Proceedings WAMIP-2010
M. S. Rao, et al. (eds)
N.I.H., 2010

V-2

On-field Management Strategies for the Sustainability of Existing Water Resources in Punjab

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Abstract : Punjab can be considered as grain bin of India. About 83 percent of the state's geographical area is under cultivation with cropping intensity more than 188 percent. Introduction of tube well and canal irrigation coupled with additional management practices during the last 60 years has helped in boosting agricultural production and witnessing all round development in Punjab. Presently, all the surface and groundwater resources are fully explored. In spite of this, the total water available for irrigation is able to meet less than 75 percent of total water requirement and is expected to decrease further in future to meet the growing demand of other users. Moreover, indiscriminate exploitation of these resources has created hydrological imbalance threatening the agricultural sustainability of the state. The introduction of the dense canal network in the South-western Punjab and non-exploitation of its native brackish groundwater has resulted in rise of water table, water-logging and salinity problems. On the contrary, the water table has already declined to critical levels (more than 10 m) and is further declining at a rate of 0.54 m per year due to over exploitation of good quality groundwater in the central Punjab, where around 66% of total tube wells of the state are located. In the present study, current status of the available water resources with factors influencing their sustainability has been discussed for the entire state zone-wise. In the end, various on-field proven strategies for effective water management in the state have been briefly described.

Keywords: Water management, groundwater recharge, management of brackish aquifers

INTRODUCTION

Geographically, Punjab extends from the latitudes 29.30° to 32.32° N and longitudes 73.55° to 76.50° E. It is bounded on the west by Pakistan, on the north by Jammu and Kashmir, on the northeast by Himachal Pradesh and on the south by Haryana and Rajasthan. A belt of undulating hills extends along the northeastern part of the state at the foot of the Himalayas. The economy of the state is primarily agro based. The state falls in the Indus-River basin and is drained by three major Rivers viz. *Ravi*, *Beas*, and *Sutlej*. Apart from these, other drainage channels also exist which includes the *Ghaggar* River that mainly drains the southern parts. With approximately 1.57 percent of the geographical area of the country, it contributes more than 50% grain in the central grain pool. Almost 85% of the geographical area is under cultivation of which 97% area is irrigated. The state has a cropping intensity of 184%. This contribution has been made mainly possible due to the creation of assured irrigation through canals and tube wells. The intense agriculture is, however, posing a serious problem for sustainable agricultural production in the state. The state as a whole is experiencing the acute shortage of water. The alarming situation of exploitation of groundwater is evident from the fact that the water table is declining at the rate of 0.54 m per year. In year 2004-05, this fall was steep at a rate of 0.75 m per year. Traditionally, the farmers had followed the Maize-Wheat or Sugarcane-Maize-Wheat cropping pattern but during last about four decades, they have shifted to Wheat-Rice cropping pattern thereby leading to increased demand on irrigation water. There has also been a spectacular increase in the number of tube wells from 0.19 to more than 1.2 million from 1970-71 to 2008-2009. If the same trend of water exploitation continued, then in the central Punjab, where around 66% of total tube wells are located, water table will fall to 20 m to 50 m by 2023. The excessive decline in water table is resulting in low discharge of tube wells, deepening of pits and tube wells, replacement of low cost centrifugal pumps with costlier submersible pumps and increased energy cost, thereby affecting the socio-economic condition of small farmers of the state. As per the survey conducted by the Department of Soil and Water Engineering, Punjab Agricultural University, sale of centrifugal pumps has been decreased to 22% in the year 2003-04 whereas the sale of submersible pumps has been increased to 32% in the stated year (Vashisht, 2008). The water management problems being faced the state need objective evaluation to develop suitable strategies for development, management and utilization of water resources to sustain the agricultural production. Keeping this in view, various on-farm water management strategies are discussed in this paper. The complete study is divided into four sections based upon different hydrological zones, viz. North-Eastern Shiwalik foothills (*Kandi*) zone; Region lying between *Kandi* zone and central plains zone; Central plains zone; South-Western zone.

SHIWALIK FOOTHILLS (*KANDI*) ZONE

Water is the major limitation to crop production in *Kandi* area of the state. The area has low inherent fertility of soil and the groundwater development extremely difficult as well as uneconomical. Average annual rainfall in the zone is 1100 mm. Much of the rainfall is wasted in the form of surface runoff. About 4500-km^2 area of this zone is severely affected by soil and water erosion due to steep slope of the Shiwalik foothills (36%) and high rainfall (Fig. 1). Available water resources in the zone and their on-field judicious utilization are discussed in the subsequent paragraphs.

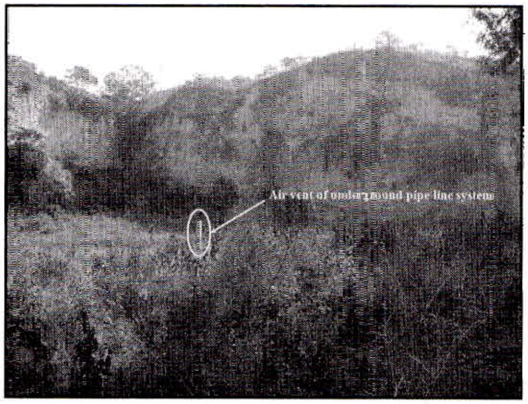

Fig. 1 Severely eroded land in the Shiwalik foothills (photo by author).

Perennial streams

The streams which have the ability to sustain flow throughout the year are called 'perennial streams'. Even during the lean season (other than monsoon season) of the year, discharge rate of these streams may vary from a few litres per minute to hundreds of litres per minute. Collection of pre-requisite data before diverting and tapping these perennial streams to the desired location is the key task of the project. The extent of unevenness of the terrain is the basic parameter. It decides the type of the conveyance system (open channel or pipeline) suitable for the area. Tapping level of the open channel or pipe-line system depends upon the flow level of the stream during the lean period. It should be lower than the yearly minimum flow level of the stream. Most efficient way of conveying water is the use of pipeline system. In case the area to be irrigated is located near or just on the bank of the floodplain of the stream, water is conveyed through open channels. These open channels may be either of permanent type, constructed using cement concrete or may be temporary field-water courses. Here, it is important to mention that the construction of open channels, permanent or temporary, should be restricted to the field boundaries. Construction of any permanent structure in the floodplain of the stream should be avoided.

Construction of conservation dams on perennial and non-perennial streams

Soil of the Shiwalik range is quite erodible.

Occurrence of flash-torrents (locally called *Choe*) in the region is a common phenomenon. These soil-load laden flash torrents cause severe damage to the downstream agricultural fields either due to erosion or due to shedding their load. Construction of conservation structures across streams is the right answer to soil erosion control and water management. By laying underground pipeline system, stored water can be used for irrigation during lean season of the year using highly efficient water application methods.

Construction of water harvesting/recharging structures

With the inception of various water management schemes in the zone, more and more area is being developed for agricultural operations. In the development procedure, provision of water harvesting/recharging should be there as shown in Fig. 2. Chosen location should be lowest in elevation as compared to the adjoining area so that runoff water can be easily diverted and allowed it to store.

Preference will be given to the location which is near to any natural drain. In the lean season, harvested water can be pump lifted for irrigation purpose.

Fig. 2 Water harvesting pond in Shiwalik foothill zone (photo by author).

Development of deep tube wells

Though the land is fertile in the *Kandi* area, yet the problem that invites the paramount attention is that of irrigation specifically those areas which are away from any perennial rivulet or water conservation dam. Canal irrigation to whole of the *Kandi* tract is not possible because of rugged topography and existence of hills and seasonal torrent basins traversing along the area. The only viable means of irrigation is installation of tube wells. However, it is also true that the installation of tube well in the *Kandi* tract is a very difficult task due to rocky geological formations and deep groundwater. Tube-well installation difficulties and cost of the project are the major causes of non-abstraction of groundwater. Even after installation, water from the tube wells for irrigating fields can only be conveyed either through an underground pipeline system or concrete channels with drop structures because of the uneven terrain of such regions. Huge investments for installing tube-wells and water-conveyance structures in such terrains make farmers incapable of undertaking these projects. Only at a few places government tube wells exist, whose primary function is to supply water for domestic as well as irrigation needs. Since the topography of the region is uneven and the soils are light in texture, viable means from the point of view of water management are the adoption of efficient irrigation methods i.e. sprinkler and/or drip system.

REGION LYING BETWEEN SHIWALIK FOOTHILL ZONE AND CENTRAL PLAINS ZONE

Promotion of natural recharging ponds

Rainfall is the only source of groundwa ter recharging, which is also declining as concluded from the analysis of the last three decades of rainfall data. Moreover, approximately 80% of the yearly rainfall is concentrated in three months of the year (mid-June to mid-September), of which considerable portion gets converted into run-off. If the current situation continues the day is not far when water will not be accessible at all. In order to adopt artificial techniques of recharging, probably we have forgotten the traditional groundwater recharging systems (i.e. natural ponds). Land value is the main cause of the extinction of natural ponds in the cities, but in villages they still exist. In earlier times, these ponds were used to store run-off and as a drinking and bathing facility for animals. The stored water slowly infiltrates and eventually recharges the groundwater. From the dried bed of the pond, deposited silt was removed for various uses. This process helps in reviving the infiltration capacity and storage volume of the pond for the coming year. But during the last few decades, urbanization has played a major role in changing the socio-economic conditions of the villagers. A pond in good condition serves both the purpose of storing water and recharging groundwater (Fig. 3). It requires cleaning once a year before the onset of monsoon. In the lean season of the year, pond water can be pump lifted for irrigating nearby agricultural areas.

Sowing of less water consuming crops

Due to deep groundwater table and light soils, this zone is not fit for paddy cultivation.

Fig. 3 : A view of the natural recharging pond in the zone (photo by author).

However, in few patches of the zone, farmers keep on cultivating paddy crop for more earning. Immediate view for this wrong practice is that they (farmers) do not understand the future consequences. Nevertheless, it is a bitter truth that they would increase the depth of their tube well every year, but they would not leave the practice of sowing paddy. Other than this, many wasteful practices have come to prevail among the farmers because of misconceptions and unconcern for conserving water. Therefore, it is the requirement of the present situation that the traditional cropping pattern should be changed immediately possible, such as during *Kharif* season, rice may be replaced with cotton, maize, pulses and oilseeds. Moreover, there is a need to strictly switch over the technologies related to soil and agronomic management that save water without a loss of crop yields, leading to higher productivity per unit use of water (Hira, 2004). These technologies include planting and transplanting time of crops, irrigation scheduling, irrigation methods, straw mulching, and tillage. There is wide scope of increasing the 'on-farm water use efficiency in the state'.

Optimization of irrigation applications

The farmers, in general, have the misconception that more and higher application of irrigations lead to higher crop yields. However, it is not true. Every crop has a certain limit of moisture stress tolerance and its water use is primarily determined by this tolerance limit, which varies with the stage of the crop and season of growth. For the maximum use of irrigation supplies, water application system should be designed to suit the crop and the soil. All over the world, row crops particularly cotton, maize, sugarcane and sunflower are raised under ridge and furrow system of irrigation. This not only helps in promoting the crops from excess water damage during rainy season but also save about 30 to 40% of irrigation water. However, in absence of the suitable machinery, this practice has not come into vogue, as until now. With the mechanization of farm operation, it is now high time that conscientious effort is made to introduce ridge and furrow irrigation system on an extensive scale for achieving sizeable savings in the irrigation water.

Conveyance efficiency for the region

It is already mentioned that the soil of the region, in general, is light. Secondly, due to bordering with Shiwalik foothill zone, north-eastern part of this region has rolling topography. Therefore, water conveyance is a big challenge. Underground pipeline system is the only suitable method. The system convey the water from tube well to different fields through reinforced cement concrete (RCC) or polyvinyl chloride (PVC) pipes. These pipes are usually buried underneath the ground and enable the water to be carried under pressure for gravity flow. Non-interference with the field operations, elimination of evaporation losses, and saving of area for construction of channels are few advantages of the system.

CENTRAL PLAINS ZONE

Exploitation of water is maximal in this zone due to highest cropping intensity, sweet groundwater, and highly mechanized farming. Annual average rainfall of the zone is 709 mm. As compared to other zones of the state, groundwater replenishment need of this zone is maximal.

Recharging through abandoned open wells and cavity tube wells

In early times, dug wells were the only source of fresh water. These days, it is uncommon to see a working dug well, as either such wells are refilled with soil or covered to avoid any accident. Further, now majority of such wells are without water since water table is continuously declining. These abandoned dug wells could be used for recharging groundwater if runoff or rooftop water is diverted toward these wells. It is well accepted fact that recharging through wells is a viable mean to replenish the declining water table. Studies conducted at PAU, Ludhiana have shown that cavity tube wells can be successfully used as irrigation-cum-recharge wells. Moreover, by constructing efficient filtering device, screened wells can also be conveniently used for the recharging purpose.

Recharging with Rooftop harvested rainwater

There is an urgent need for harvesting every drop of rainwater, since this is the major source of replenishment of groundwater. For more than 5000 years, rainwater harvesting has formed part of Indian traditions, and over centuries, they have developed a range of techniques, to harvest rain water to the last drop. Roof top rainwater harvesting is one of such techniques. It has been estimated that about 11.44 km^3 of rainwater could be harvested through rooftops in India, which is approximately 30% of the domestic water requirement of the country (Vashisht, 2008). The ever increasing population and urbanization is decreasing agricultural land, which is the natural means of surface water recharging. This valuable agricultural land is being covered with multi-storey buildings and roads. To sustain equilibrium in groundwater withdrawal and recharge in urban stretches, forced recharging of the rainwater collected through rooftops of buildings is the only option left as surface means of groundwater recharging is not possible. Considering the present situation, the state government has ordered a new building plan, according to which it is necessary for the owners having area more than 200 m^2 to construct an adequate depth percolation pit of 30 to 45 cm diameter (source The Tribune: www.tribuneindia.com).

Promoting recharge through paddy fields

As per the experiments carried out by the department of soils at PAU, $2/3^{rd}$ of the irrigation water applied in case of rice joins the groundwater and adds to the groundwater recharge. During monsoon season, by increasing the height of field bunds, sufficient water can be allowed to pond in the field that will infiltrate and deep percolate to recharge groundwater; which otherwise goes waste as runoff.

Discouraging the mal-practices adopted by the farmers

With the inception of highly efficient machines, time required to complete land preparation operations has drastically decreased. Taking the advantage of this saved time, farmers of the zone have started transplanting paddy first in the month of April and second in the month of June. In this way, they are taking two paddy crops in a year. This mal-practice of the farmers is creating undue stress in the existing water resources. Government of Punjab has taken positive action to discourage this practice by making available the electric power only after June 10 every year, but it seems that this action by the government has no effect on this mal-practice as farmers irrigate the crop using engine operated pump sets. There is need to enact proper groundwater legislation to prevent indiscriminate exploitation of groundwater resource. Besides, a vigorous educational program needs to be launched. The farmers concern for conserving the water to be initiated. Establishment of an irrigation extension service is recommended to pursue the responsibility of educating the farmers in efficient water use practices on a continuous basis.

Recharging projects which only government can undertake

There are few recharging options available in the central zone of the state, which can be made successful only at the level of government with the inception of mega projects.

1. Central portion of the state has a good network of surface drains (~3400 km length), which can be utilized for artificial groundwater recharge using surplus runoff water during rainy season.
2. Water flowing in the major rivers viz. *Sutlej*, *Beas* and *Ravi* during monsoon or rest of the year can be diverted towards natural and artificial drains, by constructing barrages at suitable locations.
3. By promoting the recharge of water through white and black *Beins* (natural drain).

SOUTH - WESTERN ZONE

Average annual rainfall in the zone is 342 mm. The long-term rise of water table studied by Takshi and Chopra (2004) for 1984-2002 reveals that water table is rising in about 20% of the state's geographical area; out of which average rise of water table is more than 20cm per year in about 50 percent of the rising water table area. Native groundwater of the zone is highly brackish, however still some good quality water in thin layers floats over brackish groundwater due to seepage from canal systems in the zone. Agricultural sustainability in the zone completely depends upon the efficient management of brackish water aquifers.

Managing saline water aquifers

As mentioned in previous sections that native groundwater of the southwestern Punjab is saline/ brackish and its quality deteriorates with depth. Earlier, naturally occurring brackish water aquifers were considered waste. But now, it is believed that these aquifers would be a good source of water for sustaining agriculture in the 21^{st} century, if properly managed (Vashisht and Shakya, 2005). Efficient drainage system is the key for achieving success while irrigating with brackish water. For maintaining low salt and alkalinity level in the root zone without compromising with crop yield, following management practices are suggested:

Use of gypsum

Application of gypsum is recommended when RSC of irrigation water exceed 2.4 me/lit. The quantity of gypsum for every additional one me/

lit of RSC works out to 86 kg per 1000 m^3 of water. Usually 1.5 quintals gypsum of agriculture grade is recommended after every 4 irrigations to neutralize the adverse effect of 1 me RSC/lit. An efficient way for dissolving the gypsum in the irrigation water is constructing a gypsum bed (Singh *et al.*, 1986) in the watercourse.

Conjunctive use of poor and good quality water

Blending of brackish groundwater with good quality canal water is another possibility for reducing the salinity/sodicity hazards of the problematic waters. Alternate/cyclic use of brackish groundwater and canal water is another technique to manage such soils and aquifers. According to a study, crop production through cyclic use of 2-canal water and 1-brackish groundwater is as good as irrigation with canal water only (Shakya *et al.*, 1995).

Aquifer-storage-recovery using multiple well point system

Another approach to manage brackish aquifers is to recharge these with fresh/canal water, when fresh water supplies are available, and subsequently pump reasonable quality water from these aquifers through skimming wells, when needed. Quality of the recovered water depends upon the groundwater velocity in the aquifer and the time gap after which the groundwater is pumped. Feasibility study of this approach was conducted by Vashisht (2004) in *Golewala* watershed (district *Faridkot*) and got encouraging results.

CONCLUDING REMARKS

The problems relating to water resources development and management in Punjab are manifolds and are of serious concern for the future development of the agriculture in the state. Even at the present level of cropping of intensity, there is a wide gap between demand and supply of water. Faulty water management, wrong selection of crop, and malpractices by the farmers at the field level has further increased this gap, which is being bridged with increased exploitation of groundwater. In order to correct the imbalance in water budget and to restore sustainability to farming system, there is immediate need to revert the situation. Water conservation and its judicious use through efficient irrigation methods for cultivating less water consuming crops is the key to sustainable agriculture in *Kandi* zone of the state. Proposed groundwater recharging methods which are in the purview of farmer should be enforced through legislation. Integrated approach for conjunctive use of surface water and poor quality groundwater involving alternative use on sodic soils helps in improving the physic-chemical properties of the soil. Thus, now it is the high time to take appropriate measures for scientific development and management of water resources to sustain the existing food grain production in the state.

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