Kisan Ayog at New Delhi	November 30, 2013
14	Meeting of Member of Working Group and Pri. Scinentist, NRM Division, ICAR and SRF at Hisar to finalise the format of cover page, back page and other corrections in the final draft for submission of HKA	December 14, 2013

In these meetings, the WG interacted with Dr. R. S. Paroda, Chairman, HKA, Officials of Govt. of Haryana, scientists of SAUs, HARSAC and relevant regional research stations and ICAR institutions located within the state, NGOs, Dr. I.P. Abrol, CASA, Er. H. S. Lohan, Ex-Additional Director, Govt. of Haryana, Dr. J. P. Singh, Consultant, Soil and Water Conservation, Govt. of Haryana, Dr. Rajbir Singh, Pri. Scientist (Agronomy), NRM, ICAR, Director, WTC, IARI and his staff, Head, CSWCRTI RC, Chandigarh and staff, Dr. R. S. Dalal, Member Secretary, Consultants of HKA; Dr. M. P. Yadav, Dr. K. N. Rai and Dr. M. L. Chadha, Dr. Anupama Deora, Research Fellow and other supporting staff of HKA and selected farmers of the state. The report reflects the major outcomes of these consultations and the WG acknowledges their valuable support and suggestions. The secretarial assistance provided by the staff of NRAA and NRM Division of ICAR is thankfully acknowledged.








Field Visits of the Working Group








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