REPORT

of

WORKING GROUP

on

PROBLEM OF WATER LOGGING AND SALINITY IN HARYANA

Haryana Kisan Kalyan Pradhikaran

Government of Haryana

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Chairman: S. K. Gupta
Member/Convener: Vijay Arora
Member: H. S. Lohan
Member: Dalbir Singh

Submitted to:

Haryana Kisan Kalyan Pradhikaran
(Government of Haryana)
Panchkula
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Report of Working Group on Problem of Water Logging and Salinity in Haryana

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MESSAGE

About 10 percent of total cultivable area in the State of Haryana suffers from the problem of water logging and salinity imposing serious limitations for raising crops. Agricultural intervention in waterlogged areas is more difficult as waterlogging causes land degradation making it unproductive. With the decreasing per capita land holding due to rise in population in Haryana, it has become quite imperative that every piece of land must be put to productive use to meet the challenges of food security.

The State Government has been implementing various schemes to address the problems of water logging and soil salinity. Haryana Kisan Kalyan Pradhikaran constituted a Working Group on Problems of Water Logging and Soil Salinity in Haryana. This Group has worked extensively with the Agriculture Universities and affected farmers across the State to make concrete recommendations for the abatement of this serious problem in this report. The report aims to identify major bottlenecks and suggest a policy framework that would enable the government to work in the direction for the betterment of the farmers. The right policies and incentives can encourage measures that are more sustainable and healthy. We aim to facilitate the creation and provision of efficient infrastructure, methodology and finding best solutions to agriculture related problems in the near future.

I express my sincere appreciation for Sh. Bhupinder Singh, CEO, HKKP, Dr S. K. Gupta, Chairman of the Working Group, Members of the Group, experts in the Water Logging and Soil Salinity field and officials of HKKP involved in the preparation of this report.

(Sudhir Rajpal)

Bhupinder Singh
Chief Executive Officer
Haryana Kisan Kalyan Pradhikaran

FOREWORD

Haryana is one of the green revolution States having made unprecedented progress in agriculture. While it paid rich dividends in so far as food security is concerned, inadequacy of drainage in expansion of irrigation proved to be a mixed blessing. Several second generation problems such as depleting water table, rising water table resulting in water logging and soil salinity, brackish groundwater, soil health deterioration and pollution of soils, water & environment have arisen during this glorious journey. Agriculture in several districts of the State has been badly affected due to the problems of water logging, soil salinization and saline/brackish groundwater. It is matter of great satisfaction that recent advances in land and water management have shown that the processes of land degradation can be reversed and degraded soils can be brought back to their normal productivity.

Haryana Kisan Kalyan Pradhikaran (HKKP) considered that time has come to look at the current scenario of these problems in the State and take a fair view on the processes to halt/reverse the land degradation. In this perspective, HKKP constituted a Working Group on Water Logging and Soil Salinity in Haryana with well-defined terms of reference. I am extremely glad that the Working Group led by Dr. S. K. Gupta, as Chairman, Dr. Vijay Arora as Convener, H. S. Lohan and Sh. Dalbir Singh as Members, gave in-depth thinking in analysing these complex problems. The Group interacted with various organizations, policy planners and other stakeholders undertook field visits and carried out their own analysis for preparing this comprehensive report. The present report focuses on promotion of preventive measures by fine-tuning some of the policies and site-specific implementation of reclamation measures in an integrated manner.

I highly appreciate and compliment the Group for their efforts in bringing out this holistic report on the subject. I believe that the socio-economic conditions of the farmers affected by these problems can be greatly improved once these recommendations are put into practice by the concerned departments/organizations. I am of the firm view that this document would benefit the planners, policy makers, administrators and scientists, and enable them to take knowledgeable decisions on site specific selection and implementation of the reclamation technologies.

Bhupinder Singh

Dr. S. K. Gupta
Chairman, Working Group

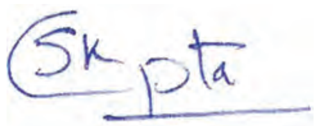
PREFACE

Water logging and soil salinity have been a part of the Indian landscape from time immemorial. Coincidently, the first reported incidence of water logging and soil salinity in 1855 is from village Munak in Haryana. Since then problems have been spreading fast so much so that human-induced land degradation has now become a major threat to the sustainability of agricultural economy of the state. Large acreage has been taken out of cultivation and rural masses are being deprived of their only livelihood resources. Most fascinating aspect of human induced land degradation is that this process is reversible. With reformed land and water governance, it should be possible to bring these soils back to their original productivity. Haryana Kisan Kalyan Pradhikaran (HKKP), Government of Haryana constituted a working group on Water Logging and Soil Salinity in Haryana to examine all issues related to the problems and suggest holistic solutions for adoption by the state to make it free from the menaces of water logging and soil salinity.

This report deliberates upon all facets of the problems mandated by the terms and references of the working group. Basically, the report presents a brief profile of the state highlighting natural impediments coupled with anthropogenic factors that have resulted in water logging and soil salinity problems in the most critically affected districts. An assessment of the extent of the problems has been made. We have consciously categorized the technological interventions into two categories. First category of interventions comprises preventive measures to halt further spread of the problems. In the second category, three drainage technological and four alternate land use practices have been suggested to reclaim/manage the already affected lands. On the basis of drainage guidelines and SWOT analysis some important site characteristics have been identifiedto help in the selection of most appropriate technology for a particular site. The comprehensive basket of alternatives provides opportunities to pool the expertise of various departments in an integrated manner. The report cautions that there is no ‘one size fits all’ solution and half-baked solutions applied half-heartedly will not work. Irrespective of the technology used, handholding of the farmers in pre and post-implementation phases is the key to the success of land reclamation projects. The report laments the current slow pace of reclamation activities and emphasizes strengthening of some organizations that are capable of implementing the drainage projects and undertake capacity building programs. The report goes beyond technological solutions and emphasizes on strengthening extension activities, and capacity building at various levels. The group attempted to make the report as holistic and comprehensive as possible by including technological solutions, socio-economic issues and policy initiatives.

This report in no case is limited to the Department of Agriculture and Farmers' Welfare but will be of immense use by other departments such as water resources and irrigation, forestry, fisheries, private entrepreneurs, non-government organizations and research institutions who may be called upon to implement site specific projects on reclamation and management of waterlogged saline soils.

The report of the working group is an outcome of series of meetings, field visits and interaction with scientists, policy planners, field functionaries and farmers. It would not have been possible to bring out this report without the unstinted support of Sh. Bhupinder Singh, CEO, HKKP,his research groupand team effort of the learned members of the working group. It is earnestly hoped that this report will be widely distributed by the HKKP amongst the various departments and interested individuals.



S. K. Gupta
Chairman

ACKNOWLEDGMENTS

We would like to express our deepest gratitude to Sh. Sudhir Rajpal, IAS, Additional Chief Secretary (Agriculture), who was kind enough to interact with the group on-line to have first-hand information on the progress of the work. It gave us confidence that this report will have meaningful outcome in the department. We express our sincere gratitude to Shri Bhupinder Singh, CEO, Haryana Kisan Kalyan Pradhikaran for his visionary selection of the subject of water logging and soil salinity, the most topical subject in the current context of sustainability of agriculture in the state. We take this opportunity to express our sincere thanks for his valuable inputs during the initiation meeting and report finalization stage that helped us in bringing the report in its present shape.

We visited several organizations of the state and central government, met experts and officials in their personal as well as official capacity and the farmers' groups to get first-hand information on the mandated tasks assigned to this group. We are immensely pleased to thank Er Satvir Singh Kadian, Engineer- in-chief, Department of Water Resources Haryana, and Shri Bajender Singh Nara, Chief Engineer (Drainage) for their valuable inputs on surface and vertical drainage being implemented by the department. We got valuable inputs from Sh. Suresh Dalal, Additional PCCF Haryana on biodrainage. Thanks are due to Shri Pawan Kumar, Joint Director, Department of Fisheries, Haryana for giving insight of the shrimp culture technology and providing useful literature. We had a very fruitful visit during which Er. Shekhon, Executive Engineer, Mukatsar and his staff showed subsurface drainage activitiesat Abohar, Punjab, We express our appreciation to SE irrigation, Ferozepur, and other staff for facilitating this visit. We are highly indebted to Dr. R.K. Yadav, Director ICAR-CSSRI, Karnal for allowing us to conduct a meeting at the institute. Special thanks are due to Dr. D.S. Bundela who not only identified the invitees to the meeting but also conducted the same in a very professional manner. We got very valuable inputs from all Heads of Divisions and Scientists of the institute. We are also grateful to Dr. Gyanendra Singh, Director ICAR-IIW&BR, Karnal for allowing Dr. Omvir Singh, and Dr. Joginder Singh to join this meeting to share their experiences on barley. The HOPP team led by Sh. Dharam Pal, DSCO, Karnal included Er. Dayabir Singh, DPD, HOPP, Dr. Mohan Lal, AE(C) and Sh. Naresh Kumar, JE, Lakhan Majra. All of them deserve special mention as they provided highly useful inputs both orally and in writing.

We would like to express our deepest appreciation to Prof. B.R Kamboj, Vice-Chancellor CCSHAU for permitting and Dr. Jeet Ram Sharma, Director of Research for conducting a very insightful meeting. Special thanks are due to the galaxy of Heads of Departments and scientists for participation and providing very useful inputs. Dr C.N. Ravishankar was kind enough to permit Dr.Babita Rani, CIFE regional Center Rohtak to help the group in all possible ways. It is our pleasure to thank Dr.Babita Rani for providing a very useful note and her team for arranging the visit to the Center. We had the pleasure of interacting with a very enlightened group of farmers due to the good offices of Sh. O.P. Godara, DSCO Rohtak ably supported by Dr. Nina Sihag, ASCO and Dr.Asha Ahlawat, District Fisheries officer, Rohtak. No word of appreciation can express our feelings for their untiring efforts. We have special words of thanks for Dr. Asha Ahlawat for organizing a field visit to the Shrimp culture farm for interaction with the owner and for supplying good photographs of few other sites. Special thanks are also due to Dr. Rakesh Banyal, Dr. D. R. Bundela and Dr. Mohan Lal for supplying good photographs, which have added to the quality of the report. We are personally thankful to Dr Surender Dahiya. Additional Director Agriculture, Sh. Devender Sihag, Joint Director (Agriculture), Sh. Pankaj Mehla of GWC Haryana, M.J. Kaledhonkar, PC (A) of ICAR-CSSRI and Dr. Ram Parkash, Asstt. Professor, CCSHAU, Hisar for supplying information related to crops, HOPP, groundwater table and groundwater quality respectively. We are also thankful to Dr. Raj Kumar, Assistant Professor (Agri. Economics), MHU, Karnal for helping us in economic analysis.

Finally, it is our pleasure to mention that our journey would not have been so easy and fruitful without the unstinted help rendered by Dr. Sanjay Yadav and Mrs. Vandana,Reserach Fellows at Haryana Kisan Kalyan Pradhikaran. Both of them were everwilling to meet our demands and facilitate our visits to various places. We wholeheartedly thanks both of them. In this long journey of few months, we have come across a large galaxy of scientists, officers and policy planners. In spite of our best inentions, it has not been possible to name each of them. Any missing link is inadvertant. We would like to once again acknowledge the direct and indirect contributions made by various organizations and many individuals.

Chairman Member Member Convener

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ABBREVIATIONS

ATMA	Agricultural Technology Management Agency
BCM	billion cubic meters
BIS	Bureau of Indian Standard
CADA	Command Area Development Authority
CCA	Culturable command area
CCSHAU	ChaudharyCharan Singh Haryana Agricultural University
CGWB	Central Ground Water Board
CIFE	Central Institute of Fisheries Education
CIRB	Central Institute of Research on Buffaloes
CPVC	Corrugated Polyvinyl Chloride
CSSRI	Central Soil Salinity Research Institute
EC	Electrical conductivity
EC_e	Electrical conductivity of soil saturation extract
ESP	Exchangeable sodium percentage
GWC	Ground Water Cell
HAMETI	Haryana Agricultural Management and Extension Training Institute
HARSAC	Haryana Space Application Center
HIRMI	Haryana Irrigation Research and Management Institute
HKKP	Haryana Kisan Kalyan Pradhikaran
HLRDC	Haryana Land Reclamation and Development Corporation
HORP	Haryana Operational Research Project
HOPP	Haryana Operational Pilot Project
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
ICT	Information and communication technology
IGNP	Indira Gandhi Nahar Pariyojana
IIWBR	Indian Institute of Wheat and Barley Research
KVKs	Krishi Vigyan Kendras
MoU	Memorandum of Understanding
meq/l	millie quivalent per liter
M ha	Million hectare
MICADA	Micro-irrigation and Command Area Development Authority
MHU	Maharana Partap Horticultural University
MoA&FW	Ministry of Agriculture and Farmer s Welfare
MSP	Minimum support price
NAAS	National Academy of Agricultural Sciences
NBSS&LUP	National Bureau of Soil Survey and Land Use Planning
PMKSY	Pradhan Mantri Krishi Sinchai Yojana
PMMSY	Pradhan Mantri Matsaya Sampda Yojana
PRIs	Panchayati Raj Institutions
RKVY	Rashtriya KrishiVikasYojana
RRS	Regional research station(s)
RSC	Residual sodium carbonate
SAR	Sodium adsorption ratio
SBI	Sugarcane Breeding Institute
SSD	Horizontal subsurface drainage
UGPL	Underground pipeline

EXECUTIVE SUMMARY

Haryana Kisan Kalyan Pradhikaran(HKKP), Panchkula constituted a working group on Water Logging and Soil Salinity in Haryana as an initiative aimed at the welfare of the farmersgrappling with the problems of water logging, soil salinity and poor qualitygroundwater. The group visited several organizations dealing with these problems, had interaction with expert groups and solicited the opinion ofthe farmers to get latest information and their view points. The major objective was to get information on the extent of the problems, understand the causes and have a fair view of monitory lossesand ameliorative measures to resolve the problems. This report outlines a comprehensive basket of alternative technologies to reclaim waterlogged saline lands in the state.

A critical analysis of topographic conditions, rivers, climate, soils, water resources, flooding events, irrigation and drainage systems, and agriculture is presented to highlight the relative role of these factors in creating twin problems of water logging and soil salinity. It appears that peculiar topography of the state particularly of the districts critically affected by these problems, soils, geology, recurring floods, high seepage losses from the vast canal network, deep percolation losses from out-dated irrigation methods, aberrations in cropping patterns in favour of water guzzling crops, and lacunae in the existing drainage systemsare to a great extent responsible for the problems. Accordingly, ameliorative strategiesneed to be framed to blunt the ill-effects of these factors.

Crop Management

As soon as irrigation is introduced in an area, farmers tend to shift from low water requiring crops to water guzzling crops. It is why; rice cropping has spread even in districts where cultivation of this crop is unsustainable. Canal water based rice is a major cause of expanding water logging and soil salinizationin critically affected districts. As such, canal water based paddy needs to be discouraged. Paddy cultivation in these districts has to be solely groundwater based.

The most critical areas affected by water logging and soil salinity in the statewere once home to coarse cereal barley and millets such as sorghum (*Jowar*), pearl millet (*Bajra*), finger millet (*Ragi/Mandua*) and minor millets. Concerted efforts are needed to convince the farmers to revert to these crops. Assurance to purchase these crops at minimum support price (MSP) can encourage the farmers to divert back to these crops. Theincreasing area under oil seed crops especially rapeseed and mustard isa positive feature. This trend should be maintained as these cropsare best suited to mildly saline soilsand can grow well in areas where brackish water is used for irrigation. In our opinion, horticulture, fodder crops and medicinal and aromatic plantsshould be given due importance in the crop diversification program.

Water Management

On-farm development with scientifically designed field drainage channels, laser land leveling, improved surface irrigation techniques such as furrow irrigation and ring basin irrigation for horticultural plants can save significant amount of irrigation water. Lining of canal network including field channels can also reduce huge seepage losses from ill maintained network. All reaches of distributaries, minors etc where damage to lining exceeds 30% should be identified. These reaches should be relined especially in districts affected by water logging and soil salinity. It is high time to switch to underground pipeline (UGPL) conveyance initially at the farm level that can gradually be extendedto water courses.

Government of Haryana is taking all steps in promoting sprinkler and drip irrigation. Demonstrations of these systems in farmers' participatory mode are needed so as to convince the farmers to adopt these technologies especially in sugarcane, cotton, and even in rice and wheat crops.Micro-irrigation systems are also quite useful for utilizing saline water for irrigation. Subsidy on drip and sprinkler systems including solar pumping systems should be extended on priority to the individual farmers adopting drip/sprinkler irrigation in canal commands.

Surface Drainage

Haryana state has made tremendous progress in constructing new drains and improving the existing systems of drains. Yet, the lack of adequate surface drainage in the inland drainage basin is not only resulting in yield penalty by aggravating the problems of water logging but also encouraging the farmers to adopt rice cultivation. Drainage wing of the department of water resources may examine feasibility of constructing new surface drains; establish permanent lift schemes in pockets of depressions that are annually flooded, and implement on-farm ponds and bore holes based drainage systems. Besides, regular cleaning of existing drains is necessary as weed growth and sloughing in drains is a regular feature. Strict monitoring of cleaning activity is even more important so that the designed sections and slopes are maintained during cleaning. If necessary, existing drains may be specially treated to keep them in proper shape and size.

A lot of infrastructural development activities are in progress in the state. Most stakeholders during interaction expressed increasing incidences of surface water logging in their fields mainly attributing to lack of appropriate drainage outlets in these structures especially the highways. While appropriate capacity water ways may be in-built in future designs, existing structures may be remodelled at appropriate places to ensure free natural flow of water.

Subsurface Drainage

Subsurface drainage seems to be the only long-term solution to protect/support agricultural infrastructure and permanently solve the problems. Our viewpoint onthree most appropriate technologies is as follows.

Horizontal subsurface drainage (SSD) is the most appropriate technology with well researched guidelines and thumb rules for design, construction and operation. The system is capable of reclaiming completely barren lands turning them into highly productive fields in least possible time. The disposal of drainage effluent often cited as a problem seems exaggerated. The disposal may be required only for the first 1-2 years that too on a limited scale. Later on the drainage effluent can be used for irrigation. Therefore, we recommend that the state should continue to implement this technology. The pace of implementation can be increased with joint efforts of Indian Council of Agricultural Research- Central Soil Salinity Research Institute (ICAR-CSSRI), Chaudhary Charan Singh *Haryana Agricultural University* (CCSHAU) and revamped and strengthened Haryana Operational Research Project (HOPP).

Vertical drainage seems to be the next option. In spite of having good experience of irrigation tube wells, little is known about the design of drainage wells, their spacing and performance in the long-term. The drainage effluent disposal problems in vertical drainage are several orders of magnitude more than SSD. Moreover, the life of the pump may be limited because groundwater being pumped is of quite high salinity. Nonetheless, we recommend vertical drainage for specific sites where good quality aquifers are available and groundwater quality is not too bad. Such areas exist along the canal network, where groundwater electrical conductivity (EC) may be in the range of 4-5 dS/m and the drainage water can be disposed of in the canal system. It can also be implemented in areas where drains with relatively high discharge are available so that salinity of mixed water does not exceed 2 dS/m.

Biodrainageis a combined drainage-cum-disposal eco-friendly system yet more research and field demonstrations are needed to establish its viability in farmers' field.Loss of agricultural land, gestation period of about 3 years before real drainage begins, farmer's unwillingness to spare the land and salt balance issues are few amongst other problems. Nonetheless, it can be implemented only in potentially waterlogged areas (water table > 2m) with low to medium salinity. It can also be adopted to intercept seepage along canal network where vertical drainage might pose problems.

Alternate Land Use

Waterlogged saline lands in the possession of Panchayats and other public institutionsare difficult to reclaim. These lands can be put to some alternate land use.White shrimp culture in inland waterlogged saline soils underlain by brackish to highly saline groundwater appears to be one of the most remunerative options. But, commercial farming of Pacific white shrimp *(Litopenaeusvannamei)* requires huge initial investments to the tune of 3 million/ha. Therefore, farmer-private entrepreneur partnership models should be put in place. Brackish water fish culture, and multi-enterprise ponds along canal network arealso good option. Besides, waterlogged, saline and alkali lands can be deployed for establishing solar parks. Individualor a group of farmers including Panchayats and public institutions can lease the land and get some regular income.

Extension and Capacity Building

Grass root involvement of all stakeholders including Panchayati Raj Institutions (PRIs) and local bodies in land amelioration activities needs to be strengthened. Existing traditional methods of conducting trainings/workshop, organizing meetings, farmers' field days, radio talks and video conferencing, farmer scientist's interactions, and entrepreneurs' scientists interactions are still relevant and can be relied upon to spread the recent advances in ameliorating water logging and soil salinization. Agricultural Technology Management Agency (ATMA) at district level should be fully exploited to extend the technologies. Besides, we must take full advantage of recent advances in information and communication technology (ICT) – especially the electronic and print media to ensure real-time dissemination of messages on new innovations.

Almost free supply of canal water and heavily subsidized power leaves little incentive for the farmer to improve on-farm water use efficiency. It is recommended that some good scheme should be framed to incentivize the farmers adopting sound soil and water management technologies.

Institutional Strengthening

HOPP, Karnal, for implementing horizontal subsurface drainage projects, Haryana Agricultural Management and Extension Training Institute(HAMETI), Jind, and Haryana Irrigation Research and Management Institute(HIRMI), Kurukshetra for conducting training programs and three Regional Research Stations of CCSHAU at Rohtak, Bawal and Sirsa for on-farm research and demonstrations on natural resource management technologies need strengthening.

1.0 INTRODUCTION

Sustainability of agricultural economy of the state is seriously threatened because of limited water resources, spread of water logging and soil salinity, brackish and saline groundwater, overexploitation of groundwater, farmer's unwillingness to come out of rice-wheat rotation, fatigue of green revolution on theirsource base together with host of other factors. This report exclusively deals with the problems of water logging and soil salinity closely linked to brackish and saline groundwater in the state.

2.0 STATE PROFILE

2.1 Topography

Problems of water logging and soil salinity and their solutions are intricately linked to natural surface drainage governed by the topography and River systems of the area. The altitude of Haryana varies between 200 m to 1200 m above the mean sea level. Leaving aside the Shivalik hills in the North and Aravalli hills in the South, the elevations of the state vary from 400 m in the north to 210 m on Rohtak-Hisar axis, 310 m in south Narnaul, 190 m in the southeast outfall point of river Yamuna and 190 m in southwest outfall point in Ghaggar.The state on the whole has a flat topography, but a topographical depression exists in thecentre with its axis on the regional scale passing through Delhi-Rohtak-Hisarand Sirsa. The contour of 215 m goes from Delhi to Sirsa almost in a straight line (Fig. 1.1). Overall, there is a good scope for natural surface drainage, which can be achieved through carefully constructed surface drainage network taking care of outflow conditions at critical junctures. Saucer shaped micro-depressions, which remain waterlogged during the monsoon seasonmay requirepermanent or temporary pumping stationsof adequate capacity to clear the water for crop cultivation.

2.2 Rivers System

The Rivers constitute the natural drainage system of any region. The entire state is divided into 3 main drainage basins namely Yamuna, Ghaggar and Inland alluvial basins (Fig. 1.1). The state also forms a water divide between Indus and Ganges basins. Geo-hydrological conditions, groundwater movement and surface drainage pattern forms few smaller basins such as Krishnawati basin, Sahibi basin, Landoha Nala basin, Kanti sub-basin (Loharu-Satnali area). The northern part generally slopes from the north-east to south-west, but the southern section is undulating due to the Aravalli hills and sand dunes.

2.3 Climate

The Climate of the state is sub-tropical, semi-arid to sub-humid, continental and monsoon type. The average rainfall varies from less than 300 mm in south-western parts to over 1000 mm in the hilly tracks of Shivalik hills with an overall average of 614 mm for whole state (CGWB, 2022). The state is extensively under low precipitation zone. While low rainfall areas have aeolian landforms, high rainfall areas have alluvial landforms. The mean temperature is highest during May (42^{o}C) and lowest during January (5^{o}C).

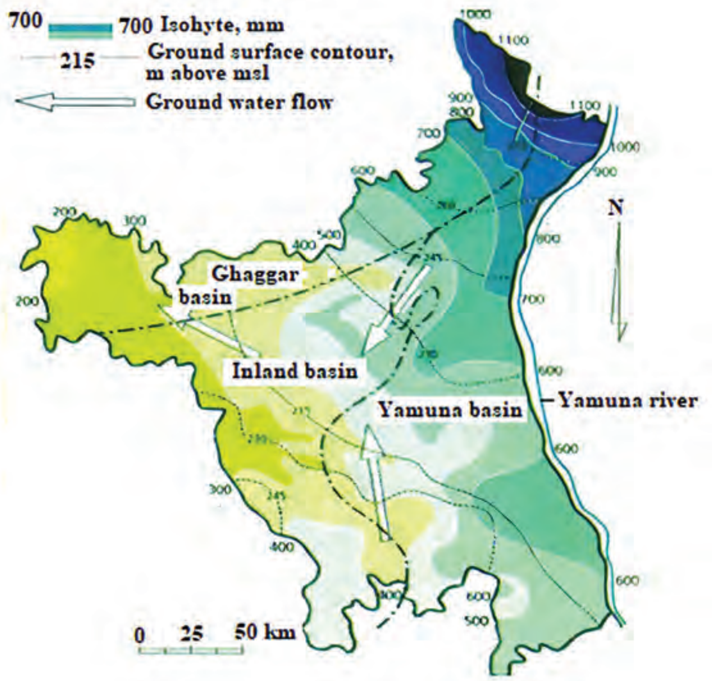

Fig. 1.1 Geographic domain of the Haryana state

2.4 Soils

Most of the area of the state (98%) is alluvial plains formed by Yamuna and Ghaggar rivers. Hard rock's area covers just around 2%. Soils, by and large,are light to medium, mostly sandy or loamy sand with calcareous concretions in the sub-soil. Texturally, fine loamy soils cover about 43%, coarse loamy soils cover34% and sandy soils form 23% of the state area. Sand dunes are found in the districts of Bhiwani, *Mahendragarh*, Hisar and Sirsa. Soils of the state are highly prone to degradation on account of erosion due to wind and water and presence of salts in the inherent material, a cause of soil salinization. Though the soils in the state are by and large productive but the resource has been intensively exploited during the last 5-6 decades leading to depletion of organic matter and deficiencies of essential nutrients. This resulted in physical degradation on account of compaction and lack of biodiversity.

2.5 Water Resources

Inadequacy of water is a major constraint faced by the state, beingdependent on inter-state river agreements. More than 60% of groundwater is brackish to highly saline. The present water availability from surface water resources is 9.36 billion cubic meter (BCM). According to the Central Ground Water Board (CGWB), annual groundwater recharge from rainwater and canal water can be taken as 10.15 BCM of which 9.13 BCM is extractable. But the current annual groundwater extraction is 13.05 BCM of which 12.08 BCM is used for irrigation while remaining goes for domestic (0.63 BCM) and industrial use (0.34 BCM). The state has 8.37 lakhs operational tube wells besides the drinking water tube wells. The current water demand is projected at 35 to 39.4 BCM. It is likely to increase to 45 BCM in 2045 (Tahal, 2001, Rawat et al., 2018). The mismatch between the supply and demand is partly met through rainfall (9.64

BCM) and partly through overexploitation of groundwater. It is resulting in declining water table having consequences of increasing cost of groundwater, degradation in water quality and increasinguse of energy to pump the same amount of water. Clearly, the state faces a gigantic task of providing irrigation water for agriculture, drinking water to more than 25 million people besides meeting the ever growing need of upcoming urban areas, industry and agriculture etc. In order to increase the resource base, state government is emphasizing on the use of treated waste water for irrigation.

2.6 Irrigation Systems

Out of a total geographical area of 4.42 million hectare (M ha) of the state, 3.82 M ha is culturable. The state adopted a policy of protective irrigation to ensure equitable distribution of water. Accordingly, it has developed an extensive canal network consisting of 59 main canals having length of 1498.69 km, 1326 distributaries and minors having a length of 12328.10 km. The state has alsocommissioned 200 pump houses on the lift schemes. The whole state has been divided majorly in four irrigation commands.

- Bhakra canal system covering a culturable command area(CCA) of 1.28 M ha in the north-western and western parts of Haryana
- Western Yamuna canals system covering a CCA of 1.00 M ha in the north-eastern and central parts of Haryana
- Gurgaon and Agra canal systems covering a CCA of 0.12 M ha in south-eastern parts of Haryana
- Lift canals covering a CCA of 0.57 M ha in south-western parts of Haryana bordering Rajasthan

Net irrigatedarea has increased from 15% of the net sown area in 1966-67 to 88% of the net area sown during 2021-22 (MoA&FW, 2023).Net area irrigated by canals is 1.22 M ha while groundwater irrigation covers 2.07 M ha. The irrigation intensity is 193.7% but is not uniform because of highly skewed distribution of canal water in different commands and groundwater use.Water distribution practices, canal seepage, water-holding capacity of soils, and irrigation methods used by farmers together cause considerable percolation losses to the aquifer. As a result, large tracts have developed water logging and soil salinity mostly in areas underlain by saline groundwater. It is an opportune time to rehabilitate canal network, undertake lining of dilapidated components of the network and water courses, and switchover to improved irrigation techniques.

2.7 Agriculture

The agriculture sector of Haryana broadly comprises agriculture, horticulture, animal husbandry and fishery. Majority of the population is dependent on agriculture and its allied activities. The state is one of the leading contributors to the country’s food grains basket. Broadly, Haryana is divided into two agro climatic zones- the north western part suitable for rice, wheat, sugarcane, vegetables, and some temperate fruits and the south western part suitable for wheat, rapeseed and mustard, pearl millet, cotton, gram, barley, some tropical fruits, vegetables and herbal and medicinal plants. The major fruits grown in the state are guava, kinnow, mango, peach, pear, plum, strawberry, chickoo, citrus, aonla and ber. Aberrations in cropping pattern in favour of water guzzling crops are quite visible in the state (Table 1.1). The rice and wheat area during 1966-67 and 2021-22 increased by 610% and 232% respectively.Rice is creeping in districts where cotton has been the most prominent crop. Cultivation of rice in light textured soils using canal water is resulting in expansion of water logging and soil salinity in these districts. Significant increase in area under oilseeds mainly through mustard and rapeseed has many positive features. Besides, meeting the edible oil requirements, the crops are most suited to medium saline soils and can even be irrigated with brackish water.

Table 1.1 Crop wise changes in area under cultivation of few crops in Haryana

Crop	Area under the crop		% increase/decrease
	1966-67	2021-22	
Rice	192	1364	610
Wheat	743	2471	232
Sorghum	270	23	-102
Pearl millet	893	483	-46
Barley	182	9	-95
Total oilseeds	212	1447	582

Prime agricultural lands in the state are being lost to urbanization/industrialization. Moreover, there is little scope for vertical increase in agriculture because of the shortage of water. Any action in this direction is bound to be counterproductive exerting enormous pressure on the limited water resources. Therefore, most important task isto safeguard the environmental integrity of existing systems to ensure food and nutritional security of the state. Human-induced land degradation, water scarcity and climate change are increasing the levels of risk in agricultural production and ecosystem services. Some of the problems associated with agriculture in the state are: erratic rainfall, recurring floods and/or drought, over-exploitation of groundwater, decreasing factor productivity, increasing crop water demand, reduced soil fertility, soil erosion, top/fertile soil loss, expanding abiotic stresses, climate change including shift in temperature pattern, and introduction of invasive alien species.

2.8 Floods

Haryana is prone to floods, which is more of a hazard than disaster. The state experienced very heavy floods during 1976 and 1977, which were rated as 50/100 years return period floods. The floods also occurred in the year 1978, due to heavy rainfall in Haryana as well as in the catchment areas of river Yamuna in Himachal Pradesh. After the devastating floods of 1978, a master plan costing Rs. 1500 millionwas prepared and executed as a long-term flood mitigation measure. Widespread flooding in the districts of Rohtak, Sonipat, Jind, Gurugram, Hisar, Bhiwani, Faridabad, Kurukshetra, Karnal and Sirsaoccurredin 1983. The Rohtak district was worst affected because Drain No.8 was not able to carry the required discharge from Gohana area for a number of days. The situation assumes serious dimensions when heavy rainfall is coupled with high discharge in Yamuna. Flooding in Rohtak, Jhajjar and Rewari is mainly attributed to poor surface drainage and outfall conditions at Yamuna. Ambala and Kurukshetra districts are affected by floods mainly from Markanda tributaries. In summary, flooding in the state can be attributed to peculiarities of the rainfall in the state, heavy runoff in the mountainous terrain resulting in overflowing of rivers, over flowing of local streams and heterogeneous topography.

It is estimated that about 2.35 M ha area in the state is prone to floods. The adverse consequences of floods are direct losses to standing crops besides the land's inability to recover for cultivating crops in the following season(s). Its major impact in waterlogged saline soils is felt through rise in water table that continues for years together because of poor internal drainage of the soils. This calls for a holistic approach in designing flood control and mitigation strategies that may include:

- Flood protection works on the river aimed at containing flood flows within the river course
- Flood mitigation works in the catchment aiming at reducing flood peaks by constructing small storage dams, increasing rainfall retention and reducing erosion in the catchment through soil conservation works
- Damage reduction works in the flood plain by improving drainage systems, flood zoning, land use restrictions, and flood proofing
- Flood warning, evacuation and emergency relief

2.9 Drainage

Surface drainage of agricultural land constitutes removal and disposal of excess water from the land surface. The state currently has vast network of drainage comprising about 800 drains covering 5,150 km length. The Yamuna basin has the most elaborate drainage network, followed by Ghaggar and inland drainage basin. Even then the system is incapable of draining accumulated surface water sufficiently fast enough due to the following factors.

- Flat terrain restricting desired slopes of the drain beds
- Outfall conditions at the river especially during monsoon season resulting in backflows
- Design of drains with zero slope to serve as drainage-cum-irrigation channels
- Inadequate maintenance and upkeep
- Sloughing of side slopes in waterlogged areas obstructing the free flow of water

Besides, topographical features in the inland drainage basin of the state make it imperative to employ pumping of water to drain large areas during monsoon season. Therefore, numerous permanent pumping stations have been installed in Sonipat, Rohtak, Faridabad and Gurugram districts to lift water from depressionsto discharge it into canals/drainage network. Many drains in the Ghaggar basin terminate into irrigation canals. The drain water is discharged either by gravity or pump-lifted.

An issue often overlooked is that a water layer of few cm always remains in the fields even after drainage. Itadversely affects crop productivity resulting in yield penalty of about 10-20%. This calls for strengthening on-farm field drainage network under the schemes of Micro-irrigation andCommand Area Development Authority(MICADA). Besides, large scale construction of infrastructure in the state is impeding the natural flow of the water. Either no or at the most few insufficient capacity outlets are provided in the design of these structures. This issuehas been raised at almost all forums by most stakeholders. They expressed that problem of surface stagnation has already increased and will be further aggravated in the near future.Group strongly feels that surface drainage system in Haryana needs significant improvements.Although, itmay not lower the water table except close to the drains, yet the quick disposal of rainwater will help inchecking the rising groundwaterlevels.

3.0 NOMENCLATURE: PROBLEM SOILS AND WATER

3.1 Water Logging

National Commission on Agriculture (1976) defined an area as critically waterlogged as and when the water table is within 1.5 m of the soil surface. Later, Ministry of Water Resources (1991) grouped problem of water logging in 3 categories namely critical (water table < 2 m), potentially waterlogged(water table 2-3 m) and safe (water table> 3 m). Haryana adopted the nomenclature of critically water logged areas proposed by the National Commission on Agriculture. In order to take care of rising and depleting water table, holistic guidelines have been framed by the state to categorize the areas as waterlogged or water stressed (Table 1.2).

Table 1.2 Guidelines for categorization of waterlogged and water stressed areas

Categorization	Water table guideline (m)	Area (km^2) in June 2020
Severely waterlogged	<1.5	131.1
Potentially waterlogged	1.51-3.00	2301.9
Buffer zone for water logging	3.01-5.00	4512.7
Good groundwater potential	5.01-10.00	7421.8
Potentially groundwater stressed	10.01-20.00	12931
Potentially groundwater moderately stressed	20.01-30.00	6111.1
Potentially groundwater severely stressed	30.01 or more	11055.1

3.2 Salt Affected Soils

USDA classification is commonly used to classify salt affected soils. Saline soils have electrical conductivity of saturation extract (EC_e) >4, exchangeable sodium percentage (ESP)< 15 and pH_2< 8.5, alkali (sodic) soils have EC_e<4, ESP > 15 and pH_2>8.5, saline-alkali soils have EC_e>4, ESP > 15 and pH_2>8.5. Soils in Haryana can be categorized based on EC_e and pH_2 obviating the need to determine ESP requiring cumbersome laboratory procedures.

3.3 Irrigation Water Quality

Irrigation water quality is governed by 3 parameters namely EC, sodium adsorption ratio (SAR) and residual sodium carbonate (RSC).Following guidelines have been framed to characterize irrigation water quality (Table 1.3).

Table 1.3 Guidelines for grouping poor quality groundwater for irrigation in India

Water quality	EC(dS/m)	SAR $(mmol/L)^{1/2}$	RSC (meq/L)
Good	< 2	< 10	< 2.5
Marginally saline	2-4	< 10	< 2.5
Saline	> 4	< 10	< 2.5
High-SAR saline	>4	>10	< 2.5
Marginally alkali	<4	< 10	2.5-4.0
Alkali	< 4	< 10	> 4
Highly alkali	Variable	> 10	>4
Toxic Water	The toxic water has variable salinity, SAR and RSC but has excess of specific ions such as chloride, sodium, nitrate, boron, fluoride, or heavy metals such as selenium, cadmium, lead and arsenic etc.		

4.0 WATER LOGGING, SOIL SALINITY AND POOR QUALITY WATER

4.1 Work Done in the Past: Historical

First-official complaint of soil salinity was lodged as early as in 1855 by a grower belonging to village Munak (now in District Karnal, Haryana). Since then this issue has been raised at various forums but no viable solutions has emerged. Indian Council of Agriculture Research in 1967 appointed an Indo-US Consultant Team to suggest a comprehensivesoil and water management research agenda needed to avert India's food shortages. The team made several recommendations forming the basis of establishment of ICAR-CSSRI, Karnal, All India Coordinated Research Project on Water Management and Water Technology Center at ICAR-Indian Agricultural Research Institute(ICAR-IARI), New Delhi. A teamsponsored*by United Nations Development Programe*estimated the cost of reclamation of the entire area in Haryana through drainage and other measures at Rs. 7200 million (Bouman, 1984). A committee under the chairmanship of the then Vice-Chancellor, CCSHAU, Hisar was constituted in 1998, which submitted its report in 2000. The cost of reclamation estimated by this committee was Rs. 23000 million, a 3-fold increase from the previous estimate of 1984. Unfortunately, nothing was implemented on the ground except for few preventive measures comprising lining of water courses etc. A similar team was constituted by the planning Commission for water logging and soil salinity in southwest Punjab. Chief Engineer, Drainage & Irrigation Works (Government of Punjab) suggested several measures including construction of new surface drains, lining of canal network, evacuation of water from the depressions through lift schemes and subsurface drainage system for ameliorating water logging. On the recommendation of this group Punjab was sanctioned funds for lining of Rajasthan feeder and Sirhind Feeder Canal. Government of

Punjab purchased subsurface drainage laying machines. During all this while, a redeeming action plan was being pursued by ICAR-CSSRI and Haryana Land Reclamation and Development Corporation (HLRDC). Both these organizations joined hands and reclaimed huge alkali affected areas especially in the districts of Kurukshetra, Karnal, Panipat, Kaithal, and parts of Yamunanagar, and Jind. Today, almost all privately owned alkalilands stands reclaimed. ICAR-CSSRI was looking for a similar breakthrough in reclaiming waterlogged saline lands and initiated subsurface drainageactivities at Sampla in district Rohtak.Government of the Netherlands came forward to support these activities and established Haryana Operational Research Project (HORP) to implement subsurface drainage at Gohana (Sonipat) and Kalayat (Jind). The activities were also expanded to other states such as Gujarat, Karnataka, Rajasthanand Andhra Pradesh.As the things were progressing, controversy on horizontal subsurface drainage, vertical drainage, biodrainagebegan appearing. Group feels that it is unnecessary as the technical and economic viability of any technology is site specific. The group is in favour of an integrated approach to resolve the ever increasing menace of water logging and soil salinity in the state.

4.2 Extent of the Problems

Several organizations are engaged in estimating the extent of water logging, soil salinity and poor quality water, yet the precise estimates of the problems have eluded so far. The problem wise reasonable estimates are summarized below.

4.2.1 Water logging

Water logging has been categorized mainly in two group's namely surface water logging and subsurface water logging due to shallow water table. According to a document submitted to the 11th Plan Working Group by the state, flood prone area has been assessed at 2.35 M ha. This area is normally affected by drainage congestion in agricultural lands. These areas require interventions in the form of flood control and management of surface stagnation of water.

Twin problems of subsurface water logging and soil salinity extend over a large area in the state in the command areas of Western Yamuna and Bhakra canal commands and more so in the inland drainage basin. The data on the extent of water logging due to shallow groundwater is being monitored and published annually by the CGWB and the State Ground Water Cell (GWC). As per June 2018, area under critical water logging and potential water logging zoneswas about 36000 ha, and about416000 ha (Table 1.4). A significant increase in area under critical water logging was observed in 2020 such that area under critical water logging and potential water logging covered about 68800 ha and327800 ha respectively. It appears that areas under critical and potential water logging shift from one group to another. According to CGWB, the water table was within 2 m of the ground surface in 49800 ha area in June 2021 (Fig. 1.2, CGWB, 2022) and was 205200 ha in January, 2022 indicating substantial increase in the post monsoon months.

4.2.2 Salt affected soils

National Academy of Agricultural Sciences (NAAS), ICAR, ICAR-CSSRI and National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) coordinated to reconcile the data available with various organizations to arrive at realistic values of salt affected soils (NAAS, 2010).

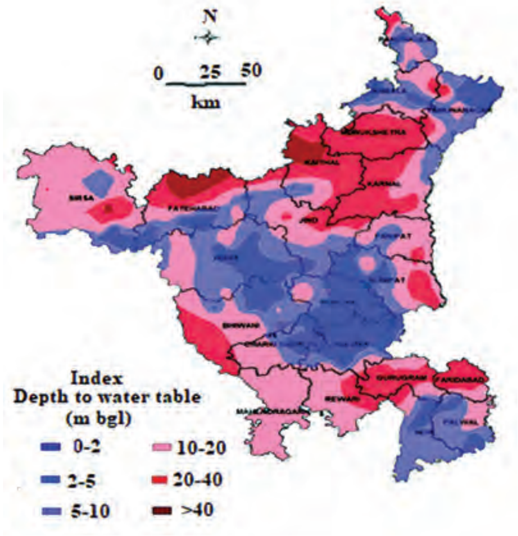

Fig. 1.2 Depth to water table map of Haryana, June 2021

Table 1.4 District-wise critical and potentially waterlogged areas (ha) in Haryana in June 2018

Serial number	District	Geographical area (ha)	Subsurface water logging	
			Depth to water table (0-1.5 m)	Depth to water table (1.5-3.0 m)
1.	Ambala	159585	570	4257
2.	Bhiwani	323549	582	23453
3.	Ch. Dadri	136517	9566 (9450)*	23871
4.	Faridabad	74045	0	1840
5.	Fatehabad	249110	0	1976
6.	Hisar	386052	1513 (18515)	29640
7.	Jhajjar	186770	5350 (32330)	56907
8.	Jind	273600	0	10278
9.	Mewat	150027	0	12315
10.	Palwal	136455	1137	8264
11.	Panipat	124988	0	18337
12.	Rewari	155900	0	0
13.	Rohtak	166777	1419 (7370)	76355
14.	Sirsa	427600	14330	109995
15.	Sonipat	226053	1342	24643
	State Total		**35809 (85626)#**	**415913**

*Values in parenthesis are based on actual survey carried out by Department of Agriculture and Farmers Welfare, Haryana, # Total in parenthesis includes recent estimates

Accordingly, salt affected soil in Haryana are spread over an area of about 232600 ha out of which about 49200 ha is saline, and 183400 ha sodic (alkali) in nature(Table 1.5). Water logging problem occurs mainly in saline areas with only few areas being waterlogged in alkali affected areas.

Table 1.5 District-wise salt affected soils in Haryana

Serial number	Name of the district	Saline soil (ha)	Alkali/sodic soil (ha)	Total area (ha)
1.	Ambala	718	5047	5765
2.	Bhiwani	107 (7891)*	891	998
3.	Fatehabad	-	10024	10024
4.	Faridabad	3470	6015	9485
5.	Gurugram	8465	1229	9694
6.	Hisar	7770	2868	10638
7.	Kaithal	832	6685	7517
8.	Karnal	3369	29792	33161
9.	Kurukshetra	-	19674	19674
10.	Jind	3680 (4241)	21906	25586
11.	Jhajjar	8357 (15953)	647	9004
12.	Panipat	872	35303	36175
13.	Rewari	283	-	283
14.	Rohtak	8563 (14058)	3757	12320
15.	Sirsa	291	4290	4581
16.	Sonipat	2380	33679	36059
17.	Yamunanagar	-	1592	1592
	Total (ha)	**49157 (71593)#**	**183399**	**232556**

*Values in parenthesis are based on actual survey carried out by ICAR-CSSRI, Karnal,#Totalin parenthesis includes recent estimates

.2.3 Poor quality water

Quality of groundwater in Haryana is being monitored by CGWB, Chandigarh, GWC, Panchkula, CCSHAU, Hisar and ICAR-CSSRI, Karnal. Whereas CGWB, and GWC monitor quality of groundwater mainly in terms of EC and some toxic elements (drinking point of view), the other two organizations monitor the quality in terms of its potential for irrigation. Thedistribution of poor quality water in Haryana from EC point of view and irrigation point of view (EC and SAR) is depicted in Fig. 1.3 (Left and Right). If we compare these figures, it is clear that EC alone does not represent the true picture of the problem of water quality. Combination of EC and SAR does improve the assessment of the problem but is not enough. Recent information onwater quality collected by All India Coordinated Research Project,Hisarcenter and ICAR-CSSRI, Karnal is based on EC, SAR and RSC (Table 1.6). The good quality water in the selected districts ranges from about 15% to 47%. The remaining water,if used for irrigation on acontinuous basismay present some kind of problems. It is assessed that area underlain by brackish groundwater on an average is nearly 60% of the total geographical area of the state.

Table 1.6 Groundwater quality distribution (%)in different districts of Haryanaas per guidelines of Table 1.3

Sr. No.	District	Good	Marginally	Saline Saline	High SAR Saline	Marginally Alkali	Alkali	Highly alkali
1.	Bhiwani	15.2	18.1	10.9	34.0	2.0	3.3	16.5
2.	Faridabad	30.9	34.6	1.4	12.4	12.4	3.7	4.6
3.	Fatehabad	47.2	14.1	2.3	16.8	5.1	3.5	11.0
4.	Gurugram	39.7	18.4	5.9	13.5	11.1	4.5	6.9
5.	Hisar	26.3	20.5	5.5	39.2	1.1	1.1	6.3
6.	Jhajjar	34.4	19.5	1.8	21.4	3.4	3.6	15.9
7.	Jind	36.3	33.0	13.0	17.2	0.0	0.2	0.2
8.	Kaithal	47.0	12.0	0.0	8.0	11.0	13.0	9.0
9.	Mahendragarh	20.7	12.7	6.0	12.0	12.4	5.0	31.2
10.	Mewat	30.0	26.0	2.0	32.0	5.0	1.0	4.0
11.	Palwal	30.3	22.4	2.8	30.0	3.5	0.9	10.1
12.	Panipat	46.1	10.5	2.7	4.5	15.5	10.6	9.9
13.	Rewari	33.2	21.6	5.9	19.1	10.1	8.1	2.0
14.	Rohtak	25.2	23.9	5.0	17.4	10.1	7.1	11.3
15.	Sirsa	29.1	23.1	10.1	31.5	5.3	0.9	0.0
16.	Sonipat	31.4	19.5	4.4	18.6	6.5	3.7	16.0

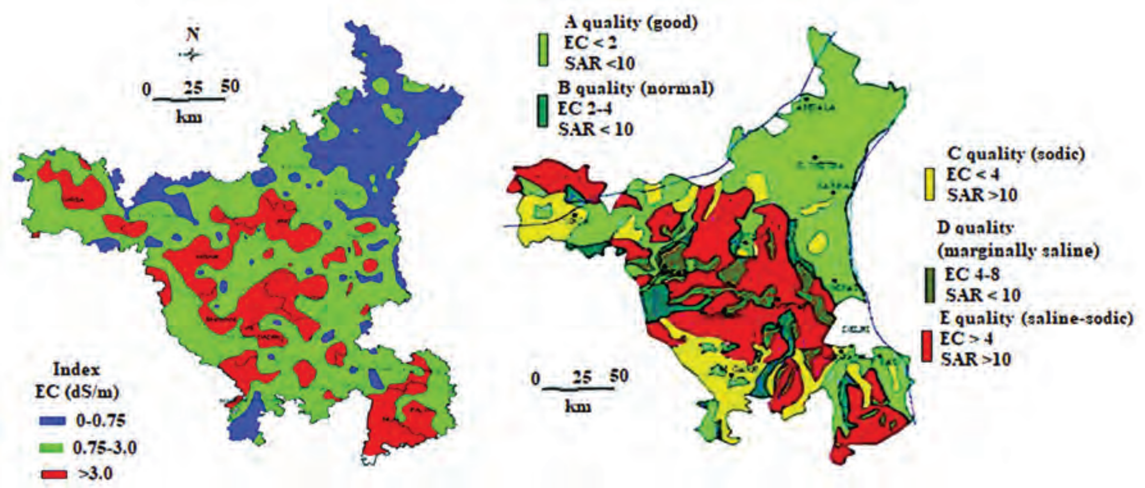

Fig. 1.3 Water quality map of Haryana based on EC (CGWB, left) and EC, and SAR (CCSHAU, right)

4.3 Evidences of Area Expansion under Water Logging and Soil Salinity

In a recent survey by the Department of Agriculture and Farmers Welfare (MoA&FW), critical water logging is reported in about 67500 ha and potential water logging in about 95000 ha in only four districts namely Rohtak (increase from 1419 to 7370 ha), Jhajjar (increase from 5350 to 32230 ha), Sonipat (increase from 1342 to 18515) and CharkhiDadri (not much change from 9566 to 9450 ha). Overall, the area under water logging in the state has increased from35809 to 85626 ha. The data by MoA&FW is based on field visits to the respective districts to collect baseline data for initiating subsurface drainage projects.The increasecould either bedue to annual shifting of areas from potential to critical water logging or due to the limitation of the method used in delineating the areas with limited numbers of observation wells for monitoring. Similarly, the area under soil salinity has increased in 4 districts namely Bhiwani (107 to 7891 ha), Jind (3680 to 4241 ha), Jhajjar (8357 o 15953) and Rohtak (8563 to 14058 ha)as reported by Sethi, et al. (2012) of ICAR-CSSRI, Karnal. The overall increase in the extent of saline soils is from 49157 ha to 71593 ha. Reports have also come that large stretches of waterlogged areas in Fatehabad district have turned saline. Similar increase in respect of water logging and soil salinity might be expected in other districts. It appears that menaces of water logging and soil salinization will further increase with time, if we continue to follow the business as usual approach.

5.0 MONETARY LOSSES DUE TO WATER LOGGING AND SOIL SALINITY

The soil salinization has significant adverse impacts on agriculture, environment, ecology, and social fabric of the affected regions. Adverse impacts appear in terms of decrease in cultivated land, low agricultural productivity, reduced value of land, uncertain and unstable livelihood security, low economic returns, and poor quality of life. Initially, small patches of soil salinity begin to appear that mostly go unnoticed. These patches continue to expand such that yield loss increases evento the extent of 80% (Fig. 1.4 left). At this stage most farmers abandon cultivation. These lands then turn barren, often termed as wet deserts, where no crops can be grown (Fig. 1.4 right). ICAR-CSSRI carried out an extensive survey in several irrigation commands of north India and concluded that crop loss due to water logging varies in the range of 38-77% and due to salinity from 40 to 63%. On the basis of base line surveys carried out in Haryana in various districts, it emerged that wheat yield in affected areas is in the range of 10-12 q/ha, paddy 3.2-10 q/ha and pearl millet 10-12 q/ha. These yields are uneconomical, give negative returns with B:C ratios less than 1.0 (See section 8.1.4 Table 1.9). Still the farmers continue to grow the crops for their household food security. The economic loss due to water logging soil salinity in Haryana was assessed at about Rs. 23,900/ha in 2002by Datta and Jong. ICAR-CSSRI estimated annual monetary losses due to water logging, soil salinity and soil/alkalinity in 2015 at 7.78 billion, out of which annual losses attributed to water logging and soil salinity are 1.24 billion (Sharma et. al., 2015). Projected loss of inaction to reclaim 40500 ha (100000 acres) is assessed at 4.40 billion for rice-wheat and 1.72 billion for pearl millet-wheat sequences per annum. It takes into account current cost of cultivation, prevailing MSP of rice, wheat and pearl millet, commonly reported yields of these crops in salt affected lands and the expected optimum yields after 3-4 years of reclamation.

Fig. 1.4 Photographic views of salinity patches in cultivated land (left) and a completely barren salt affected soil (right)

5.1 Escalation in Cost of Land Reclamation

The issue of increasing cost of land reclamation over the yearshas not been flagged so far. As stated in section 4.1, reclamation of the entire area in Haryana through drainage and other measures was estimated at Rs. 7200 million in 1984, which nearly trebled to Rs. 23000 millionin 2000. Per ha cost of reclamation through SSD and biodrainageor per tube well cost for vertical drainage as assessed in 1998 and 2020-21 reveal significant increase (Table 1.7). The increase may be attributed to improved technology (Solar pumps in horizontal and vertical drainage) and inclusion of operation and maintenance cost for 3 years in the case of vertical drainage. It may not be out of place to mention that cost of horizontal subsurface drainage may further increase to about Rs. 150000/ha. It is mainly because of the higher fixed cost of the new machines needed to implement the technology. Thus, any delay in land reclamation not only deprives the state of additional revenue assessed at 3.06 billion per annumat current pricesbut will also require higher investments for land reclamation in future. Thus, there is an urgent need to allocate adequate funds for sustainable land and water management and for restoring degraded ecosystems in the state in a time bound manner.

Table 1.7 Escalation of cost of land reclamation technologies

Technology	Cost per ha or per tube well (Rs.)		Remarks
	1998	2020-21	
Horizontal subsurface drainage, cost per ha	54700	112650	-
Vertical drainage, cost per tube well	360000	1500000	May be because of inclusion of water disposal system, solar pump, 3 years operation and maintenance and a store room
Biodrainage, cost per ha	20000	50000	-

6.0 GOVERNMENT SCHEMES ADDRESSING WATER LOGGING AND SOIL SALINITY

It is matter of great satisfaction that state and central governments are taking several proactive steps to improve production and productivity of agricultural lands and to increase water productivity in agriculture. This section lists and briefly discusses few schemes having direct relevance to the problems of water logging and soil salinity.

Soil Health Cards: Soil health management is one of the most important interventions under National Mission for Sustainable Agriculture (NMSA). Component of soil health card under this scheme can prove to be a boon to the farmers affected by the twin problems of water logging and soil salinity. In problem areas, this scheme should also include water health cards as many of the soil problems in these areas have direct link to water quality. Strengthening of soil testing facilities involving agriculture students, Regional Research Stations of CCSHAU and increasing frequency of visits by mobile soil and water testing laboratories should be ensured in critically affected districts.

Rashtriya Krishi Vikas Yojana (RKVY): It is a flagship scheme having a component of reclamation of problem soils such as saline, alkali and acid soils. It has also a component of crop diversification (MeraPani-MeriVirasat) wherein subsidy of Rs. 7000/- per acre is given for diversifying area under rice to other low water requiring crops. The incentive is also given to rice farmers who decide to leave their fields fallow. In the context of water logging and soil salinity, farmers should be advised not to leave their fields fallow as itmay aggravate the problems.

Direct Seeded Rice Scheme: A grant of Rs. 4000 per acre is given under this scheme to all farmers who opt to shift from transplanted rice to direct seeded rice. Additional subsidy of Rs. 40000 is provided to procure the machine for direct seeding. It is emphasized that direct seeded rice has to be carefully implemented in areas affected by waterlogging and soil salinity.

National Horticulture Mission: The mission objective is to develop horticulture to the maximum potential available in the state and as a means of crop diversification. This scheme can help in alleviating the problems.

Compensatory Afforestation Fund Management and Planning: The scheme has been designed to compensate the forest area whenever the forest land is diverted to non-forest uses. Inclusion of waterlogged salt affected soils in this scheme is welcome as it will help in overcoming the problem of water logging. Waterlogged saline lands should also come under the purview of schemes like ‘Trees Outside Forests in India (TOFI)’ and oxy-forests.

Construction of Ponds in Saline/Alkaline Areas: This scheme can prove to be a game changer as on-farm ponds can facilitate quick drainage, as well as used for aquaculture and multi-enterprise agriculture.

Pardhan Mantr iMatsaya Sampda Yojana(PMMSY): This scheme is advantageous for planning alternate use of waterlogged saline lands. There is an urgent need tofine tune thesubsidy components of this scheme since the cost of white shrimp cultivation in inland saline areas is comparatively much higher than the coastal regions.

National Mission on Agriculture Extension and Technology: Restructuring and strengthening agricultural extension to enable delivery of water management technologies should receive priority in waterlogged salt affected districts.

Pardhan Mantri Krishi Sinchai Yojana (PMKSY): It is a flagship programdevised to expand area under assured irrigation, improve on-farm water use efficiency, adoption of precision irrigation including other water saving technologies, and use of treated wastewater for irrigation. More Crop per Drop and Community based micro-irrigation on canal outlets is also a component of this scheme. Application of these technologies can prove quite useful in preventing further spread of the problems.

Rainwater Harvesting Scheme (Jal Shakti Abhiyan): "Catch the Rain Where it Falls When it Falls" is the slogan that highlights the objectives of this scheme. It is an important component of the package of practices to reclaim saline and saline water irrigated lands.

There are plenty of schemes that address the development of agriculture and irrigation water management in general and problem soils in particular. The utility of these schemes can be further enhanced by taking some of the following steps.

- Too many sub-schemes under the main schemecan be avoidedto minimize confusion amongst the stakeholders
- Extension agencies should be deeply involved in popularizing the schemes and their benefits amongst the stakeholders
- The staff besides disbursing subsidy should ensure handholding in implementing the technologies. This aspect is normally left to the dealers
- Monitoring, evaluation and mid-term corrections should be ensured right in the initial document of the schemes
- Enough funds under each scheme should be provided so that beneficiaries get immediate funds before theystart losing interest

7.0 LAND RECLAMATION AND MANAGEMENT

Water logging and soil salinity problems in Haryana are 3-in-1 kind of problems occurring either singly but mostly in combination. The three problems are:

- Water logging
- Soil salinity
- Saline/alkali groundwater

The degree of the problems also varies from one location to another. The extent of the problems discussed in section 4.0 mainly relates to areas that have gone out of cultivation. On the other hand,problems have already invaded large areas where yield reduction is in the range of 10-

50%. Most fascinating aspect of land degradation is that this process is reversible. But it is easier said than done. Reversing land degradation is possible only under much-reformed land and water governance especially at macro-scale. Recent advances in agricultural research have broadened the technical palette for land and water management, but the problems arise when one looks for 'one size fits for all' solution that does not exist. Besides, the problems also arise when half- baked solutions are applied or part solutions are applied half-heartedly. Not all problem lands may require costly interventions. Whereas some of the lands are amenable to preventive measures, others may require some kind of costly reclamation measures. Many workable packagesto reclaim site specific waterlogged salt affected soilsare available, butall of them will yield positive results only under enabling environment, and inclusive land and watergovernance.

7.1 Preventive Measures

Preventive measures are short-term interventions to buy time before a suitable drainage program is in place. Three suchinterventions are adoption of appropriate cropping patterns that require less water, select crops and varieties that are tolerant to salts, and adoption of improved water management practices. These practices implemented over large areas will help further spread as well as lower the reclamation cost of the remaining areas.

7.1.1 Crop diversification

Rice-wheat crop rotation has significantly expanded in the state, even to districtswhich are not suitable for the cultivation of this crop. This cropping sequence cannot be sustainedin these districts because of low rainfall and inadequatewater supplies. Moreover, soils beinglight textured, excessive deep percolation losses occur from transplanted rice fields resulting inexpansion of water logging and soil salinity. Salt tolerant coarse grain barley and sugar beet, millets such as sorghum (*Jowar*), pearl millet (*Bajra*), finger millet (*Ragi/Mandua*) and minor millets, drought tolerant horticultural crops(date palm, Indian jujube, jamun, Indian gooseberry, karonda, and bael), grasses for fodder and medicinal and aromatic plants can prove quite beneficial in crop diversification programs. This adaptive approachplanned at the watershed or landscape level can reduce environmental degradation and restore the ecosystem. This simple option can be easily adopted by the farmers. It can prove to be the key to future agricultural and economic growth ofregions infested with salt affected soils and/or where saline groundwater is used for irrigation. Crop diversification program, a sub-scheme of RKVY should focus on this program in salt affected soils.

7.1.2 Cultivation of salt tolerant crop varieties

Use of salt tolerant varieties is one of the cheapest and easily adoptable option to solve the problem of soil salinity. Farmers can continue to grow same crops which they are growing but can switch to new high yielding salt tolerant crop varieties. This approach has proved quite useful in alkali land reclamation in Haryana, Uttar Pradesh and for saline soils in Andaman and Nicobar following Tsunami disaster. ICAR-CSSRI, ICAR- Indian Institute of Wheat and Barley Research (IIWBR), ICAR- Sugarcane Breeding Institute (SBI) and several other institutes have developed many high yielding salt tolerant crop varieties through biological manipulation of the plants (Table 1.8). These varieties can also be used with poor quality irrigation wateras is commonly encountered in water logged salineareas. Efforts on breeding crop varieties must continue with renewed vigour as new varieties are vital to boost yields under various stressors, such as drought, water logging, heat waves, cold and salinity. Besides, these can prove to e quite useful in climate smart agriculture and complementingother solutions of land reclamation.

Table 1.8 Promising salt tolerant crop varieties for saline and alkali soils

Crop	Varieties	pH/ESP	Salinity, EC_e(dS/m)
Rice	CSR 10, CSR23, CSR27, Basmati CSR30, CSR36, CSR 43, CSR 46, CSR 49, CSR 52, CSR 56, CSR 60, CSR 76	9.4-9.8	7-10
Wheat	KRL 1-4, KRL 19, WH 157, KRL 210, KRL 213, KRL 283, Raj 3077, KRL 283	9.2-9.3	6.5
	HD 2009, HD 2285, HD 2329, WH 542, C 306	8.7-9.0	5.5
Indian mustard	Pusa Bold, Varuna, Kranti, CS52, CS54, CS56, CS 58, CS60, CS61, CS62	6.9-9.5	6.5
Barley	RD 2907, RD 2552, CSB1, CSB2,CSB3, DL200, BH97, BH 393, DL348	< 9.3	11.0
Sugar beet	Ramonskay 06, Poly rava – E, Tribal, Meribo-resistapoly, LS 6,IISR Comp 1 and LKC 2020	9.5-10.0	10.0
Sugarcane	CO 453, CO 1341,CO 6801, CO 62329 and CO 1111	<9.0	-
	CO395, CO 453, CO 87263, CO 975, CO 453, CO 1148	-	Water logging and salt tolerant
Gram	Karnal*chana*1	<9.0	6

7.1.3 On-farm water management

Water logging can be managed either by reducing the groundwater recharge or by increasing the groundwater draft. The basic premise of on-farm irrigation water management is to reduce groundwater accretions.

Lining of water courses and field channels: Liningof canalsis practiced to minimize seepage losses. But significant seepage losses occureven from the lined canals as lining deteriorates with time. It has been observed thatseepage losses are more or less the same as from an unlined canal, ifthe lining is damaged by about30% or more. Therefore, allsuch reaches should be identified andrelined especially in waterlogged saline areas.

Conveyance losses through leakage and seepage in the water courses and farm field channels constitute a major loss especially in unlined, ill-maintained water courses and channels. For a fully unlined canal system, water use efficiency is assessed at about 30%or even less. Losses in water courses and field channel can be as high as 22% and field percolation losses as high as 27% constituting about 50% of the water diverted for irrigation. These losses can be reduced to about 12% with lining of water courses, field channel and replacing flood irrigation with sprinkler irrigation. Underground conveyance of water in the water courses and field channels coupled with drip irrigation can reduce the losses to less than 10%. Good initiative of rehabilitation/extensionof watercourses is being taken up by the Department of Water Resourcesto realize the vision of "Har Khet KoPani".

Land leveling: The field application losses are quite high going up to 40% of the water delivered to the farm. Laser land leveling is the latest method used to precisely level the land. It helps to save as much as 15-20% irrigation water over traditional land leveling. Besides,10-15% increase in wheat yield is achieved in the rice-wheat cropping sequence. Similar increase in yield has been reported for other crops besides facilitating cultivation of direct seeded rice.

Rainwater conservation: Conservation of rainfall through land management is the best way to ensure uniform leaching of saline or saline water irrigated lands. Proper land leveling with provision of 30 to 40 cm high strong bunds is essential pre-requisite for capturing and retaining rainwater for this purpose. Ploughing the fields in between rains also increases the intake of rainwater for leaching.

Improved irrigation techniques: Traditionally, water is applied through uncontrolled flooding,whichis the least efficient method of water application. Proper selection of irrigation method that suits the crop and is in tune with the soil characteristicscan save 20-40% water available at the field head compared to traditional method of flooding. Border irrigation method is suitable for irrigating wide varieties of close growing crops such as wheat, barley, groundnut, pearl millet and berseem. Furrow irrigation system is primarily used for vegetable crops but is equally suitable for other crops that are line sown. Broad bed furrow planting of wheat is recommended because itnot only savesirrigation water but also gives higher yields. Ring basin method is best for orchards against the practice ofirrigatingthe whole orchard.

Sprinkler and drip irrigation: Precision agriculture by way of micro-irrigation (drip and sprinkler) must become a compulsory agenda in our efforts to save water. Amongst all methods, sprinkler and drip irrigation are the most efficient in conserving irrigation water. Just to illustrate the benefits in terms of water saving, the net utilization of water in canal command area is of the order of 46 per cent for a wholly lined conveyance system with traditional methods of irrigation. It increases to 82 and 90% under sprinkler and drip irrigation respectively. Thus, a shift from flood irrigation to pressurized systems offer a single most effective means to enhance water use efficiency. Comparative performance of surface and sprinkler irrigation have shown that nearly 40% savings in water and about 20% increase in yield of crops like wheat, maize, pearl millet etc can be achieved with sprinkler irrigation. About 50% increase in yield can be obtained with almost half the water in drip irrigation compared to traditional surface irrigation. Besides, 50% saving in fertilizers can be achieved through fertigation because of improved nutrient use efficiencies.Great opportunities exist for the expansion of drip irrigation for crops such as cotton and sugarcane.

Drip and sprinkler irrigation are preferred methods to have better control on salt and water distributions. For example, when saline water is used for pre-emergence application then soluble salt concentration in the seeding zone is lower in sprinkler irrigation than other surface irrigation methods. It results in better germination, higher plant population and growth of crop. Similarly, frequent irrigation with drip irrigation system maintains optimum soil moisture that does not fluctuate much as in surface irrigation methods. The salts in a high moisture regime remain diluted besides moving away from the plant roots towards the wetting front. These systems can be used in saline soils as well as for irrigation with saline water.

Irrigation scheduling: Irrigation scheduling is the decision of when and how much water to apply to a field. In waterlogged areas a part of irrigation water requirement is met from shallow water table even if water is brackish (<6 dS/m) in nature. Therefore, one can save at least 1-2 irrigations in wheat crop,if the water table remains in the range of 0.5 to 1.0 m.

Water saving technologies in rice: Most farmers don't want to lose the benefits of rice crop in terms of its MSP and easy marketability. Water saving techniques such as shift to direct seeded rice, application of irrigation at hair cracking stage in transplanted rice, short duration rice varieties and storage of rainwater in rice fields should be promoteduntil farmers are convinced of crop diversification.

Innovative on-farm drainage techniques: Water retained in large topographical depressions ultimately percolates to the groundwater aggravating the problem of water logging.These depressions can be converted into on-farm or community ponds for efficient drainage in land locked fields. On-farm ponds help in immediate clearance of shallow submergence in the cropland. A deep pond say about 1.75 m may also lower the water table in the adjoining area to some extent. The state has taken note of this intervention and is keen to exploit its potential through Pond Authority of the state. Bore hole technology is yet another innovative means of providing immediate drainage to local saucer shaped depressions. The only concern is about the quality of agricultural runoff that may be laden with silt, chemical fertilizers and pesticides. Since the waterdirectly enters the aquifer, it may spoil the aquifer and pollute the groundwater. Therefore, impeccable investigations must be carried out before this set-up is used at a particular site. There is no margin of error in this case lest the future generations pay for our mistakes.

7.1.4 Conjunctive use of saline and fresh waters

Potential of highly saline waters or brackish water can be exploited through conjunctive use of saline and fresh water. Two basic practices for conjunctive use are blending and cyclic use.

Blending: Main principle of blending fresh and saline water is to mix two types of water in suitable proportions so that the salinity of the mixed water is less than the permissible limit of crop salt tolerance.

Practically, it can be achieved by blending saline water in the water course/field channels or by constructing a pond at the farm where fresh and saline water can be mixed. The best way of course is to mix the saline water in the irrigation network keeping in view the downstream requirements.

Cyclic mode(s): Two sources of water are independently used in this mode in a pre-defined sequence. For example, one sequence is alternate use of fresh and saline water. In this case,irrigation with fresh water is followed by irrigationwith saline water. The other option can be switching mode where first few irrigations are given by fresh followed by few irrigation with saline water. Overall salt build-up in the root zone is relatively less. Following precautions should be exercised to take full advantage of this mode.

- Use fresh water in the initial crop growth stages (Palewa and first irrigation) and at critical growth stages at which crop is sensitive to salts
- Delay the application of saline water as much as possible because crops are relatively more tolerant to salts at later than at initial growth stages.

The rainwater harvested in farm ponds or from roofs of the farm structures can be a good source of irrigation water for conjunctive use in cyclic mode.

7.1.5 Alkali water

Alkali water having RSC>2.5 meq/l has to be used with caution as regular application of this kind of water will turn the soil alkali in nature. Alkali water can be successfully used with application of chemical amendments such as gypsum, pyrites or press mud etc. Gypsum is commonly used amendment and has to be applied every year. Therefore, we recommend that:

- Organizations involved in monitoring groundwater quality should prepare RSC based irrigation water quality maps. Such a map may depict both EC and RSC or a separate map may be prepared to depict RSC waters
- Department of Agriculture and Farmers Welfare may identify such areas where alkali waters are found in abundance. The department may extend the technology of amendment application and arrange gypsum on annual basis at appropriate subsidy

8.0 RECLAMATION TECHNOLOGIES

Water logging in any region is attributed to mismatch between the groundwater accretion and groundwater draft, former being in excess of the later. Therefore, the only way to reclaim these areas is by reducing accretions as discussed in section 7.0 and increasing the draft. Reclamation technologies discussed in this section are basically meant to increase groundwater draft. Three commonly usedtechnologiesbesides surface drainage discussed in previous section are: horizontal subsurface drainage, vertical or tube well drainage, and biodrainage. Disposal or reuse of saline drainage effluent in horizontal and vertical drainageforms an integral part of the drainage projects. The lands not amenable to reclamation through these techniques can be put to some productive use such as aquaculture, solar parks and biomass production discussed in section 9.0.

8.1 Horizontal Subsurface Drainage System

Horizontal subsurface drainage constitutes laterals, and collectors made of perforated corrugated Polyvinyl Chloride (CPVC) pipes. While lateral pipes are laid at an average depth of about 1.5 m, collectors are placed at slightly deeperdepth below the ground surface. Existing surface drains constructed by the state Irrigation and Water Resources Department serve as the main line of the system. Research work on this technology was initiated by ICAR-CSSRI at Sampla, Rohtak- Haryana in 1978-79 (Gupta, 2019). It is probably the only one of the three technologies that has been intensively and extensively researched. Realizing that reclamation does not end with installation of a drainage system, a package of practices has been prepared to get optimum yields from reclaimed lands. On the basis of encouraging results of the Sampla field studies, HORP was established with support from the Government of the Netherlands in 1995. At about the same time, Government of Rajasthan initiated a project named Rajasthan Agricultural Drainage project with the help of Government of Canada. Later on, a network pilot project (supported by the Government of the Netherlands) came into operation to test the efficacy of the system under various agro-hydrological settings. Pilotstudiesin Haryana covered several districts namely Mundlana and Kailana Khas in Sonipat, ICAR- Central Institute of Research on Buffaloes (CIRB) and CCSHAU and HLRDC farm at Hisaretc. Most ambitious work was accomplished at Gohana (Rohtak) and Kalayat (Kaithal) under HOPP. Drainage guidelines have been framed for different agro-climatic conditions using information generated over a period of more than 30 years. Drainage systems designed on the basis of these guidelines currently cover 11300 ha area in Haryana and around 75000 ha in India. Some salient features of this technology adopted by ICAR-CSSRI and HOPP are:

- Priority is given to severely affected areas(Fig. 1.5 left). The drainage laterals and perforated collectors are laid on killa lines in Haryana (Fig.1.5 middle)
- Pre-installation interaction with the stakeholders includedtheir field visits to operational drainage sites, training, and organization of kisanmelas at the project site. Post-installation hand holding proved to be the key to success (Fig. 1.5 right). Such an approach should be replicated in all drainage projects irrespective of the drainage technology being implemented
- Quantity of drainage effluent is quite less as drains are established at shallow depth (average of about 1.5 m). Moreover, it is of relatively better quality than the deeper depths tapped in vertical drainage. Limited quantities of the drainage effluent aredisposed of in a nearby surface drain only for the first 1 or 2 years. Later on, it is used to irrigate the crops. Subsurface drainage water at Kalayat and Jagsiwas used by the farmers even in the first year. The man holes in the fields served as horizontal wells to skim the fresh water floating on brackish water.
- Farmer's Drainage Societiesfor each block are constitutedfrom the very beginning to ensureeffectiveparticipationofthefarmers. These societies are given the responsibility of operation and maintenance of the systems

- Reclamation in a subsurface drainage projects begins from the first season itself yielding about 70% of the optimum yield of most crops. Optimum yields are obtained within 3-4 years. The system is economically and financially viable (Section 8.1.4)

8.1.1 Replication of Egyptian model of subsurface drainage

Government of the Egypt established the Egyptian Public Authority for Drainage Projects to implementlarge-scale drainage projects to cover the whole irrigated area. Drainage Research Institute, Cairo, Egypt (equivalent of ICAR-CSSRI) was established toprovide technical support to the implementing authority. This model can be replicated for large-scale implementation of drainage projects in Haryana by holistically restructuring and strengthening the HOPP. ICAR-CSSRI has model Memorandum of Understanding (MoU) with HOPP, which can be suitably restructured.

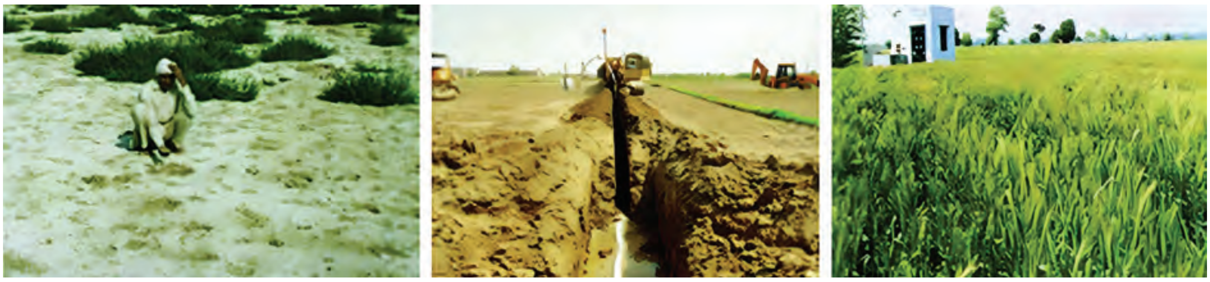

Fig. 1.5 Highly saline soil (left), mechanized laying of subsurface drainage (middle) and bumper crop of wheat in the reclaimed land

The group examined two options to undertake this gigantic task. One is the restructuring of HOPP and other is the outsourcing of work through an open bidding system. Both the options have their merits and demerits but can well serve the purpose of the state.

8.1.2 Restructuring of HOPP

HOPP has now graduated from pilot projects and is implementing large drainage projects in the state. But the current support system for the organization is highly inadequate. To follow the Egyptian model, we recommend restructuring and strengthening of HOPP. HOPPshould be under the direct control and supervision of whole time Project Director (Reclamation) with headquarters at Panchkula. He should be in the rank of Additional Director Agriculture. He should be responsible to coordinate, manage and supervise all the activities of the HOPPfor which adequate staff should be provided to him.A decision at the highest level is needed to strengthen this implementing agency and broaden its scope of work.

Working headquarters: HOPP should have two units having their headquarters at Karnal and Hisar. Each unit should be headed by a Deputy Project Director. One unit of deputy project director should have at least two or three trenching machines. Head office of the design engineer should be at Karnal, who should cater to the requirement of both the units for the sake of uniformity.

Machinery: The pace of installing subsurface drainage projects under HOPP during the last 1 decade or so has not been encouraging mainly because of lack of machines and manpower. HOPP has 3 machines, which are quite old, require frequent maintenance and remain non-operational for considerable period of time for want of spares. Therefore, HOPP should be provided with at least 5 new drainage trencher machines to cover at least 4000 to 5000 ha area each year. These machines should be supported by other indigenous machines such as BD-50 bulldozer, JCB excavator loader, 4-wheel tractor trailer, 22.5 KVA generator, dewatering pumps and staff van etc to complete the related activities in the project area.

Staff: In line with the new responsibilities, the staff strength should be substantially increased. Teams at both the units should include Engineers, Agriculture Development Officers, Social scientists, Ministerial staff, Computer operators, Machine operators and Peons/Helpers.

8.1.3 Outsourcing of drainage activities

The other option to undertake land reclamation is to outsource the work to an outside agency. In this set-upHOPP should act as supervising authority. The agency submits the design for approval and implements the project on turnkey basis. The agency should be made responsible to operate and look after the system for at least five years. Third party monitoring and evaluation should be entrusted to ICAR-CSSRI, Karnal. This model was tried at Kalayat in Haryana but was not found workable. Punjab on the other hand implemented several projects by outsourcing the work. No doubt, the model will be bit costly, but it will hasten the pace of land reclamation.The success of this modelis mainly linked to the following two activities.

- A drainage master plan of the state should be prepared so that industry/contractors can appreciate the quantum of work and accordingly equip themselves for this task
- A proper tender document with well quantified quality control parameters should bedeveloped

For these activities, a multidisciplinary inter-departmental group having experienced outside experts should be constituted.

8.1.4 Financial feasibility

Financial analysis of rice-wheat and pearl millet-wheat crop sequences was carried out considering current cost of cultivation and prevailing MSP. It emerged that subsurface drainage is financially viable for both the crop sequences (Table 1.9). An investment of Rs. 100000/- per ha made on the system is fully recovered in 2 years i.e. the payback period is just 2 years. Previous studies have indicated payback period of 3 years. Our analysis seems justified becausewe have not included operational cost because of the use of solar pumps as against diesel pumps used in the previous projects. If these results are projected over an area of 40500 ha (100000 acres) net profit of Rs. 2.87 billion is generated in rice-wheat sequence and Rs. 1.78 billion in pearl millet-wheat sequence in the first year with an initial investment of Rs. 4.05 billion. From 4th year onward these values will increase toRs. 6.27 billion andRs. 4.16 billion per annum for the two cropping sequences respectively.

8.2 Vertical or Tube Well Drainage

Principally, tube wells can effectively lower shallow water table as experienced in about half of the state where groundwater quality has been excellent and farmers are able to use the water for irrigation. Group is of the opinion that application of this technology to reclaim waterlogged saline soils may not be as effective as in areas ofgood quality groundwater. Vertical drainage systems implemented on large scale in Pakistan were abandoned because the tube well components got rusted within few years of operation as the groundwater was highly saline in nature. The experiences of Department of Soil Conservation in Punjab and Department of Water Resources in Mahi Kadana command have also been far from satisfactory mainly because of slow drawdown during critical periods and disposal problems of saline water.

Table 1.9 Financial analysis of land drainage for waterlogged saline soils

Crop sequence	Before drainage treatment	Net profit (Rs./ha), BC ratios and lease rate (Rs./ha) years after drainage treatment			
		1	2#	3	4*
Rice -wheat					
Net profit	-59973	70951	96190	121533	146765
BC ratios (rice-wheat)	0.22 - 0.66	1.53-1.90	1.74-2.17	1.96-2.44	2.18-2.71
Pearl millet-wheat					
Pearl millet-wheat	-13577	44148	61067	77986	94794
BC ratios	0.96-0.66	1.23-1.90	1.41-2.17	1.58-2.44	1.76-2.71
Lease rate					
Lease rate	12500	50000	625000	75000	87500

#Cost of reclamation assessed at Rs. 100000/- is recouped in the second year in rice-wheat and pearl millet-wheat rotations; *After 4 years land is fully reclaimed and the benefits will continue to accrue at the same rates

On the basis of synthesis of the available guidelines and SWOT analysis of various drainage options, it emerges that most practical application of this technology can be around canal networks where EC of the groundwater may be around 4-5 dS/m because of dilution. Damage to the submersible pumps in that case will be minimal. The pumped groundwater can be disposed of in the canal system (Fig.1.6 left). Irrigation water quality guidelines discussed in Table 1.3 should be used to decide the mixing ratio of the drainage effluent and canal water. Moreover, it must be ensured that tube well water does not contain any toxic elements because the canal water is used for drinking purposes downstream. BIS drinking water quality standards should be strictly adhered.We learnt that some projects of this nature have been implemented and are working well. The plan is to handover the systems to the farmers after 3 years of operation. Worthwhile communication should be established with the farmers from the beginning so that they are aware of the benefits of the project. It will encourage them to take over the project after 3 years.

The other areas that are amenable to this technology are along drains having relatively high discharge (Fig. 1.6 right).The farmers downstream of the project may resist the disposal of saline water in drains because they fear that salts may intrude into their fields through seepage/leakage or due to use of drain water for irrigation in emergent situations. In irrigation-cum-drainage channels, downstream farmers are more concerned about the quality deterioration of irrigation water. This issue has emerged in Sikrona (Faridabad) vertical drainage project. Therefore, appropriate conflict resolution mechanism must exist in the project framework. To be safe, the salinity of the mix water in these drains should not exceed 2 dS/m. It will allow downstream farmers to use the water for irrigation.

The group realized that there are no worthwhile guidelines on vertical drainage system design and operation except the one recently framed by ICAR-CSSRI and HOPP based on limited experience of two projects. Therefore, site specific drainage investigations for implementing any vertical drainage project should include: geo-hydrological conditions, availability of good quality aquifers (transmissibility exceeding 600 m^2/day), groundwater salinity profile (in Haryana salinity in general increases with depth), layout and arrangement of wells, overlapping of cones of depression, construction and maintenance of the system and willingness of farmer's to take over the system after initial few years of operation. The layout of the wells must ensure some overlapping of cones of depression to ensure uniform lowering of the water table and leaching of salts. Otherwise the reclamation will be patchy in nature. The water disposal problem in a vertical drainage is about 10 times more than a horizontal subsurface drainage system to achieve similar draw downs. Therefore, disposal of saline drainage effluent should be given highest priority while implementing a vertical drainage project.

Fig. 1.6 A view of vertical drainage system installed along canal near Meham(left) and a vertical drainage system installed at Sikrona (right)

8.2.1 Skimming wells for vertical drainage

Native salinity of groundwater in areas affected by water logging and soil salinity is high. The groundwater salinity normally increases with depth. Often times, aquifer quality is also poor that cannot sustain high discharge wells. Fortunately, good quality groundwatermounds oftendevelopover the saline water because of recharge from rainfall, other water bodies especially from irrigation network. As a result, a fresh water layer develops that floats over native saline groundwater. The thickness of this freshwater layer varies from place to place depending upon the native topography, infiltration rate and quantum of recharge. The water in this layer is fresh to marginal in nature and can be directly used for irrigation. A single well in this set-up may result in up coning of saline water resulting in mixing of saline and fresh water (Fig.1.7 top). Therefore, various skimming well techniques are used to extract freshwater including conventional shallow wells (coastal Andhra Pradesh), multi-strainer (multi-point) wells (southwest Punjab, Haryana and Indus basin Pakistan, Fig. 1.7 bottom), radial collector wells (coastal Andhra Pradesh), scavenger wells and dug wells. Any of these techniques can be used to skimfresh layer of water without interfering with the saline water in the lower layer. Amongst all, multi-strainer skimming wells have become quite popular because such aset-up is easy to install and operate. Since the discharge of one well is quite less, 1 to 6 shallow tube wells (multiple well point system)are used and operated with a single pump. Although, there are little chances ofupconingof saline water yet it can be minimized by proper operation of the tube wells. These kinds of wells can be encouraged along canal network in the state. Experienced drillers can help to tap the fresh water layer. Farmers opting for this technology on their own may be incentivized by providing solar pump with appropriate subsidy on priority basis.

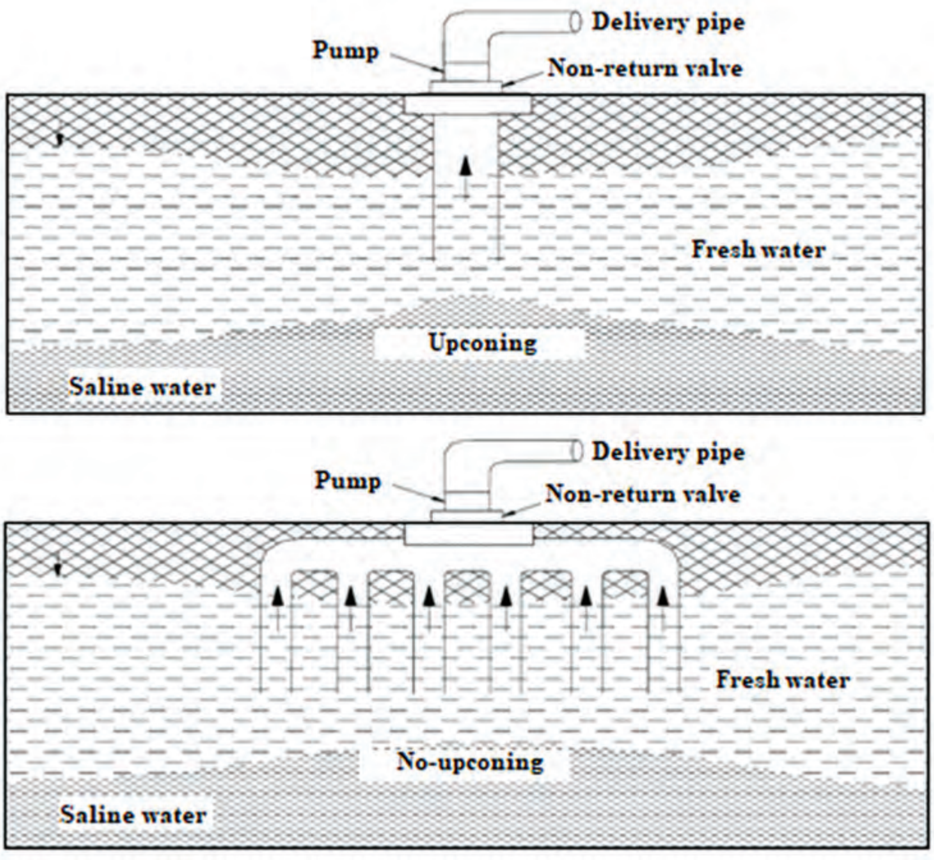

Fig. 1.7 Single strainer well with up coning (top) and a multiple strainer skimming well without up coning (bottom)

8.3 Biodrainage

Biodrainage has been proposed to reclaim waterlogged saline lands on the basis of some international experiences especially of Australia and our own experience in the Indira Gandhi Nahar Pariyojana (IGNP) in Rajasthan, The primary requirements for planning a biodrainage system are: to identify trees tolerant to water logging and soil salinity, assessing the water balance to decide number of plants required to consume excess water and precise identification of recharge and discharge sites to decide the planting sites in the command. National Academy of Agricultural Sciences, New Delhi organized a brain storming session and came out with a Policy Paper on biodrainage (NAAS, 2015). The paper lists *Eucalyptus* species such as *Eucalyptus hybrid*, *Eucalyptus tereticornis C-10*, *Eucalyptus tereticornis C-130*, and clone *Eucalyptus* as the principal plant species for water logging control and reforestation. *Acacia ampleceps* and *Prosopisjuliflora* are also good candidates for biodrainage. Potential of biodrainagecan be exploited to control seepage along canal networks (Fig. 1.8 left) and as a preventive measure for potentially waterlogged oflow to medium salinity (Fig. 1.8 right). Moreover, it is possible to use the potential of trees to bio-drain some of the excess water with general agro-forestry plantations.It will help in reducing accretions to groundwater.

Fig. 1.8 View of biodrainage along canal network to intercept seepage (Left) and a biodrainage system installed on killa line in a potentially waterlogged low salinity land

In order to understand the limitations of the technology, the group critically examined the IGNP Phase II project, which formed the basis of recommending biodrainage for land reclamation. IGNP phase II is a contour canal that irrigates the fields only on one side. Trees for biodrainage were put on the upper side where canal water isnot available for irrigation. The seepage water accumulated in borrow pits on this side was evaporated by the plants grown on a 261 m wide strip along the canal. Thus, this classic example does not represent the real field situation where deep percolation losses besides seepage constitute a greater fraction of water accretion to the groundwater. Moreover, few other problems are also associated with this technology. Firstly, it may almost be impossible to spare a very wide strip along canals or roads in Haryana. Secondly, most reports mention that real benefits of biodrainage accrue only after 3 years of plantation. Thus, a gestation period of about 2-3 years in the beginning as well as after every harvest will be encountered. Thirdly and the most important one is the likely inability of the biodrainage system to maintain salt balance. It is because salt uptake by the plants is negligible compared to the total salt applied through irrigation or that enters the root zone through capillary rise. As such, biodrainage may not be workable in areas where groundwater salinity is high say > 10 dS/m because of salt accumulation under tree strips/blocks.

8.3.1 Plantation models

The state has proposed to spent Rs. 3000 million per year until 2030 on biodrainage costing about Rs. 50000 per ha. Following models can be considered in planning keeping in view their technical and economic limitations.

Boundary plantation: Boundary plantation has been practiced in India as a general agro-forestry model mainly using*Eucalyptus spp.*It cannot serve the purpose of biodrainage because of limited number of plants.A major problem reported in the applicationof this model is the conflict betweenthe neighbouring farmers. The neighbouring farmer blames thefarmer who plants the trees on the boundary as it results insome yield decline in a 4-5 m strip on both sides along the planted strip. This conflict can be resolved by joint plantingof the trees and allocating even-odd trees between thetwo neighbours.

Tree strips in crop land: In this model, parallel ridges on killa lines are constructed as far as possible in the north-south direction (Fig. 1.8 right). Two rows of trees per line are planted in 10 paired rows/ha covering a minimum of 10% of the land to have realizable benefit of biodrainage. It is a good model for potentially waterlogged areas (water table > 2 m), having low to medium salinity and brackish groundwater (< 6 dS/m).Main limitation arises as farmers are generally unwillingto spare 10% of land for this purpose. Besides, yield penalty in a narrow strip along plantations has been reported as plants and crops competefor nutrient and moisture. The model using Clonal *Eucalyptus* has been successfully tested at some farmers' fields in Haryana (Jeet Ram et al., 2011).

Growing plants on raised ridges: This model has been experimented for critical waterlogged areas coupled with medium to high salinity. The ridges, as high as 1 m, are constructed at regular interval varying from 30-50 m. The planting is done at the top of the ridges to avoid water logging stress. The model has been tried in Haryana and south-west Punjab on experimental scales. Ithas not beenyet been upscaled mainly because of the cost involved.

Plantations along canal networks to control seepage and maintain water balance: The system has worked partially well in IGNP, Rajasthan and even in other states where planting is normally done along canal network. The plantations mix in IGNP included*Eucalyptus camaldulensis, Acacianilotica, Tecomella undulate, Prosopis cineraria* and *Dalbergiasissoo*. For seepage control 2-4 staggered tree lines may be planted along both sides of the canal. But for water balancein the canal command, simple calculations reveal that around 30% of the irrigated land needs plantations. As such biodrainage alone may not prove to be a practical and viable solution. It should be integrated with some other kind of engineering solution.

Block plantations: The water table decline under trees plantations creates a hydraulic gradient between planted blocks and the adjoining non-planted area. As a result, water and saltsmove from the nearby cropland towards the planted blocks. Not much is known as to how the plants will behave while salts from the adjoining area continue to accumulate in the planted block. Moreover, block plantations may work well as a means of land utilization by absentee farmers. Farmers generally refrain to spare such blocks exclusively for biodrainage.

9.0 ALTERNATE LAND USES

9.1 Aquaculture

Central Institute of Fisheries Education (CIFE), Regional Research Station, Lahli, Haryana, has perfected a technology for economic utilization of inland saline soils and water and come out with a package of practice for growing *Litopenaeusvannamei*, the Pacific white shrimp. Itcan give optimum yield with inland saline waters of about 25 ppt. Severely waterloggedsaline areas not amenable to other methods of reclamation can be put to productive use with this technology. More than 1200 haof highly saline soils have already been put under this technology in various districts of the state(Fig. 1.9). Average shrimp production is 7.0 t/ha, but can goup to 10 t/ha with good management. The technology has since spread to states of Punjab (400 ha), Rajasthan (400 ha) and few acres in Uttar Pradesh. According to the working group on ‘Fisheries Development in Haryana: Status Prospectus and Options’ 20000 ha highly saline and 2000 ha waterlogged areas can be put under this technology (Working Group Report, 2012).The technology besides boosting the socio-economic conditions of farmers is capable of generating employment opportunities.

Fig. 1.9 Pacific white shrimp cultivation in Haryana

Major limitation of this technology is its high cost and technical nature requiring regular monitoring of water quality. The total investments in fixed and operational cost are to the tune of 30lakhs per ha. Subsidy to the tune of 40-60% of the estimated cost of Rs. 14 lakh per hectare is provided under the Pradhan Mantri Matsaya Sampda (PMMS) scheme. There is a need to increase subsidy for inland marine shrimp culture on actual cost basis since the cost is much higher compared to the coastal states.

One window system should be established to ensure credit, seed supply, feed supply, and other technical support to the stakeholders. Most officers and stakeholders are of the view that white shrimp cultivation is an energy intensive technology. Electricity consumption is one of the major components of operationalcost. It is proposed that fish farmers should be treated at par with agricultural farmers and should be extended the same benefits in terms of power charges as farmersengaged in agricultural.

Quality of groundwater in the state varies widely especially in areas manifested by water logging and soil salinity. The brackish groundwater in such areas can be used for brackish water fish culture rather than costly Pacific white shrimp cultivation. The technology for brackish water fish culture is available with CIFE, and CCSHAU etc. and can be popularized for resource poor farmers.

9.2 Multi-purpose Ponds

As stated elsewhere in this report, large areas are affected by water logging along the canals network. It is mainly due to seepage from the network besides higher deep percolation losses at the head ends. Therefore, farmers should be encouraged to adopt aquaculture on these lands. A large number of such fish ponds have come-up along the Gurgaon canal. Similar situation was encountered in Sharda Sahayak Main canal in Uttar Pradesh. ICAR-CSSRI, Lucknow center developed an aquaculture based multi-enterprise model to reclaim waterlogged alkali lands in Raebarely district, UP. A one ha model comprised 0.40 ha fish pond 1.75 m deep, 0.2 ha cereal crops, 0.15 ha fruit crops, 0.10 ha vegetable crops and 0.10 ha forage crops. The pond always remains filled with seepage water. The productivity of the land and water increased many folds. This technology has immense potential of replication to reclaim waterlogged saline soils in Haryana. Location specific pilot projects of multi-enterprise models need to be demonstrated at selected sites by Department of Agriculture in collaboration with CCSHAU, ICAR-CSSRI Karnal and other State Departments for building confidence amongst the farmers. The funds from water resources department/Pond Authority may be used to construct such ponds on farmer's lands.

9.3 Solar Parks on Wastelands

Renewable energy is an effective tool to enhance energy security, enabling energy access to all besides mitigating climate change effects. The Haryana Solar Policy 2016 has committed state solar plants to produce an additional 4.03 GW by 2022 but the target could not be achieved. The major objectives of this policy has been to promote generation of green and clean power in the state using solar energy, productive use of wastelands / non-agricultural lands thereby leading to socio-economic transformation and a reduction in regional disparities in development, employment generation and skill up gradation of the youth. The state should encourage farmers or farmer'sgroups owning wastelands including waterlogged, saline and alkali lands to lease their lands to an entrepreneur for the renewable solar energy projects. Salt affected soil especially under the Panchayats and Governmental institutions can also be leased for solar parks (Fig. 1.10). Landowners will receive regular lease money for their lands. Besides, government can frame lease rules in such a way that farmers may also get royalty based on the gross revenue generated from the project.

Fig. 1.10 Establishment of solar parks on saline waterlogged and alkali lands

9.4 Managed Plantations for Fuel/Industrial Purposes

Most of the medium and high salinity areas stand abandoned supporting only sporadic vegetation of no economic value. There is a need to identify at least few such areas where pilot studies can be launched by the CCSHAU/ICAR-CSSRI/Department of Forestry to explore the possibility of using such lands for biomass/fuel-wood managed plantations. In medium saline areas multipurpose woodlots can also be established by growing tree species like *Acacia nilotica, Albizialebbeck, A. procera, Azadirachtaindica, Cassia siamea, Casuarinaequisetifolia, Eucalyptus tereticornis, E. hybrid, Leucaenaleucocephala, Pithecellobiumdulce, Pongamiapinnata, Prosopisalba, Prosopisjuliflora, and Terminaliaarjuna.* These trees can provide wood for industrial and fuel purposes. Besides, such woodlots can help in lowering water table as a consequence of biodrainage. In Tamil Nadu local farmers put highly saline areas under *Prosopisjuliflora* and use it to produce charcoal. This practice is being adopted in many villages In Haryana as well. Appropriate incentives can be provided to the farmers to adopt charcoal productionsince the demand for charcoal is quite high.

10.0 CONSTITUTION OF A COORDINATION COMMITTEE

The group considered several options of an efficient drainage organization but finally decided to continue with the current arrangements of work bifurcation amongst the various departments.Group proposes the setting-up of a state level coordination committeeunder the chairmanship of Chief Secretary to ensure proper coordination and to avoid duplication.This committee may meet twice a year to approve all identified projects and monitor the progress of on-going projects. The committee may also constitute an interdisciplinary group of experts for preparing the drainage master plan of the state.

11.0 EXTENSION AND CAPACITY BUILDING

All the existing platforms of extension can be used to extend knowledge based technologies with some policy level support and mid-way change in the track. We may continue to use traditional methods of conducting trainings/workshop, organizing meetings, farmers' field days, radio talks and video conferencing, farmer scientist's interactions, and entrepreneurs' scientists interactions. But as said before, all these activities should be demand driven by the farmers.Attention should be given to grass root level involvement of all stakeholders including PRIs and local bodies in land amelioration. It should be made mandatory for each PRI to organize World Water Day and World Soil Day in their jurisdiction. Let these organizations invite the experts of respective field for talks on problems confronting the village rather than continuing with the ritual of going to an institutionto listen to some general issues. If the suggestion is implemented, then each village will haveat least two days earmarked for generating awareness on management of natural resources.

We must take full advantage of recent advances in ICT – especially the electronic and print media to ensure real-time dissemination of messages on new innovations. Mobile technology is very effective as it is being used for dissemination of short and long-term weather forecasts. In the same way, this can be used for immediate advisories on emergent field problems.

On the policy front, farmers have little incentive in enhancing on-farm water use efficiency due to almost free supply of canal water and heavily subsidized power to extract groundwater. Even within this regime, some good scheme can be framed to incentivize the farmers who adopt sound soil and water management technologies. They can be given this incentive and honour by the respective Panchayat on the World Water and Soil Days.

11.1 Capacity Building

Our interaction with various groups and farmers revealed that awareness and capacity to plan and deliver on land reclamation is low and highly compartmentalized. There is little awareness and appreciation of technologies being implemented across departments. Therefore, efforts should be made to demystify the strategies proposed by various departments at regular interval. Both departmental and inter-departmental courses should be organized to improve interaction so that everyone appreciateseach other point of view on various options of land reclamation. The process should be facilitated by institutes of learning by organizing 1-7 days courses developed by a working group constituted for this purpose.

Institute	Level of training and type	Days and frequency
Haryana Institute of Public Administration, Gurugram	Appreciation course for planners and higher level officers	1-2 (Quarterly)
Central Soil Salinity Research Institute, Karnal	Appreciation course for planners and higher level officers	1-2 (Biannual)
	Appreciation course for middle level officers	1-2 (Biannual)
	Technical courses for field staff Farmers' training	2-5 (Biannual) 1-2 (As and when need arises)

CCS Haryana Agricultural University, Hisar	Appreciation course on land reclamation/drainage	1 month (online or offline, two times a year)
	Appreciation course for planners and higher level officers	1-2 (Biannual)
	Appreciation course for middle level officers	1-2 (Biannual)
Extension Education Institute, Nilokheri	Technical course for field staff	2-5 (Biannual)
	Farmers' training	1-2 (As and when need arises)
Central Institute of Fisheries Education, Lahli, Rohtak	Appreciation course for middle level officers in brackish fish and shrimpculture	1-2 (Biannual)
Aquaculture Research and Training Institute, Hisar/ Jyotisar	Technical course for field staff in brackish fish and shrimp culture	2-5 (Biannual)
	Farmers' training in brackish fish and shrimp culture	1-2 (As and when need arises)
Haryana Irrigation Research and Management Institute, Kurukshetra	Appreciation course for middle level officers in water management	1-2 (Biannual)
	Technical course for field staff in reclamation of waterlogged saline soils	2-5 (Quarterly)
	Farmers' training on general water management issues	Every month or at higher frequency
Haryana Agricultural Management and Extension Training Institute, Jind	Appreciation course for middle level officers in water management	1-2 (Biannual)
	Technical course for field staff in reclamation of waterlogged saline soils	2-5 (Quarterly)
	Farmers' training on general water management issues	2-5 (Monthly or more)
Haryana Institute of Rural Development, Nilokheri	Appreciation course for representatives of PRIs	1-2 (Monthly)
Indira Gandhi Open University, New Delhi	Appreciation course on land reclamation/drainage	3 months (on-line two times a year)

12.0 RESTRUCTURING AND STRENGTHENING OF INSTITUTIONS

12.1 Haryana Irrigation Research and Management Institute (HIRMI), Kurukshetra

The group has learnt that Irrigation and Water Resources Department of Haryana, MICADA, the Haryana *Pond* and Waste Water Management *Authority and Ground Water Cell are getting increasingly involved in agriculture including land drainage/reclamation. It isa very good sign for the state. Officers of the department at various levels should get attuned to these new developments and responsibilitiesfor achieving best results. Group, in this context, recommends the* restructuring and strengthening of HIRMI, Kurukshetra, a pioneer institute to train the officers and farmers of the state in irrigation water management. Structurally, HIRMI should be in tune with the Water and Land Management Institutes (WALMIs) conceptualized at the time of their establishment. It should be headed by a full time Director General. The institute should have core faculty in engineering, agriculture, social sciences and watershed management besides hiring experts on case to case basis.

12.2 Haryana Agriculture Management and Extension Training Institute(HAMETI),Jind

HAMETI, Jind is a state level Institute with a mandate of conducting training courses on agricultural technology, management, gender, extension reforms and information technology. One of its objectives is also to provide management input for extension functionaries of agriculture and line departments. The Institute needs to be equipped with core faculty in various disciplines. The courses should be so designed that both local and state level problems are addressed. The courses may be framed and publicized well in advance. Until the core faculty is in place, best experts of related streams may be invited keeping in view the course contents.

12.3 Regional Research Stations, CCSHAU, Hisar

Three out of the four RRS of CCSHAU, Hisarnamely Rohtak, Sirsa and Bawal are located in regions affected either one or a combination of the problems of water logging, soil salinity or water quality. Some of the technological interventions suggested under the preventive strategies should be demonstrated and validated in farmers' participatory mode involving concerned Government Departments and other extension agencies. These 3 centers should address the natural resources management problems in their respective jurisdictions.

- RRS, Rohtak may deal with problems related to rise in water table of the inland basin and undertake irrigation water management activities covering areasirrigated with poor quality groundwater as well as with canal water
- RRS, Bawal should focus on water quality problems in districts under its jurisdiction, water logging, salinity and water scarcity areas of Mewat and lift canal irrigated areas
- RRS, Sirsa should address the twin problems of rising and falling water table and interlinked issues in its jurisdiction

The centers may recruit new faculty in natural resources management and take proactive actions for capacity building of the existing staff to tackle the problems through adaptive research programs.

13.0 RECOMMENDATIONS

Data Acquisition

1. There is an urgent need for latest data acquisition, reconcilingand preparation of base maps of flooded, water logged, and salt affected areas. Groundwater quality map of the state for irrigation purposes should be generated on priority. The exercise may be repeated at regular intervals say every five years.

Surface Drainage

2. Land acquisition is becoming increasingly difficult causing problems in construction of new drains. There is a need to implement new innovative surface drainage solutions such as on-farm multi-enterprise ponds, bore wells, and underground pipelines to dispose of pumped drainage water from depressions.

3. Blocking of natural surface flows through infrastructural development programs such as highway construction hasalready aggravated the problem of agricultural land submergence. Utmost care needs to be exercised whiledesigning and implementing such projects so that natural drainage remains unhindered.

4. Regular maintenance of drainage system should be undertaken maintaining the design section and slopes so that water moves freely towards the outlet.

5. Bore holes to drain depressions is increasingly practiced but needs to be implemented very carefully to avoid groundwater pollution. Run-off from agricultural fields might contain several hazardous agricultural pollutants.

Crop Management and Improvement

6. Farmers should be encouraged to shift to salt tolerant crops, like barley, sugar beet, cotton, mustard, safflower and semi-tolerant crops like wheat,pearl millet, sorghum, and guar.

7. While efforts in crop diversification program may continue, yet an equally important activity is to popularizewater saving technologies in rice crop. The water saving technologies comprise adoption of direct seeded rice, irrigations of transplanted rice at hair cracking stage than to keep the land submerged throughout, and storage of rainwater in rice fields by raising the height of dykes.

8. Cultivation of rice in waterlogged saline areas and/or light textured soils with canal water should be discouraged.

Water Management

9. Lining of canal networks including water courses in areas affected by water logging and soil salinity should receive priority. Periodic maintenance especially of water courses should receive attention tocheckseepage and leakage losses.

10. Improved surface irrigation techniques, irrigation scheduling and modernmethods of irrigation such as sprinkler, and drip irrigation should receive the highest priority of the MICADA and other executing and extension agencies.

11. CCSHAU centers at Rohtak, Bawal and Sirsa including Krishi Vigyan Kendras (KVKs) in affected districts may take lead to propagate recommended cropping practices in flood affected areas during the post monsoon period.

Land Reclamation

12. Horizontal subsurface drainage technology may be implemented in the state without any inhibition. Itis a well-researched technology with all kinds of thumb rules available for its design and construction. It ensures uniform reclamation over the entire area. The drainage effluent generated is much less and is of relatively better quality compared to a vertical drainagesystem becausethesystem islaidatmuch shallower depth.

13. There is an urgent need to strengthen HOPP to enhance the pace of land reclamation using horizontal subsurface drainage.

14. Vertical drainage is feasible in areas where aquifers with high transmissivity (KD > 600 m^2/day) having fresh or at the most brackish water (groundwater of 4-5 dS/m) are available. Since the volume of drainage water is huge, most suitable sites amenable to vertical drainage are along canal networks. Drainage water can be mixed in canal water for reuse downstream. These systems can also be laid along big drains so that EC of the drain water after mixing does not exceed 2 dS/m.

15. Biodrainage is a good alternative in waterlogged areas where groundwater is brackish and soil salinity is low. Such areas are also found along canal networks. Biodrainage as a seepage control measure may be tried where vertical drainage is difficult to implement.Biodrainage should not be looked upon as a standalone system; rather it should be integrated with other engineering solutions.

16. Agro-forestry as a means of biodrainage should occupy a central place in promoting biodrainagefor potentially waterlogged areas having low to medium salinity (< 6 dS/m). Trees should be planted in two rows on either side of killa line covering about 10% of the farm area. Superior water logging tolerant and fast bio-drainers planting stocks like *Eucalyptus clones, Tamarixarticulata*, and *Casuarinaglauca,* Poplar, and Bamboo should be made available to the farmers.

17. Aquaculture (Shrimp culture) should be treated at par with agriculture. Fish farmers for all purposes should be treated as agricultural farmers especially with respect to water charges, electricity tariff, farm loan interest and income tax exemptions.

18. Government of India norms for subsidy on initial investments @14 lakhs per ha are insufficient. Initial investments in inland shrimp culture are higherthan in coastal states. This issue needs resolution at the highest level.

19. Priority may be accorded in using wasteland for solar energy projects, which are land intensive requiring about 1.5-2.0 ha/MW.

20. Management and utilization of sodic water for irrigation requires use of appropriate amendment like gypsum/pyrites/press mud every year. Supply of subsidized amendments on regular basis should be ensured.

Institutional Strengthening and Extension

21. Several organization/institutions in the state require strengthening. Notable amongst them are: HOPP, Karnal, three Regional Research Stations of CCSHAU, Hisar located at Rohtak, Bawal and Sirsa, HIRMI, Kurukshetra and HAMETI, Jind.

22. There is strong need to impart knowledge and training to all stakeholders including PRIs and local bodies in land and water management. All PRIs may be instructedto organize World Soil Day and World Water Day in their jurisdiction.

23. There is need of developing proper and functional coordination amongst research institutions in the state, relevant State Govt. Departments/developmental agencies and stakeholders to address complex and interlinked problems of water logging, soil salinity, saline/sodic water and other issues of natural resource management. Only this kind of integrated approach may help to resolve such complex issues.

General Issues

24. The government should form a permanent high level inter-departmental committee headed by the chief secretary to deal with land reclamation including related environmental issues.

25. A drainage master plan for the state as a whole must be prepared having the provision of short-, medium-, long-term strategies to augment the drainage needs.

14.0 RESEARCHABLE ISSUES

Major research organizations dealing with the problems of water logging, soil salinity, saline/alkali water and other relevant issuesin the state are: CCSHAU, Hisar, ICAR-CSSRI, Karnal, ICAR-IIW&BR, Karnal, HARSAC, Hisar, MHU, Karnal, and CIFE, RRS Lahli. Some specific issues that require the attention of these organizations are listed as follows.

1. There is a need to undertake regional water and salt balance modeling to understand and arrive at holistic solutions of the problems of water logging and soil salinity in the state.

2. It is feared that brackish groundwater is marching towards groundwater aquifers containing fresh water. To ensure that it does not happen, regularexercise must be undertaken every five years to assess the present status of the threat. In the meantimeresearches must be initiated to devise strategies to take care of any such eventuality.

3. Efforts must be directed toward the development of salt tolerant crop genotypes through the use of plant breeding strategies involving the introgression of the genetic background from salt tolerant wild species into cultivated plants. Current efforts in developing high yield abiotic stress tolerant varieties of cereals should also include especially barley, hulless barley, millets, high-yielding uniformly-maturing pulses and oilseeds.

4. Salts lying deep into the aquifer are brought to the soil surfaceduringoperation of vertical drainage projects. Since huge amount of salts enters the already salty environment, its short-term and long-term impacts on soils and water need to be investigated through field trials and mathematical modeling.

5. CCSHAU and other research organizations should develop package and practices for growing sugar beet in Haryana. They should also standardize jaggery, vinegar and ethanol production processes from sugar beet so that farmers can set-up small units to add value to the crop for higher income.

6. On-farm participatory research and demonstrations are needed to highlight the benefits of drip and sprinkler irrigation systems in sugarcane, cotton, rice and wheat crops.

7. Performance of sprinkler and drip irrigation systems should be evaluated for use of saline and alkali waters in different soils and agro-climatic regions. Guidelines for use of saline and alkali waters for crop specific use on sustainable basis should be established.

8. There is need to identify fruit plants that can tolerate water logging/soil salinity and have good biodrainage capabilities.

9. Fruit and vegetable grafting on wild species can be one option to improve their tolerance to biotic and abiotic stresses. Such root stocks should be identified and grafting protocol standardized to improve yield and input use efficiency of plants.

10. Evapotranspiration capacity of various plants under varying sub-soil water salinities should be scientifically assessed for developing biodrainage designguidelines.

11. There is urgent need to associate experts of vertical drainage and biodrainage, Bureau of Indian Standard (BIS), and research organizations to develop BIS standard for implementing vertical drainage and biodrainage schemes.

12. Whereas white shrimp technology has gained ground, brackish water based fisheries should be investigated and popularized as brackish groundwater in the range of 2-6 dS/m is in plenty in this region.

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ANNEXURE I

Constitution of Working Group and Terms of Reference

The Haryana Kisan Kalyan Pradhikaran constituted a Working Group to study the Problem of Water Logging and Salinity in Haryana & make recommendations for improvement, as under:-

1.	Dr. S.K.Gupta, Retd. Principal Scientist & Head, Division of Irrigation & Drainage Engineering, CSSRI,Karnal.	Chairperson
2.	Dr. Vijay Arora, Retd. Professor, Soil Science, CCS FIAU, Hisar.	Member/ Convener
3.	Er. H.S.Lohan, Retd. Additional Director Agriculture, Haryana.	Member
4.	Sh. Dalbir Singh, Vill. Kahni, Rohtak	Member

The Terms of Reference are as under:-

1. To review the current status of the problem of water logging and salinity inHaryana and suggest measures for improvement.
2. To analyze the current support system (schemes, policies, technical andinfrastructural support) for addressing the problem of water logging and salinity in Haryana from the State /Central Governments and propose measures/ methods for further improvement in this area.
3. To assess the present status of training programs and extension facilities forfarmers and suggest measures for skill development of persons engaged inaddressing the problem of water logging and salinity in Haryana.
4. To review the status of research and development and suggest measures to address current gaps as per the specific needs of the farmers.
5. To recommend most appropriate strategies for adoption to tackle the problemof water logging and salinity in the State.
6. The Working Group may hold consultation meetings with farmers, scientists,entrepreneurs, policy makers, etc.
7. The Working Group should submit its report within a period of four months.

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ANNEXURE II

MEETINGS /FIELD VISITS

S. No.	Date	Venue of meetings	Contact Officers/ Persons	Remarks
1	15th March, 2023	Initiation meeting in Committee room of HKKP, Panchkula	Honourable CEO and Research fellows of HKKP	CEO, HKKP gave brief background of the constitution of various working groups and highlighted the importance of this group in the context of the state
2	28th March, 2023	Respective offices of the officers at Panchkula	Director Fisheries, Engineer-in-Chief, Irrigation, Additional PCCF, Department ofForest,Panchkula	Interaction on policy and plans of the respective departments to solve the problems of water logging and soil salinity. Aquaculture especially growing of white shrimp Innovative drainage techniques, cleaning of drains lining of water courses, introduction of sprinkler and dripirrigation, bore well and use of overflowing pond water and treated water for irrigation. Role ofbiodrainage in land reclamation.
3	12thApril, 2023	Committee Room, ICAR-CSSRI Karnal	Director, Heads of Divisions, SE (Irrigation), Jind, Scientists from CSSRI, IIW&BR,Karnal and Officers of HOPP	Integrated approach based on prevention and reclamation, cultivation of barley for its salt tolerance, horizontal subsurface drainage, vertical drainage along canals, biodrainage plants, training of stakeholders and policy makers
4	12th May, 2023	Committee Room of the Director of Research, CCSHAU, Hisar	Director of Research, Heads of Departments, and scientists	Diversification of crops, characterization of water quality in terms of EC, SAR and RSC, irrigation water management and biodrainage

S. No.	Date	Venue of meetings	Contact Officers/ Persons	Remarks
5	8th June, 2023	CIFE, committee room, Lahli	Head of the station and scientific and technical officers of the research station	Technology and economics of white shrimp cultivation and bottlenecks, if any
		Committee room ofDivisional Soil Conservation officer, Rohtak	Divisional soil conservation officer, Asstt. Soil Conservation officers, Other officials of the department, District Fisheries officer and Farmers	Vertical drainage in farmers' fields, and farmer's viewpoint on horizontal and vertical drainage
6	6th July 2023	Committee room of HKKP, Panchkula	Honourable CEO, HKKP and members of the working groupand research fellows of HKKP	Section-wise discussions were held within the group and suggestion received from honourable CEO, HKKPwere incorporated
			FIELD VISITS	
1	29th March, 2023	Saline and waterlogged areas near Abohar, Punjab	Executive engineer, Sub-divisional officer and JE	Interaction with project stakeholders and to understand the differences in technology implemented in Punjab and Haryana
2	8th June 2023	Project on cultivation of white shrimp in Rohtak district	District Fisheries officer, Owner farmer of 12 acre shrimp farming set-up	To interact with the owner farmer of shrimp culture ponds and understand the problems to plan the way forward to expand the technology


INTERACTIVE MEETING

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