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Integrated Water Management for Waterlogged Command Areas

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Waterlogging in most of the canal commands is increasing rapidly and it is being considered as one of the most serious constraints to agricultural production. Frequent floods, flat topography or bowl shaped lands, obstruction in natural drainage ways, seepage from water bodies, excessive irrigation are some of the important reasons for waterlogging to occur in canal commands. In arid or semi-arid regions, due to rise in ground water table and salt, it encroaches the crop root zone, whereas in humid regions due to high rainfall temporary water stagnation/ ponding at the land surface occurs frequently in monsoon periods. Both the situations adversely affect crop yield. Depending on extent and duration of subsurface waterlogging or surface water stagnation suitable plans/ strategies for surface or sub-surface drainage activities, multiple use and conjunctive use of water as well as other efficient and effective water management interventions should be chalked out to improve water productivity in waterlogged areas. This paper presents the problems of subsurface waterlogging and surface water stagnation in various parts of the country with the help of some case studies and suggests possible strategies as well as water management technologies communicated in canal command to minimize the waterlogging.

INTRODUCTION

Water is a crucial input for augmenting agricultural production towards sustainability in agriculture. Therefore, expansion of irrigation resource was given top priority in five-year plans leading to creation of a cumulative irrigation potential of 101 M ha by 1999-2000 out of a ultimate potential of 140 M ha. No other country has attached so much attention to irrigation development as India in recent years. Irrigated agriculture has been the ultimate choice to increase food production. But introduction of irrigation is not without problems. Water loss in conveyance and distribution has been found to be as high as 50-70 per cent and losses in watercourses alone are estimated to be about 20 per cent of water delivered at canal outlet, figures far greater than what was originally envisaged. Water losses at the farm are substantial depending upon the texture and other soil characteristics, irrigation method and cropping pattern etc. Indiscriminate irrigation in several commands had led to water logging and salinity problems. In most of the canal commands, water supply is supply-driven rather than demand-driven. It has been reported that water supply is inadequate, irregular, unpredictable and untimely, resulting in wide gap between supply and demand of water. Due to this either water users don't get adequate quantity of water at appropriate time or they get water more than their requirement. Both the situations of water scarcity or water abundance create adverse impact on agricultural production.

Our country is blessed with fairly rich rainwater resource (about 115 cm per annum), but agricultural productivity of rainfed areas continues to be low and unstable. Management of rainwater assumes significance, both in low as well as high rainfall areas, for preventing rain-induced degradation and enhancing on-site and off-site agricultural productivity.

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Under the situation of declining per capita water availability and quality degradation, water management assumes a great importance. Researchers are trying to answer questions like: How to irrigate? When to irrigate? How much to irrigate? and How to improve the water use efficiency so that with limited water resources more area can be brought under irrigation and achieve sustainable production. This needs sufficient attention to be paid to adopt the cost effective and efficient water management practices/technologies suiting to soil-crop-climate-socioeconomic status of the study area. In this paper, an attempt has been made to highlight some case studies and experience gained after implementation of water management interventions in canal commands in order to utilize waterlogged canal commands more efficiently and productively.

Development of waterlogging generally takes place due to natural as well as artificial conditions caused by irrigation and drainage works resulting in rise in water table. Singh (1998) reported that the rate of rise of water table in various irrigation commands of the country varies from 0.26 m to 1.2 m per annum. Combination of all these situations, in turn has resulted 8.53 M ha of land in the country as waterlogged and 2.46 M ha land to be under inadequate drainage in irrigation commands. Out of 5.5 M ha of saline land, 3.06 M ha is estimated to be affected due to irrigation related problems. Thus, the total affected land area is 14.03 M ha under waterlogging and salinity, of which 5.52 M ha is affected by irrigation related problems and inadequate drainage.

The time gap between project construction and first large scale appearance of waterlogging and salinity varies from project to project. Singh (1998) reported that in Rajasthan Agricultural Drainage Project (India) first large scale salinity and waterlogging appeared with in the period of less than 30 years whereas in south west Punjab project it appeared after around 50 to 70 years. So it is necessary to understand the process of waterlogging and salinity development.

Waterlogging

Waterlogging occurs, when the total quantity of water introduced into the soil from various sources exceeds the total quantity disposed off through natural drainage process, plus the quantity used by crops to meet their physiological needs. It may be in the form of,

(i) Surface ponding i.e. water standing at the soil surface for prolonged periods due to inadequate surface drainage and

(ii) Rise in water tables and remaining in the root zone for prolonged periods due to inadequate subsurface drainage.

A special committee of the Central Board of Irrigation and Power explains Waterlogging as,

> *"An area is said to be waterlogged when the water table rises to an extent that the soil pores in the root zone of a crop became saturated, resulting in restriction of the normal circulation of air, decline in the level of oxygen and increase in the level of carbon dioxide"*

The National Commission on Agriculture defines waterlogging as,

> *"Excess water in the root zone due to high water table restricting the normal aeration of the crops roots."*

Chanduvi and Vasquez (1997) states that waterlogging is not an inevitable result of irrigation, but it is due to excessive input of water into systems that have finite natural drainage capacities. The sources of excess water include seepage from unlined canals and on farm distribution systems, deep percolation from irrigation fields and rainfall.

The excess water in the root zone affects the crop production in several ways.

1. Deficient aeration in the root zone prevents growth of soil microorganisms that help in the development of plants.
2. Some plant disease and parasites are encouraged in humid environment.
3. High water table limits root penetration.
4. Soil structure is adversely affected due to prolonged saturation.
5. Salts, if present in the soil or ground water, tend to concentrate in the root zone or at the soil surface.
6. Evaporation from wet soil lowers soil temperature, which in turn affects the seed emergence and plant growth.
7. Excess moisture in the field hinders timely farm operations for the next crop.

To check the negative impact on sustainable crop production in an area the approach should be to maintain water table within the safe limit so that it should not affect the soil air water balance of root zone. Most of the norms for a safe level of water table suggest for restricting the water table 2 m below the ground level. Wherever rise in the water table exceeds 1 m per annum, the area should be considered potentially sensitive. However, even a lesser magnitude of rise per year may be considered critical depending upon local conditions. The harmful depth of water table considered as from 0 m for rice to about 1.5 m for other crops. To control the water table within safer limit one should be aware of its causes. Some of the main causes for development of waterlogging are poor natural drainage, existence of hard pan below the soil surface, submergence due to floods, deep percolation from rainfall and hydraulic pressure from saturated areas located at higher elevations, practice of high intensity irrigated agriculture without any consideration of soil and sub soil conditions, excessive enclosing of irrigated fields with embankments, choking up and blocking due to obstruction and poor maintenance of natural drainage. In order to get acquainted with the causes and status of waterlogging, a brief review of various case studies and some experiences are presented below before suggesting appropriate measures to control waterlogged situations.

CASE STUDIES-REVIEW AND EXPERIENCES

Ukai-Kakrapar Command

Gupta and Tyagi (1996) reported that the existing drainage systems in the Ukai-Kakrapar command of Gujarat are inadequate and deficient to dispose off the runoff due to flat topography and excessive weed growth. Other factors contributing to the development of waterlogging are: excessive seepage/leakage from unlined canals, inadequate knowledge of irrigated farming among the farmers, lack of institutional support in extending the knowledge and use of unscientific methods of irrigation. This has led to sizable area experiencing water table within 3 m, while part of these areas are also experiencing ground water table within 1.5 m. A drainage plan (Surface drainage and modernization of the project) with a view to minimize quantity of water used for irrigation per unit area and to increase water use efficiency were implemented with following key steps,

- Creation of artificial scarcity of irrigation water,
- Irrigation for areas situated at the higher levels by a high level canal.
- Restriction of the areas under high water intake crops.
- Adoption of Participatory approaches.
- Implementation of drainage plans.

South-west Punjab

Some of the blocks in this region were experiencing rise in water table at the rate of 33 cm/year. Before the inception of the canal system, the areas were rainfed and desert conditions prevailed with water table as deep as 40-50 m while rise in water table started after introduction of canal system. The study carried out on drainage investigations, anti-waterlogging measures and crop production technology for the waterlogged areas in the region shows that seepage by various means, poor state of drainage structures, very less withdrawal of ground water, etc. are some of the main reasons for occurrence of waterlogging conditions. The study suggested following remedial measures

- Encouraging more utilization of good quality ground water through installing shallow skimming wells,
- Encouraging more evapotranspiration through early rice transplantation, sunflower and sugarcane cultivation,
- Reducing irrigation to cotton and wheat crops at later growth stages as to use ground water through capillary rise under high water table conditions,
- Decreasing allocation/supply of canal water to these areas only during later crop growth stages.

Canal Command of Semi-arid Region (Haryana State)

In this state the canal irrigated area is underlain by saline aquifers in deeper level. The area becomes waterlogged when the water table rises within 2 m below ground surface. The waterlogged and salt affected lands have increased the flood intensity in excess rainfall years, whereas the flood absorption capacity of groundwater reservoir has decreased.

The flood causes direct or indirect devastation but if the flood is predicted timely and is managed effectively, the problem can be mitigated to the economic usefulness. Tanwar (1997) suggested following remedial measures for the area.

- Provisions should be made for water table control, depletion, and absorption of flood into groundwater reservoir.
- Detention and diversion of the floodwater in paddy irrigation in upstream areas to avoid gush of waters to the low-lying areas.
- Storage of the floodwater in depression and lakes for its use in dry season.
- Diversion of the floodwater into the sand dune areas through lift canal system.
- Evacuation of the floodwater to the rivers through drains. The creation of flood absorption capacity can be achieved by depletion of the water table through a) Drainage tube wells and b) Shallow irrigation tube wells.

IGNP-Rajasthan

Hooja *et al.* (1997) reported that the rate of rise of water table per year between 1952 to 1972 was 0.42 m, in 1972 to 1982, 1.17 m and in 1982 to 1992 it was 0.76 m in the command. The reasons for major falls in the water during 1982-1992 reported were:

- Deliberate reduction in water allowance and stoppage of supply of irrigation water from the canals for the waterlogged areas not under cultivation.
- Low rainfall and low water availability overall in the canal systems of' IGNP.

- Attempts to get farmers to adopt more efficient water application techniques to avoid over irrigation, and to take up conjunctive water use where ever possible through CAD'S.

Based on the observed rate of water table rise, it is projected that without adoption of measures for water table control, the critical condition would extend to cover 2,85,000 ha or more with a major part becoming completely waterlogged. Hence, above-mentioned three reasons can be considered as key steps for remedial measures.

Mahanadi Delta

It is estimated that out of 3.03 lakh ha culturable canal command of Mahanadi Stage I and II, 1.725 lakh ha is suffering from different degrees of waterlogging problem. The causes of waterlogging are mentioned below.

- Construction and strengthening of embankments along the rivers, siltation of river beds in Cuttack and Puri leads to higher bed level than the adjoining fields. Continuous flow of water to the fields occurs through seepage causing waterlogging problem.
- Manmade blockades owing to the construction of roads and bridges have also been instrumental in creating drainage congestion.
- Depth of the existing drainage system is not adequate to completely drain out the low-lying areas due to topographic and economic constraints, hence water continues to stagnate in the depressions.
- The excess of groundwater recharge over withdrawal in canal command areas resulting in to rise of water table and waterlogging and in process reducing the capacity of the soil-aquifer system to take more water in its storage thereby increasing the rainfall excess causing water congestion.
- Uncontrolled flow of canal water through distributaries, minors, watercourses and excessive field to field irrigation by farmers resulting in wastage of water that finds it way to the lowest part of the terrain and causes waterlogging.

Improving existing surface drainage system can minimize the above listed problems.

Drainage of Barachouka Area

The Barachouka area of Rasulpur basin in Midnapur district has representative features of the waterlogging problems in southern West Bengal. It has a mild concave shaped topography with about 65 m deep alluvium of clay texture, which has poor internal drainage and high water retention capacity. The natural surface drainage impeded due to siltation of the natural and man-made drainage system. The internal drainage is delayed due to the heavy textured deep soils. The salinity is caused by sea water ingress. The salinity hazard in some area of Barachouka is so severe that the land has remained fallow for over two centuries. Though the land is fertile, it suffers from severe drainage congestation causing total failure of *kharif* Paddy crop. The implementation of surface drainage in the area has favorably modified the hydrograph of ponding as well as the soil water regime in the rice fields. The adoption of surface drainage measures has increased the productivity of rice to the tune of 29 to 34% and the land is free of excess water due to which the land is available for *rabi* preparation in time.

Mahi Right Bank Canal Command, Gujarat

After the introduction of irrigation in 1959, there has been continuous rise in groundwater table. The rate of rise in water table in the year 1965 to 80 reported was 0.28% on an average. The main causes for drainage problem in the command are excessive irrigation to the crop, percolation of water from canal and its distribution system, heavy rainfall during rainy season, poor drainage property of heavy clay soils and inadequate drainage system in the command. The study suggest that

- A proper conjunctive use of surface water and ground water resource must be undertaken in both space and time domain,
- A farmers' cooperative should be formed to look after the proper distribution of canal water in head as well as tail reaches to resolve the internal differences among the farmers regarding water distribution to avoid wastage and over irrigation of water,
- New surface drains should be constructed in the prominent valley lines and older be remodeled to carry the excess water at the rate of 2.46 lps/ha.

Sirhind and Eastern Canal Commands, Punjab

The area is part of alluvial plain with very flat slope. The feeder canals in this command have been constructed through the shortest route irrespective of the fact that these canals involve high filling reaches. The reaches of the canal in filling cause severe waterlogging and salinity problems. These areas fall in low rainfall region of less than 50 cm annually and the water allowance in these areas vary from 3.5 to 5.5 cusec per 100 acres. There is no scope for reduction of irrigation water allowances. Almost the entire area has been covered with surface drains. There are some isolated depressions, which need to be drained still by link drains and may require lifting of water from such pockets. The drains are in general at flatter slopes with improper condition of outfall. The monsoon rainfall combined with lack of cross drainage works was considered responsible for rise in water table. The general estimate of recharge is 10 cm/yr, which is more than the withdrawal of ground water, resulting in to rise of ground water table.

Brahmputra and Barak Basin, North East India

With average annual rainfall of 2,500 mm the command has undulating topography. Most of the areas under tea plantation face problems of water congestion. The water table was found to be fluctuating 60 cm to 200 cm below the soil surface. In these areas since most of the time one rainstorm follows another much before the drainage from the first one is completed, it causes continuous fluctuation in the water table throughout the season and thus causing shallow rooting of the plants, which may necessitate taking decision regarding drainage based on seasonal criteria.

Some Experiences in Right Parallel Channel V (RPC-V) a distributary of Patna Main Canal under Sone Canal command in Bihar

The RP Channel-V is a distributary of Patna Main Canal in Sone Command. The area under this distributary is about 2,500 acres. Area is bounded by PMC and RPC-V at one side at its upland and by a drain at its low lands. In the monsoon seasons the drain carries water ultimately to river Pun-Pun and acts as a drain for the command of RP Channel-V and area falling left side of the Adampur distributary. The lowlands of RP Channel-V are partially irrigated by canal water, but all the water

flowing from uplands as a runoff or sub-surface lateral movement falls in to the drain after crossing over these low lands.

Walkthrough surveys of the command particularly in low lands were conducted in the kharif 2001. It was observed that the rainfall in the area was very scattered and there were no symptoms of surface stagnation of water even in low lands up to 15th August, during which there was little rainfall in the area. After third week of August when the area started receiving high intensity rainfall and runoff entering from right side of the Adampur distributary in the command, most of the area adjoining drain (low lands) was found submerged by water just within a week time. This resulted in to spreading of water slowly and slowly in larger areas of the command creating ponding in the fields, ranging from 15 cm to one metre. This spread and ponding started decreasing as the rainfall decreased. The depth of ponding at various locations in the drain was recorded, which varied in the range of 0.20 m in village Nisharpura and 2.30 m recorded in Gopalpur village of this command. Hence, the area faces drought like situation in non-rainy periods and waterlogging during rainy periods.

To the first remedial measure the drain of this area can be designed, properly and maintained accordingly, the losses to the crops can be minimized to a great extent by controlling the spread of water in the fields and reducing the depth and duration of ponded water by increasing the capacity of the drain.

Budhana Distributary

Budhana distributary is under Gandak Command situated at Indo-Nepal border. It is directly diverted from the Main Western Gandak Canal. The command area falls both side of this distributary to its Northern and Southern sides. The river Little Gandak flows to the southern and western boundary of the command.

Singh *et al.* (2001) reported that in monsoon season there is substantial amount of ponding in these depressions and water spreads to a larger area due to blockade of natural drainage system. Besides this, the Northern side villages adjoining to the distributary face water ponding for at least 2 to 3 months duration. The water table in this command is always within 1 m from ground surface from July to mid November while during post monsoon periods the water table starts declining and goes down approximately up to 4 to 5 m in May and June. This leads a very tough situation for the farmers in the area even in *kharif* as well as *rabi* seasons.

To minimize the losses to the crops there is an urgent need of cross drainage structures below the distributary, since the natural gradient of flow is still towards the master drain (river little Gandak), existing surface drains should be developed as workable and if necessary for appropriate capacity to minimize the spread of water in the farmer's field, which will minimize the losses to the kharif crop to a great extent as well as minimize the duration of excessive moisture conditions during start of the *rabi* season for timely sowing of *rabi* crops.

Tal and Chaur lands of Bihar-Mokama group of Tal Lands

The problems of Tal and Chaur lands of Bihar are specific. Along the southern bank of river Ganga behind its natural level, there is a saucer shaped naturally created vast stretch of lands, which get inundated during rains. The natural topography of tal land is such that rain water as well as back water from river accumulates in this area and depth of water inundation goes up to 14 feet. Of the total water accumulated in the area 40% goes to the Ganga and the rest 60% remains in the Tal up to October. Since the soils become bone dry during summer and remain inundated during rains only, mono cropping during rabi season was almost a rule. Since these lands are low lying and there are no drainage facilities, they remain inundated for 3 to 4 months in a year i.e. for almost entire kharif season.

A team of scientist from ICAR research Complex for Eastern Region, Patna. visited the Bariarpur Tal area for suggesting remedial measures, the team observed the following:

- Number of ditches and nallas are loosing their carrying capacity due to excessive weeds and silt deposition,
- Excess water of Mani river flowing down towards north causes waterlogging in many villages in this region,
- Waterlogging was observed in west and north direction of village Khand Vihari, where due to stagnation of water most of the fertile lands were full of weeds and became uncultivable,
- Lack of drainage facilities for timely disposal of excess rain or flood water from land,
- Choking of existing drains in the region.

It was observed that some of the area do have problems in draining out the standing water, but still there is a great possibility if planned drainage work are undertaken involving cleaning of the existing drain ditches and providing cross drainage structure at various points in the area. Many of these submerged lands can be saved for timely cultivation and losses to the crops can be minimized to a great extent. Khan *et al.* (2002) suggested strategies for resource management to improve agricultural productivity in Bariarpur Tal area and Upadhyaya *et al.* (2006) mentioned problems and prospects of agricultural production in Mokama group of Tals in Bihar. Some of the important suggestions/ remedial measures for this area are given below.

- Proper maintenance of surface drains and providing cross drainage structures of required capacity to allow free flow of runoff.
- Construction of ring bund at appropriate locations.
- Vertical drainage in the form of shallow tubewells.
- Shifting the existing date of transplanting in July.

These case studies and experiences give some idea of possible water management plans in waterlogged canal commands. Most of the case studies reflect that various areas in the country face the surface water stagnation during monsoon months. It is severe in the areas, which are receiving high rainfall as well as having means of surface irrigation systems. Whereas many pockets in the country receive low rainfall but face waterlogging problems due to seepage from water bodies and leading to development of salinity. Areas facing these situations need a better drainage planning to minimize waterlogging situations. In this context we have to control (i) depth and duration of surface water ponding and (ii) encroachment of water table in the crop root zone by adopting surface, subsurface, vertical drainage or bio-drainage or a combination of these systems keeping in view the applicability of these systems.

Surface Drainage

Surface drainage is the orderly removal or safe disposal of excess water from surface of land through improved natural channels or constructed ditches and through shaping of land surface.

A surface drainage system is composed of field drains which collect the excess water from land surface and conducts it to lateral ditches in which water flows to a main ditch and then to the drainage outlet, usually a natural drainage way. Since most of the crops in the irrigated area are being damaged due to non-availability of surface drainage systems, hence a judicious crop selection and proper planning for removal of ponded water can change the scenario of waterlogging in the country.

Subsurface Drainage

Subsurface drainage is one of the most feasible solutions to overcome the waterlogging and salinity problems. By providing adequate subsurface drainage excess water and harmful salts can be appropriately removed from the root zone. Subsurface drainage not only helps in providing favourable environment for growth and maturity of plants by maintaining a desirable water table depth and salinity, but also improves soil temperature, soil workability and trafficability, tillage conditions, biological, microbiological, biochemical processes in the soil and hydrological conditions of soil. This can be practically implemented in two ways, either by vertical drainage or horizontal drainage. Vertical drainage is used generally in two contexts. In one context it implies lowering of water table by pumping of closely spaced tube wells resulting in overlapping of drawdowns, whereas in other context it promotes conjunctive use, which is implemented by intensification of minor irrigation works involving installation of a large number of shallow tubewells and pumping them for irrigation. In horizontal drainage perforated pipes are laid at 1 to 2 m depth, which drain the water from high water table areas, conveying it to a collector and finally to a disposal system. Depth of drain is generally decided on the basis of crop-water-soil hydrological characteristics, crops to be taken, extent of salinity control, depth to impermeable layer in the subsoil, availability of gravity outlet, as well as the available capacity of drain alying equipment.

Bio Drainage

Bio drainage is proposed as a good method of subsurface drainage. However, it is important to identify appropriate situations where this method can be effectively and usefully utilized. It is unfair to assign it an objective, which it cannot take care and then misinterpret the approach. It is a good method to reduce bank seepage from canals and have been used for this purpose in many canal commands. It is not only an economic method of drainage but also improves the ecology of the area and is environment friendly too. It provides costly wood useful for multifarious purposes and also various ranges of biomass. It can transpire water from ground water table in good amounts. A large range of crops tolerant to salinity can be grown in salt affected lands. It is a thus good method for economical exploitation of a wasteland. Biodrainage approaches are generally hypothetical without having been implemented anywhere for agricultural drainage. They are slow process activities, which may be used as supplemental devise along the canal banks or for wasteland reclamation.

Drainage systems may be applicable in the areas, where possibility of evacuating the land by safe disposal of excess water through drainage channel up to the outlet exists. But where an outlet is not available for disposal of excess water and water quality is good, it's efficient and productive utilization should be planned to convert the curse of waterlogging into boon.

TECHNOLOGIES FOR EFFICIENT USE OF WATER

The efficiency of irrigation water can be increased by its judicious use on the farm. The on-farm water management including in-situ moisture conservation, reduction in seepage loss through lining material and improvement in conveyance efficiency of irrigation channels, application efficiency, scheduling of irrigation, change in crop establishment and other management practices, and multiple use of irrigation water increases the water use efficiency and crop productivity.

Reduction of Seepage Losses through Lining Materials

Use of plastic sheet Silpaulin, 250 Micron thick LDPE film have been found as effective lining material over brick and cement concrete lining to control seepage from channels and ponds at Dapoli, Almora and Palampur. Undoubtedly, lining is effective in reducing the seepage loss but technical skill and precautions are required in joining and fixing of lining material to make it viable and acceptable by users.

Rain water harvesting

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Maximum storage and utilization of rainwater resource reduces the irrigation cost drastically. The effect of bund height on water, soil and nutrient conservation and rice yield under the agro-climatic conditions of Bhubaneswar were studied. No reduction in crop yield was observed even at rainfall storage depth of 20 cm. The crop yield did not differ significantly under different storage depths. A simple technology to store and utilize the rainwater is to raise the bunds of about 25 cm around farmers' fields. This technology was tried in farmers' fields and following benefits were reported.

(i) Arrests the rainwater in the fields during monsoon. Allows rice crop to utilize maximum rainwater and reduces the irrigation requirement through other source of irrigation.

(ii) Arrests the soil and nutrients in the fields by minimizing the runoff. This practice does not allow soil deposition in drains resulting in increase in their bed levels and thus more water spillage and spread in the area.

(iii) Bunds help in storing the rainwater on the land surface and replenishing the ground water below the land. This causes ground water to rise and it can be utilized for irrigation during non-monsoon period.

Surface Water Management

In surface water management, the water available at the surface through canal, tanks, ponds or other sources needs strategic planning. The main problem in the canal commands as reported by the farmers is non-availability of canal water when it is required and excess flow of water when it is not required. Due to this some of the command is over-irrigated whereas others don't get water as per their requirement. In nut-shell there is a large gap between supply/ availability and demand/ requirement of water. Under such situation spatial and temporal crop water requirement in the canal command can be computed and given to Water resources department in order to inform the water users well in advance about time and quantity of water to be released from canal. If water users know about the water deficit, they can plan about meeting out this deficit through other water resources. Thus, the gap between availability and requirement can be reduced to a great extent. Involvement of wider group of constituencies in water management could lead to more effective

participatory water management. Through training camps, farmers may be educated and made aware about the proper utilization of available water. Encouragement for formation of Water Users Associations in canal commands and establishing linkages with Water resources department (Water suppliers) through frequent meetings, dialogue and discussion could help in appreciating the problems and seeking the solutions in participatory mode.

Ground Water Management

Development of rigid PVC tubewells, improved propeller pumps, improved foot valve, chain pumps for water lifting in tribal areas, efficient reflux valve, safety device against overheating of diesel engines, low cost well screens for shallow tubewells are some of the water use efficient technologies developed under AICRP on optimization of ground water utilization through wells and pumps. Proper selection, care and timely maintenance of pump, motor suction and delivery pipes and other accessories/ attachments not only improves the efficiency of the system but life of the system also increases. Accelerated adoption of optimization of rice transplanting time not only improved rice-wheat productivity but also encouraged groundwater utilization in the project area. Timely raising of rice nursery using tubewell water, registered 2.5 times increase in groundwater market. Routing of pumped water for irrigation through a reservoir or tank and integrating with horticulture, fishery & livestock is another example of technological push to encourage ground water utilization for improving water productivity in the region.

Conjunctive use of Water

In order to explore the possibility of conjunctive use in canal command, a simple decision support tool has been developed in visual basic (both in Hindi and English), which is capable enough to convince the water users about conjunctive use under the situation when increase in yield leading to monetary benefit is more than additional cost incurred in providing irrigation through ground water. The tool is being tested for various situations like (i) owning tubewell, (ii) Renting pumping set and (iii) purchasing water.

For conjunctive use of saline and canal water, it has been suggested by CSSRI, Karnal that under the short supply of canal water, when the farmers are forced to pump saline ground water or drainage waters to meet the crop water requirements, water from the two sources can be applied either separately or mixed. Mixing of waters to acceptable quality for crops also results in improving the stream size and thus the uniformity in irrigation, especially for the surface method practiced on sandy soils. Allocation of two waters separately, if available on demand, can be done either to different fields, seasons or crop-growth stages such that higher salinity water is not applied to sensitive crops or at sensitive growth stages.

Multiple uses of Water

Multiple use of water in waterlogged/ water stagnated area by routing the canal or ground water through a fish pond-cum-secondary reservoir and planting vegetable or fruit plants on the bunds is widely accepted technology among farmers. By weekly exchange of water, fish harvest upto 10 t/ha as additional income can be obtained. If an integrated farming system is followed in which output of one system (like excreta of animals and birds) is input to other system (fish in the pond), the nutritional value of water for fish, crops, fruits and vegetables increases resulting in increase in production and income many folds.

Water management technologies communicated by ICAR Research Complex for Eastern Region, Patna and adopted in the canal command

Some of the water management technologies communicated and adopted by large number of farmers in the canal command are:

(i) Installation of low cost wooden gates on outlets of distributary for better control on water and its efficient utilization.

(ii) Raising bund height (from 7.5-15 cm to 25-30 cm) around rice fields to conserve rainwater in their fields and reducing pressure on canal.

(iii) Advancement of rice transplanting time by 15-30 days by raising nursery in the last week of May to the middle of June and transplanting the crop between the last week of June and middle of July.

(iv) Multiple uses of water, which has been adopted by the SHGs and farmers of the project area under four situations i.e. (i) Pen culture for fish cultivation in waterlogged areas, (ii) Rice-fish cultivation in seasonally waterlogged areas, (iii) Rice-fish cultivation in irrigated areas, and (iv) fish cultivation in local depressions/ pits. This technology has not only helped the SHGs and farmers in improving their income and livelihood but their understanding has also developed.

(v) One of the recent water application devices developed at ICAR Research Complex for Eastern Region, Patna is Low Energy Water Application (LEWA) device, which operates at 0.4 kg/cm2 pressure. It can be used for irrigating rice, wheat and other close growing crops. The developed device has resulted in reduced overall energy requirements and high water and nutrient-use efficiency of the system as compared to other pressurized irrigation systems.

(vi) Zero tillage for wheat establishment as it saves 25 to 30% of water in first irrigation as compared to conventional method of wheat sowing. It also saves time, energy and money.

(vii) Boro-rice in waterlogged areas equipped with irrigation facilities.

CONCLUSIONS

There is a need to adopt an integrated approach to solve water related problems in waterlogged canal commands. Different case studies presented above may be helpful in realizing the problem and developing appropriate water management plans/ strategies to overcome waterlogging. Waterlogged areas can be made more productive and profitable provided need based and cost effective water management interventions are adopted in participatory mode. Certain key Steps to manage waterlogged command areas are: (i) drainage planning should be a prerequisite and an integral part of water resource development plans, (ii) natural drainage ways should not be disturbed at the cost of water resources, (iii) main branches of surface irrigation commands may be thought for lining, (iv) the carrying capacity of historical or existing natural drainage ways must be improved and maintained to provide adequate surface drainage in the area and minimize the depth and duration of water stagnation, (v) provision of new cross drainage structures and maintenance of existing structure for allowing the free flow of water from canal command underneath the canals/channels, roads, embankments, railways tracks etc, should be made (vi) areas falling between two distributaries must be taken into account as one unit in drainage planning, (vi) conjunctive use plans should be developed for balanced utilization of surface and

ground water in an area, (vii) multiple uses of water to improve land and water productivity of waterlogged area should be promoted and (ix) farmers' participation and feedback in planning and on-farm development works must be considered.

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