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WATER MANAGEMENT THROUGH CONJUNCTIVE USE: EXPERIENCES AND PROSPECTS IN HARYANA

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ABSTRACT

The management of water implies protection of quality and quantity of the resources, its allocation in a manner that meets the objectives of the society and the improvement in the productivity and efficiency of the system. Amongst the several management strategies employed to meet these objectives conjunctive use of water resources is perhaps one of the most important practice. The impact of conjunctive use of surface and ground water in the Ghaggar-Yamuna basin of Haryana state is presented.

Development of ground water through public deep tubewells and the farmers owned and operated shallow tubewells in the fresh water zone of the basin improved dependability and adequacy of the water supply system. It also controlled the water table and helped in reclamation of alkali lands. Development of ground water in saline zone through skimming wells/shallow tubewells and horizontal sub-surface drainage on limited scale has also given encouraging results.

Further improvement in performance of irrigated agriculture is possible through proper rain water management in the fresh water zone and better integration of poor quality ground water with canal water in the saline zone. Appropriate systems of rain water management and conjunctive of canal and saline water could be developed through application of systems analysis.

1.0 INTRODUCTION

Conjunctive use management can be defined as the management of multiple water resources in a co-ordinated operation such that the total water yield of the system over a period of time exceeds the sum of water yield of individual components of the system resulting from un-coordinated operation. Research on conjunctive use has focussed attention on the potentially large benefits that can be gained from efficient integrated use. The physical interdependence of the surface and ground waters and the potential benefits have been dealt at length in Hall (1986), O'Mara (1989) and Tyagi and Agrawal (1990) among many others. The major advantages that occur from conjunctive use could be (1) augmentation in the capacity of water supply system, (2) improvement in equity of water distribution among the beneficiaries, (3) correction in mismatch between demand and supply, (4) improvement in the water utilization efficiency of the canal system and (5) minimization of the incidence of waterlogging and salinity.

Experiences in conjunctive use, benefits gained in achieving prioritized objectives and approaches to improved management of water resources with reference to Bhakra Canal (BC) and Western Yamuna Canal (WYC) systems in the Yamuna-Ghaggar Basin in the state of Haryana are presented.

2.0 GEOGRAPHICAL SETTING

The state of Haryana occupies an area of 44,212 sq.km and lies between the latitude 27° 35' and 31° 55.5' and longitudes 74° 22.8' and 77° 35.6 E. It is bound by the River Ghaggar on the northwest, extensions of Aravali hills towards the west and the Yamuna river on its north-eastern side Fig.1.

Except for the Siwalik, the Sub-Siwalik and the piedmont plain area, the state has a remarkable flat terrain. The average elevation ranges from 150 to 300 m above the mean sea level. The physiographic situation makes it a closed and depressed saucer shaped basin.

The climate of the area is classified as sub-tropical monsoonal. The mean annual rainfall varies from less than 200 mm to more than 1000 mm. About 83 per cent of the annual precipitation occurs during the summer monsoon period (June to September). The uneven distribution of rainfall leads to drainage problems during monsoon months and increased irrigation requirements during rest of the period.

The pumping test data of the exploratory bore holes indicate high transmissivity values upto 4000 sq m/day, in Ambala, Karnal and Kurukshetra and it decreases towards south of Karnal. The occurrence of saline ground water in the clay predominant environment of Rohtak, Sonepat and Gurgaon gives rise to the probability of a close relationship between lithology and ground water salinity.

3.0 WATER RESOURCES

The sources of water in the state are: canal water supply from the WYC and the BC system, rain water stored in ponds and lakes, and ground water.

3.1 Canal Water

The water available from BC and WYC systems is 1.05 M ha M. In addition, 0.43 M ha M water is likely to be allocated to the state as its share in the Rabi-Beas waters.

3.2 Rain Water

Rain is a major source of water which meets requirements of the crops directly, supplies water for storage in ponds and lakes, and for ground water recharge. Of the total runoff 4732 million cubic meter (MCM), only 55 MC is at present stored in different lakes. It is planned to raise this capacity to 129.3 MCM by increasing the storage capacity of these lakes (Anonymous, 1983).

3.3 Ground Water

Ground water is the second important source of water. The estimated ground water recharge is 1.03 M ha M of which 0.94 M ha M is considered usable. From considerations of ground water quality the state of Haryana can divided into two broad zones of the fresh water and saline/sodic water.

3.4 Status of Water Demand and Supply in the State

The total culturable area of the state is 38500 sq km, of which only 35000 is commendable under canal system. The actual canal irrigation extends to only 12000 sq km. At 100 percent annual irrigation intensity the irrigation requirements have been estimated at 4.13 M ha M. The present canal irrigation intensity, even with deficit irrigation, is only between 60-70 percent. Both the major canal systems including BCS and WYC operate at low reliability (ratio of actual water supply to that of designed supply) factors (Fig.2). The average value of reliability factor is 0.76 in BCS as compared to only 0.45 in WYC. In both cases the reliability is low during critical periods of rabi season when demand for irrigation is high. The seasonal adequacy water is of the order 0.70 during kharif and 0.63 during rabi in BCS (Tyagi et al). The relative water supply (demand/supply) for two typical distributaries one in BCS and the other in WYC, was worked out by Tyagi and Mishra (1990). They found that there were unacceptable intra and inter seasonal variations in the relative water supply values which caused reduction in crop productions to the extent of 20 percent. It may therefore be concluded that both WYC and BCS are high tension systems where demand for water far exceeds its supply.

3.5 Scope for Conjunctive Use

Both, the fresh as well as the saline water zones have scope for optimizing water use through integrated resources development and use. The problems of water management in fresh water areas centers around optimizing ground water withdrawal, while maintaining watertable at levels where it may not be uneconomic to develop ground water for irriga-

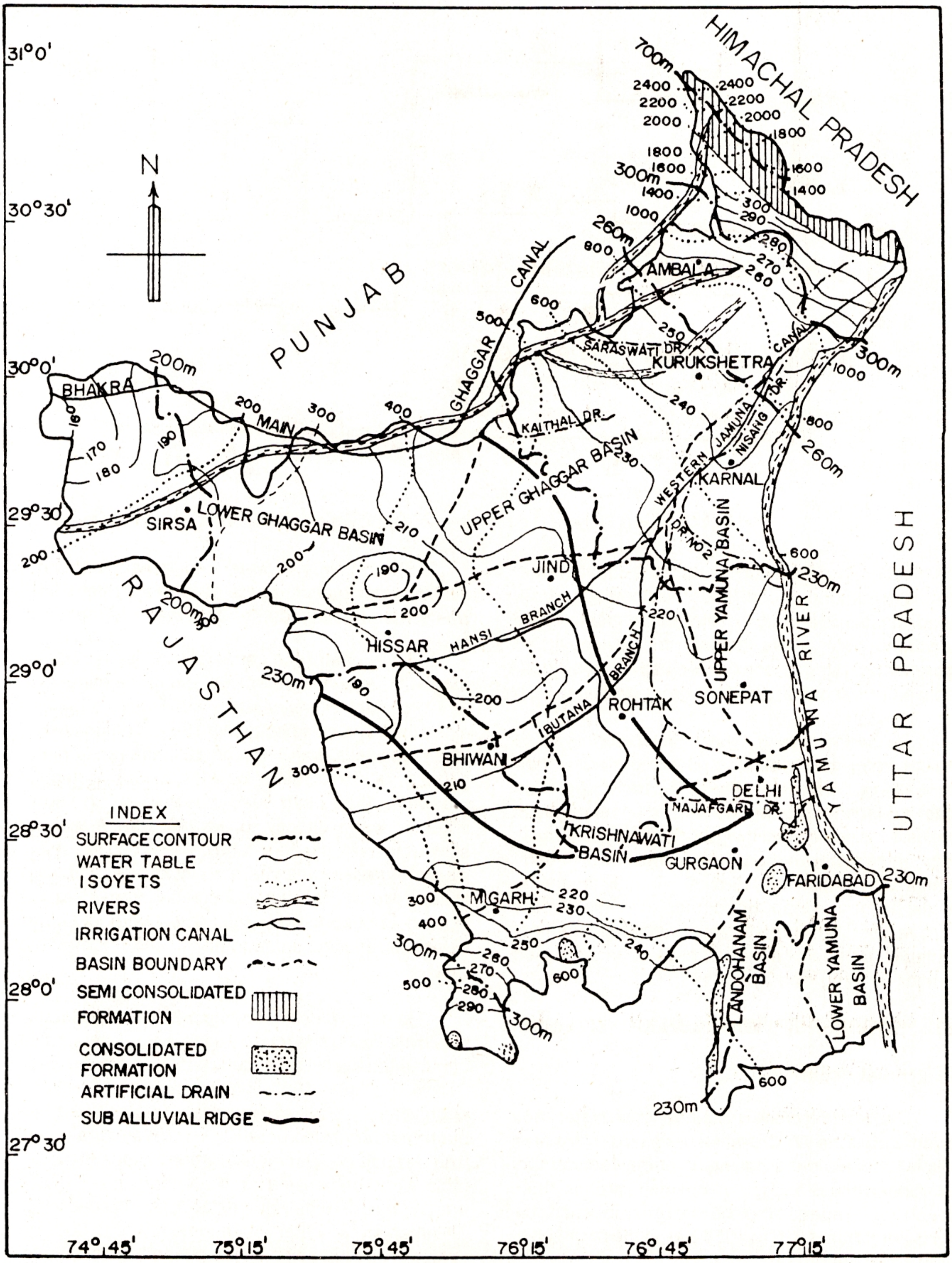

Figure 1. Hydrogeological Map of Haryana State

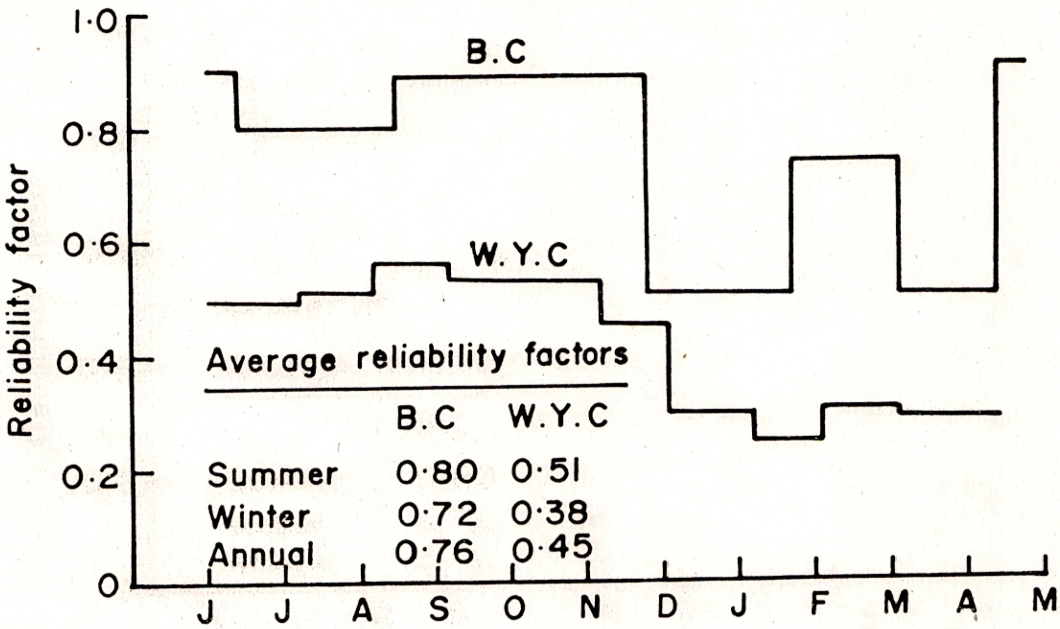

Figure 2. Relability factors in WYC and BC Systems

tion. Since the water supplies from the canal system are mostly inadequate to meet the demands of irrigated agriculture and can be only partially augmented by ground water, there is scope for developing an appropriate system of conjunctive use of rains, irrigation water from canals, and the groundwater.

Unlike fresh water zone, development of saline ground water may result in an increase in the root-zone salinity. However, the rising trend in ground water table following introduction of canal irrigation makes it imperative that the ground water recharge is disposed off either through reuse in irrigation or through evaporation ponds and drains. It may again be necessary to develop appropriate systems of conjunctive use. The appropriate water management strategies for these conditions have been discussed in detail by Tyagi and Tyagi (1990).

4.0 EXPERIENCES WITH CONJUNCTIVE USE

4.1 Fresh Water Zone

A major part of the area under fresh water zone is irrigated by the WYC System. Irrigation in this area was introduced in the beginning of the 19th century and reports on waterlogging were made around 1850. Uppal (1972) reported that the rate of rise in watertable in this zone from 1926 to 1958 was in the range of 40 to 50 cm per year Fig.3.

The problem of waterlogging was accompanied by water scarcity as the water supply from WYC was inadequate to meet the crop water demands.

To augment the canal water supplies and to reduce the sub-soil water level along the canal system, a project for installation of 256 deep tubewells along the WYC was planned in 1949. The number of these tubewells, with a discharge in the range of 40-170 lps, reached 1593. Besides the augmentation tubewells, 1488 other deep tubewells which supply irrigation water directly to the fields were also installed. Initially, the deep tubewells served the objectives of increasing the total amount and dependability of canal water. The supply increased from 85 to 110 cumecs in periods when river flows were low. This helped in reducing canal rotation period from 4 to 3 weeks.

In mid sixties the technology for installation of shallow tubewells reached village level. The number of these tubewells increased from 1,04,358 in 1970-71 to 4, 57, 850 in 1989-90 (Economic and Statistical Organization, Govt. of Haryana, 1991). There has been several fold increase in ground water draft. Due to large scale development of ground water, the water table, which had a rising trend throughout the irrigated area before 1970 has either stabilized or is declining. The problem of water management in this area revolves around keeping water withdrawals within acceptable limits of mining. This may require change in crops and cropping pattern.

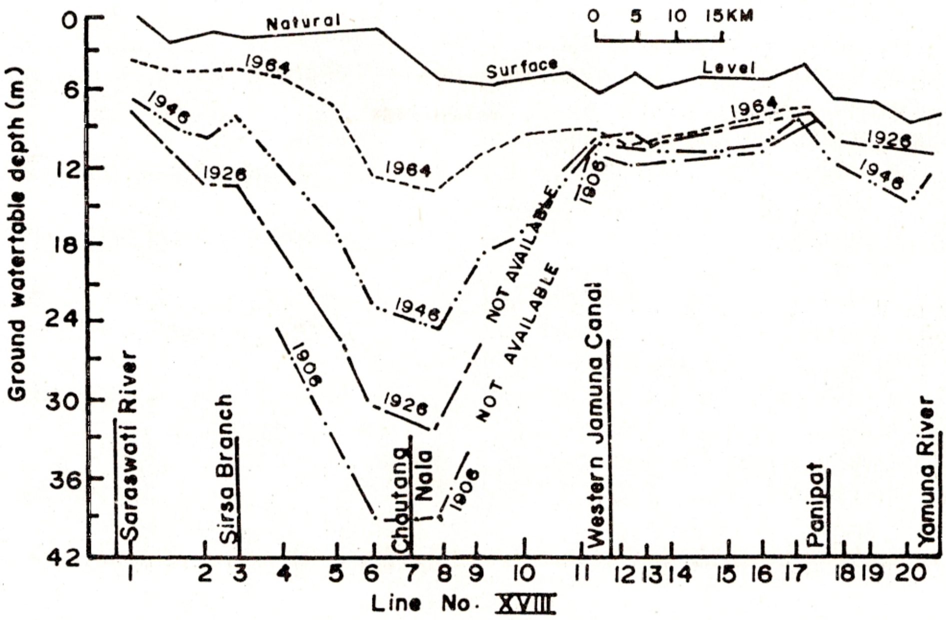

Figure 3 Rate of rise in watertable in a WYC tract

4.2 Saline Water Zone

A major part of the area under this zone receives irrigation from the BCS. Prior to commissioning of the Bhakra reservoir around 1955, irrigation was practised on a limited scale from waters of WYC System. Due to the problems of salinity and the difficulties in installation of tubewells in poor formations, the development of ground water was limited to low discharge dug wells.

In order to devise strategies for arresting the rise of water table in this otherwise fertile zone, hydrogeological investigation to ascertain the feasibility of ground water development in conjunction with canal water were made (Anonymous 1984) and appropriate pilot project were formulated. The approaches being tried on field scale include: development of ground water through skimming and ordinary shallow tubewells, mixing of the ground water with canal water, use of canal and saline water in rotation and provision of horizontal drainage. There has been only limited success in arrest of water table and augmentation of water supply. The operation has been more successful in areas where ground water quality is relatively better. The strategies that may be adopted on large scale are discussed in Tyagi and Tyagi (1990).

The past experiences on conjunctive use in Haryana can be summarized in the following words:

Conjunctive use controlled water table in fresh water zone, augmented canal water supplies for use in water deficit areas which made it possible to reduce the period of rotation from 4 to 3 weeks during winter season in areas served by WYC. Additional ground water supply, that was developed facilitated reclamation of alkali lands in the fresh water belt and thus helped in meeting food production targets. At present the development of ground water in the saline zone is limited. But the success achieved in skimming wells, horizontal drainage and saline-water-use technology has opened avenues for increasing irrigation intensity without inviting environmental problems.

5.0 FURTHER PROSPECTS

Though development of ground water in conjunction with surface water supplies has assisted in achieving some of the water management objectives, there are several other compliments of the conjunctive use that have not been fully explored. The two important aspects that need some in depth analysis are: (1) need for and scope of conjunctive management of rain and irrigation waters (2) improvement in canal water utilization efficiency through conjunctive use of ground and canal waters.

5.1 Conjunctive Use of Rain and Irrigation Waters

The lowering of water table due to over exploitation of ground water on one hand, and the wastage of good quality rain water, which creates flood problem during monsoon on the other, is a paradoxical situation. The development of apprpriate systems of rain water management and their integration with canals and aquifers can, to some extent, mitigate the problem of water scarcity and improve the efficiency of water resources utilization.

There could be several approaches to rain water management and the amount of rain that could be managed depends upon the rainfall amount and its distribution. The difficulty in optimizing conjunctive use of rain and irrigation water lies in combining the use of limited irrigation water with resources of inherently unpredictable rainfall (Stewart and Musick 1981). The surplus rain water could be managed in the following subsystems.

(1) Storage in rice fields upto various depths (RFS)

(2) Storage in fallow alkai. .ands (RFL)

(3) Storage in lined and unlined ponds (RPS)

(4) Runoff diversion for artificial recharge through tubewells (GWR)

The water so managed could be allocated to crops in conjunction with normally available rainwater. Tyagi et al (1989) developed decision models to determine optimal management strategies. A schematic diagram of the decision process is shown in Fig.4. The results of analysis showed that

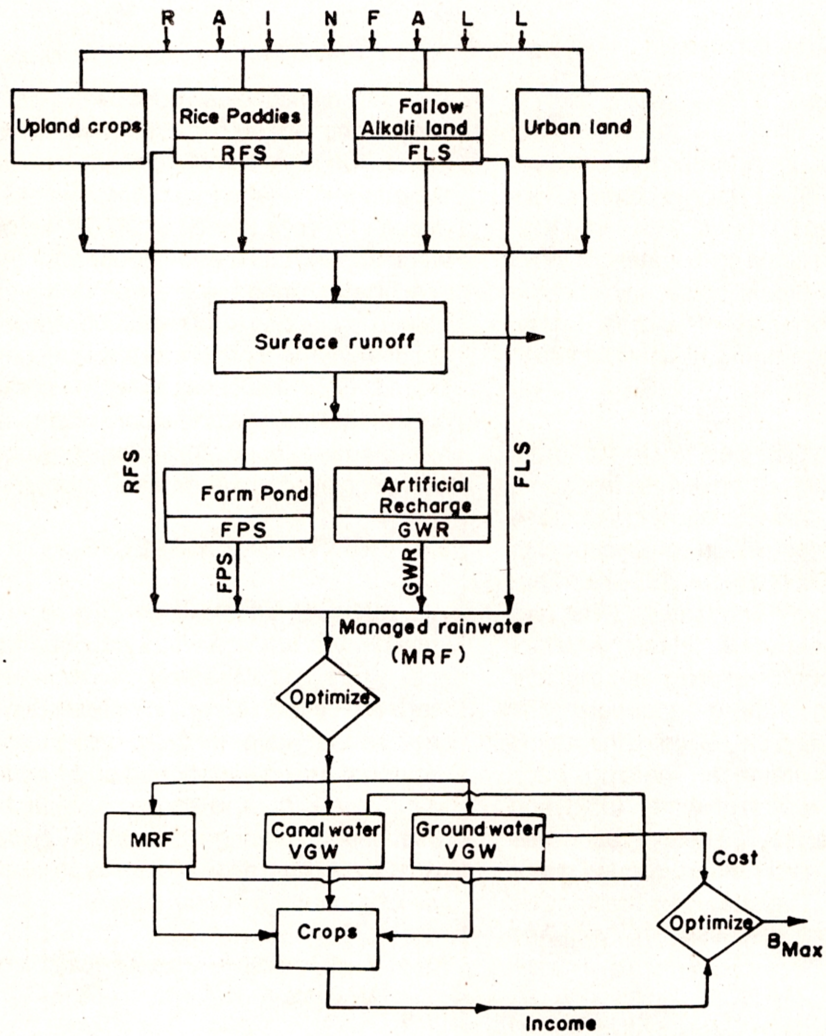

Figure 4. Schematic diagram of rainwater management systemand conjunctive use model

(1) Storage of rain water underground in aquifers is much more cost effective as compared to surface storage. Building up ground water resources through induced recharge could be used as means of stabilizing the declining water table.

(2) Attempts to utilize the total rainfall may not be very cost effective. It would be economically advantageous and environmentally advisable if only 70 to 80 percent of the runoff was stored through suggested management system.

(3) Agricultural production could be boosted in the fresh water zone to the extent of 20 percent.

5.2 Improving Canal Water Utilization Efficiency (CWUE)

Utilization efficiency may be defined as the average of demand for water over the crop growth periods and the corresponding canal water diversions. To investigate the feasibility of improving CWUE it requires consideration of optimal cropping patterns with and without conjunctive use. The optimal cropping patterns may be based on the results of systems analysis which use some sort of optimization models to allocate resources. To illustrate the scope of improving CWUE in BCS a linear programming model is formulated for a typical irrigated (Bhirud, 1989). The results are briefly discussed.

5.2.1 Conjunctive use model

The model aims at allocating water from canal and groundwater reservoir optimally in a conjunctive manner. The model is based on use of linear programming algorithm. To economize on space the mathematical formulation is not given.

The model included crop activities alongwith their irrigation requirements and net income. Besides crop activities the model had periodic canal and tubewell water diversions as decision variables and aimed at maximizing income from crop production. The planning horizon was kept one year divided into 24 periods of 15 days, the first period beginning with 1-15 June.

5.2.2 Periodic water demands

The water demands estimated for the optimum cropping pattern with and without ground water use alone are shown in Fig.5.

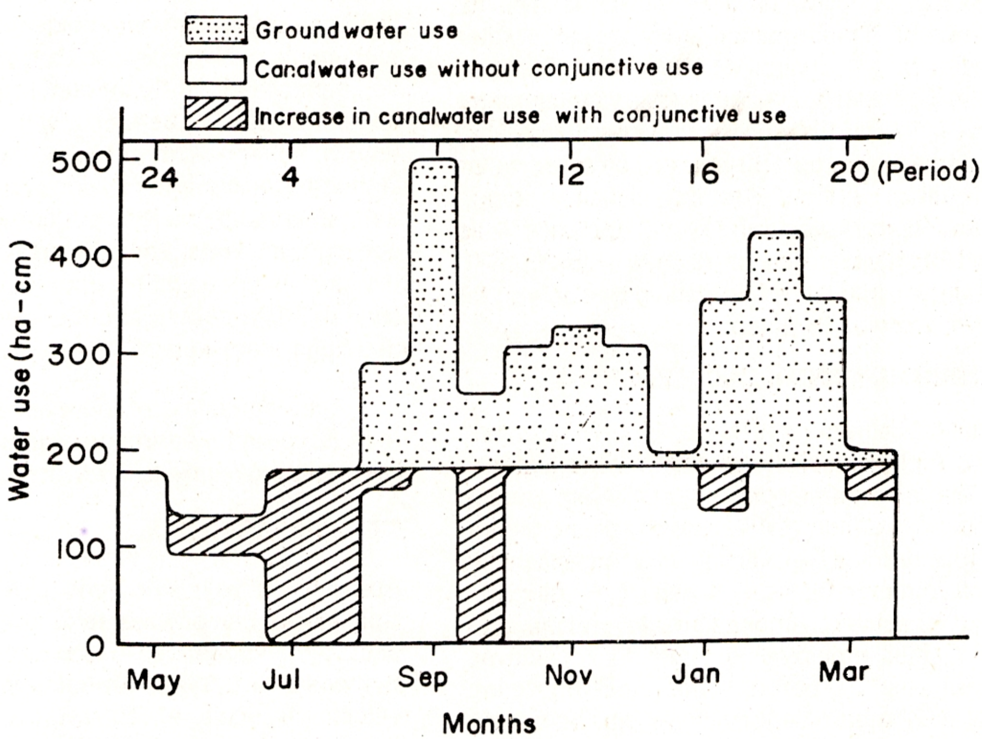

Figure 5. Increase in canal water utilization with conjunctive use of canal ground values

Under the situation of no ground water development the cropping pattern generated no demand for water in rotation periods 4, 5 and 8, whereas the requirement in periods 2 and 3 was about 50 percent of the supply, 87 percent in period 6, 70 percent in period 13 and 80 percent in period 16. The overall water utilization efficiency (water demand/water supply) was of the order of 70 percent with 30 percent going waste. This could look strange for an area where water supply is scarce. There are two possible reasons for this under utilization of water supply: (i) period 4 and 5 falling in July and August have higher incidence of rainfall and therefore, less demand for irrigation water, also (ii) the model selects only those crop activities which can be sustained with the available water supply during subsequent periods 7 and 8. As would be seen in the following section, this situation could be rectified by resorting to conjunctive use of canal water and sodic ground water which could be treated with gypsum.

5.2.3 Effect of groundwater use on canal water utilization

In irrigation planning, percent utilization of the available supply is an important performance criterion. The system management is considered to be good if the ratio of canal water demand and supply is closer to one. The optimal cropping pattern under situations of conjunctive use changes and so does the water demand. The demand pattern for canal water under situation of conjunctive use is also shown in Fig.5. It may be seen that as against no water demand in periods 4, 5 and 8 in case of no conjunctive use, the optimal pattern utilizes 100 percent of canal water supply in these periods. Also the utilization during second period improves from 50 to 74 percent. This improves the overall utilization of canal water from 70 percent under situation of no conjunctive use to 98 percent with conjunctive use.

6.0 SUMMARY AND CONCLUSIONS

Water management is the key to increased efficiency and productivity of water resources in a region. The management is concerned with protecting quality and quantity of the water resources, improving their productivity and efficiency and allocating them in a manner that would help in meeting the prioritized objectives. Amongst the several management strategies employed to meet the objectives, conjunctive use is perhaps the most important. Haryana, in Ghaggar-Yamuna basin, has been practising conjunctive use in the command areas of Western Yamuna Canal (WYC) which is fed from run of the river Yamuna and Bhakra Canal System (BCS) from a reservoir on river Satluj. Water management strategies revolving around conjunctive use and their impacts on dependability, adequacy and timeliness of water supply; control of waterlogging and salinity and further prospects are presented.

Development of ground water and its integrated use with canal water in fresh ground water zone augmented the canal water supply making it possible to reduce the rotation period from 4 to 3 weeks in WYC in lean flow periods. Large scale development of ground water through farmers owned shallow tubewells eleminated waterlogging and generated additional water supplies for reclamation of alkali lands. Further ingress of alkalinity has been checked. Continued mining of ground water may, however pose some problems in future.

In areas with saline ground water, conjunctive use has been practised on a limited scale. Recent advances in development of appropriate technology in the form of skimming wells, horizontal drainage and package of practices for use of saline/sodic water, are likely to have positive effect on development of ground water and its integrated use.

Development of appropriate management systems for improving rain water use in fresh water zone and increased saline/sodic ground water in saline ground water zone holds promises. Management plans evolved by using systems analysis technique show that 70-80 percent runoff resulting monsoonal rains could be used, with economic advantage without impairment of the environment quality. Underground storage through increased recharge is more advantageous than surface storage. In saline/sodic ground water zone the utilization efficiency of the canal water could be improved from the existing level of 70 percent to about 95 percent by development of ground water.

Strengthening of the existing water management programmes through suggested measures is likely to improve environment and add to quality of life.

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