WATER ACCOUNTING IN JAUNPUR BRANCH SUB-BASIN OF SARDA SHAYAK CANAL SYSTEM

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ABSTRACT

Within the constraints of available resources, sustainable agricultural strategies in irrigated command areas aim to produce more crop per drop of water applied in irrigation which is the largest user. Integrated water resources management must combine the agricultural system and socio-economics; provide greater role to stakeholders in management and operation of delivery system. Government agencies can provide decision support system to basin development and management board involving stakeholders, WUAs and public representatives. Water accounting is fundamental for water management and monitoring the services to users. These calls for revisiting water balance studies for present-day cropping practices and to have the system capacity flexible to provide demand driven services.

The study area, Haidergarh/Jaunpur branch sub-basin (HBS-JBS) of Sarda Shayak Canal system lies in doab of Gomti and Sai rivers covering gross command 0.60 million hectare and culturable command area 0.32 million hectare. Project is designed for 115% irrigation intensity. HBS takes off at 171.5 km of the main Sarda Shayak System with design discharge 165 cumec. JBS takes off at 22.98 km of HBS with head design capacity of 123 cumec. Landholding average size is 0.54 ha. HDI index of project districts is 0.53 that equals to state average and income index is 0. 551. Climate is subtropical. Average normal rainfall is 900 mm and soil is part of central Gangetic alluvial plain. Slope is 0.15 to 0.09 m/km and becomes flat towards east. At any given time 25% command area along canal within buffer of 1 km is waterlogged whereas command tail end and fringe areas face decline in groundwater table even more than 8 mbgl. The difference between pre and post monsoon groundwater table varies along the canals. Decline in crop yield in head reaches seen but found highest where groundwater supplementation is being practiced (that counter water logging in root zone of crops) and highest wheat yield is found in tail command because of more concentration of private shallow tubewells for the reasons of uncertain and inadequate canal supplies. More diversified agricultural practices have been seen in areas far off from canal and only paddy-wheat rotation (80 to 70% of sown) near canal where canal water dependency syndrome persists.

This paper focuses on water accounting of rainwater, canal and groundwater available in the basin and calculates the crop water requirement according to current cropping pattern of 177% intensity. The net irrigation water requirement is estimated 5126.78 MCM against which effective rainwater available is 2171 MCM, canal water is 1416 MCM and groundwater availability is 2367 MCM. Thus if all water resources available are used in conjunction with each other then total water availability of 5954 MCM could easily meet the present day demand of 5127 MCM. What needs to be done by project authorities is to a) redesign the canal system for variable discharges in place of fixed one; b) provide head and discharge control structures at places where sensitivity of structures is found critical; c) WUAs and let farmers push their own agenda, d) introduce simple way to collect and to charge for irrigation water.

The idea is that if the farmers pay for services they receive, it would encourage them to use water more

efficiently and release it for other down stream uses, addressing water scarcity. People do not mind paying for water for irrigation, if they got a good service, but they do mind 'paying for someone else's wife's jewellary.'

Under Uttar Pradesh Water Sector Restructuring Project (IDA support US$ 150 million) project authorities are modernizing HBS- JBS irrigation system. Service oriented management includes rehabilitation of canals and drains, Duck Bill Wear/wear and gated structure in place and adoption of PIM activities, conjunctive use of water and diversified agricultural demonstration. People awareness taking help of NGO, women SHG and WUAs have started showing benefits in productivity of paddy rise from 2.6 tonnes/ha to 6 - 7 tonnes/ha in demonstration fields of progressive farmers by optimum use of water for irrigation and adopting better agricultural practices.

INTRODUCTION

The most of the studies relating to irrigated command strategies for sustainable agriculture aimed to focus around examining the water balance and optimization of conjunctive use of water available on disposal. A thorough examination on the literature on the subject of management of water resources, shows that the major sources of the water pool is rainfall water, ground water and surface water. The irrigation water plays a crucial role in strategy planning for water allocation in development of agriculture. The judicious use of water for irrigation depending upon multiple options requires overhauling of policy strategies through water balance models. The inefficiency of water use, inequitable distribution at head and tail reaches, water logging along the canal system, and use of different irrigation practices has raised the question mark on efficient utilization of water resources. The conjunctive use and water harvesting potentials is demand of the time for promoting agriculture to ensure food and livelihood of large section of farming community constituting the one-third economy of the state.

The water balance studies and planning for conjunctive use of water for irrigation of crops has become high demand for comprehending the agricultural growth and sustainable agricultural production in years to come.

The issues raised here were also identified in Tenth Plan few of them are given below:

- An increasing demand for water accompanied by constraints on availability.
- A gap between created and utilized irrigation potential.
- Low water use efficiency in irrigation
- Low tariffs for surface water supply, which do not cover even the operation and maintenance (O&M) costs.
- Slow pace of take-over of irrigation systems by Water User Associations (WUAs).
- Overuse of groundwater and ineffectiveness of legislation to check this.
- Floods, drainage and water logging.
- Surface and groundwater pollution; problems of water quality.

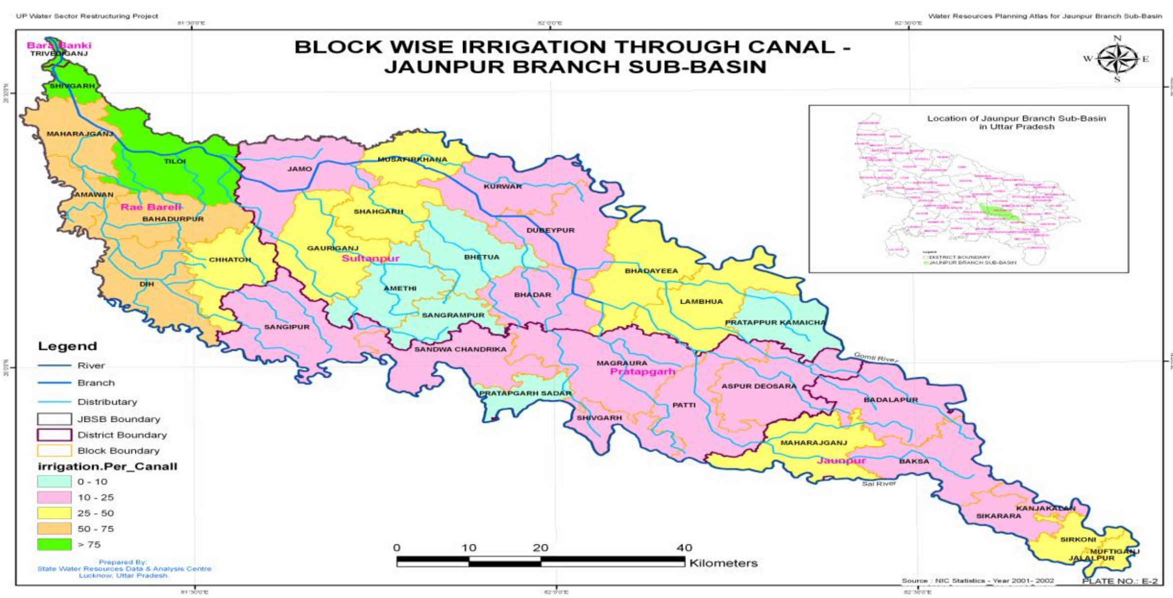
Out of the 167.5 lakh hectares net area sown in the State in 2003-04, the net irrigated area was only 132.27 lakh ha (78.97%). There is still a large un-irrigated area in the State accounting to 35.23 lakh ha (21.03%) of net area sown. The resultant loss of agriculture production on this account is not difficult to imagine. There is also large gap in potential created and utilized. Thus there is a large scope for the State to work for utilizing of irrigation potential, and finally increasing the agricultural production. Further water use efficiency in most irrigation systems is low in the range of 30-40 percent as against an ideal value of 60%. There has also been steady decline in water table due to over exploitation of ground water and deficient recharge from rainwater. Declining trend of groundwater has been observed in 559 of 819 blocks in the State. Between 1987 and the year 2007, percentage groundwater used for irrigation has gone up from 30 to 69% for the State as a whole. The statistics supports the hypothesis of the study.

OBJECTIVE OF STUDY

At present crops grown in the Sahara Sahayak Canal Project area are early paddy, medium paddy, mazie, fodder (Kharif), sugarcane early wheat, late wheat, potatoes and oil seeds. The cropping intensity for the present situation is Jaunpur canal command is 177% only. The area irrigated by canals has been continuously declining over the years. There has also been steady decline in water table due to over exploitation of ground water and insufficient recharge from rain water in the certain areas. It is also note worthy that there is a big gap between the created irrigation potential and actual utilization. There may be several reasons for this gap such as non construction of on-farm development works below the outlet, change in cropping pattern to more water intensive crops, loss in live storage due to sedimentation, low water use efficiency due to improper maintenance of the system etc. Hence the need of the hour is to quantify the present **water requirement** of the basin and analyze the water balance comprising water availability and demand. The objectives of the paper are to calculate crop water demand and do water auditing for the JBS-sub basin.

BACKGROUND OF STUDY AREA

The Study Area covers the Jaunpur Branch Sub-basin (JBS) and falls in the Gomti and the Ghagra river basins. Jaunpur Branch Sub-Basin (JBS) covers 0.6 million ha areas located between Sai and Gomti Rivers, of which 0.32million. ha is in the canal command. It lies in parts of Barabanki, Jaunpur, Pratapgarh, Raebareli and Sultanpur Districts covering 43 blocks. Jaunpur Branch Sub basins including the Haidergarh Branch comprises the present study area.



Map1. Status of canal Irrigation

The Haidergarh Branch which is the carrier branch for Jaunpur Branch takes off at km 171.5 of the main Sarda Sahayak Feeder Channel and has a head discharge capacity of 165.5 cumec. The Jaunpur Branch takes of at km 22.98 of the Haidergarh Branch and has a head design discharge capacity of 123.2 cumec. During the Kharif season in 2004-05, the Jaunpur Branch was rostered for about 210 days to deliver 1298 MCM of irrigation. This is equivalent to about 24 cm depth of irrigation over the gross area of JBS or 47 cm over the CCA. If the Jaunpur Branch operated at design capacity over the entire season, it would be able to deliver approximately 2235 MCM, equivalent to approximately 81 cm over the CCA. This means that the canal at present is running only at the 58% of the original capacity in Kharif season.

During the Rabi season in 2004-05, the Jaunpur Branch was rostered for about 140 days to deliver 613 MCM of irrigation. This is equivalent to about 11 cm depth of irrigation over the gross area of JBS or 22 cm over the CCA. If the Jaunpur Branch operated at design capacity over the entire Rabi season, it would be able to deliver approximately 1450 MCM, equivalent to 53 cm over the CCA. This means that the canal at present is running only at the 38% of the original capacity in Rabi season.

In JBS-basin the average groundwater level is within 5 m of the natural surface at the end of the monsoon, and several meters lower at the end of the dry season. The groundwater is generally of good quality for irrigation and can be readily accessed by shallow tube-wells. There are several areas at the tail-ends of canal systems where the groundwater is more than 10 m below the natural surface. JBS drains to the Sai and Gomti rivers. These rivers have relatively small catchments, originating within U.P. To provide Irrigation in an area, a wide network of canals is constructed so as to carry water from a natural source such as River, Lake, and Ponds etc. and to distribute it in a fairly uniform and equitable pattern in the entire command area. This network is called the distribution system.

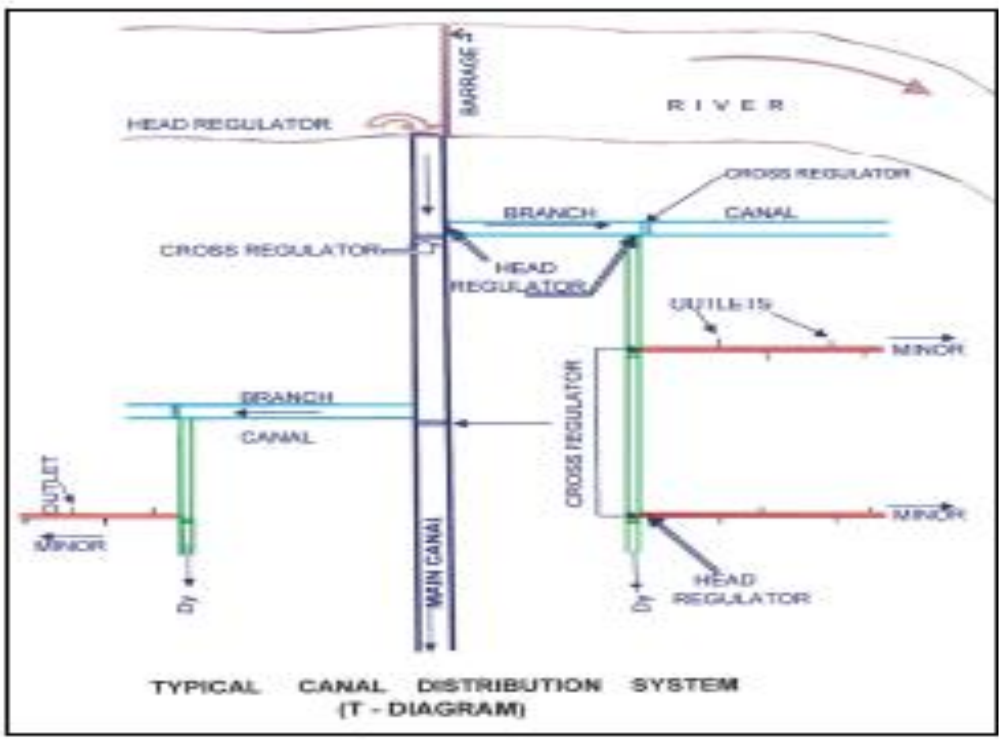


Figure1. A typical irrigation canal distribution system is shown below

METHODOLOGY & DATA

The crop water requirement model requires information on climatic data like precipitation, temperature, wind velocity, humidity, sunshine etc. for each basin. These data are used for computing individual crop water requirements. Long time series climate data are necessary in order to analyze the impact of climate variability on irrigation requirements. The average annual rainfall of the study area is around 900 mm. Thus, the sub-basin districts fall in the medium rainfall region of the country. The deep alluvial soils in the districts offer ample opportunity for soil moisture storage and ground water recharge. Average monthly rainfall data for the past seventy years was used to calculate effective rainfall through fixed percentage method in the area which is as follows:

Table 1 . Effective monthly rainfall in JBSB

Months	J	F	M	A	M	J	J	A	S	O	N	D	Total
MCM	47	41	29	13	41	267	494	489	470	251	10	19	2171

The data reveals that around 70% of the rainfall is received in the three months period i.e., June to August.

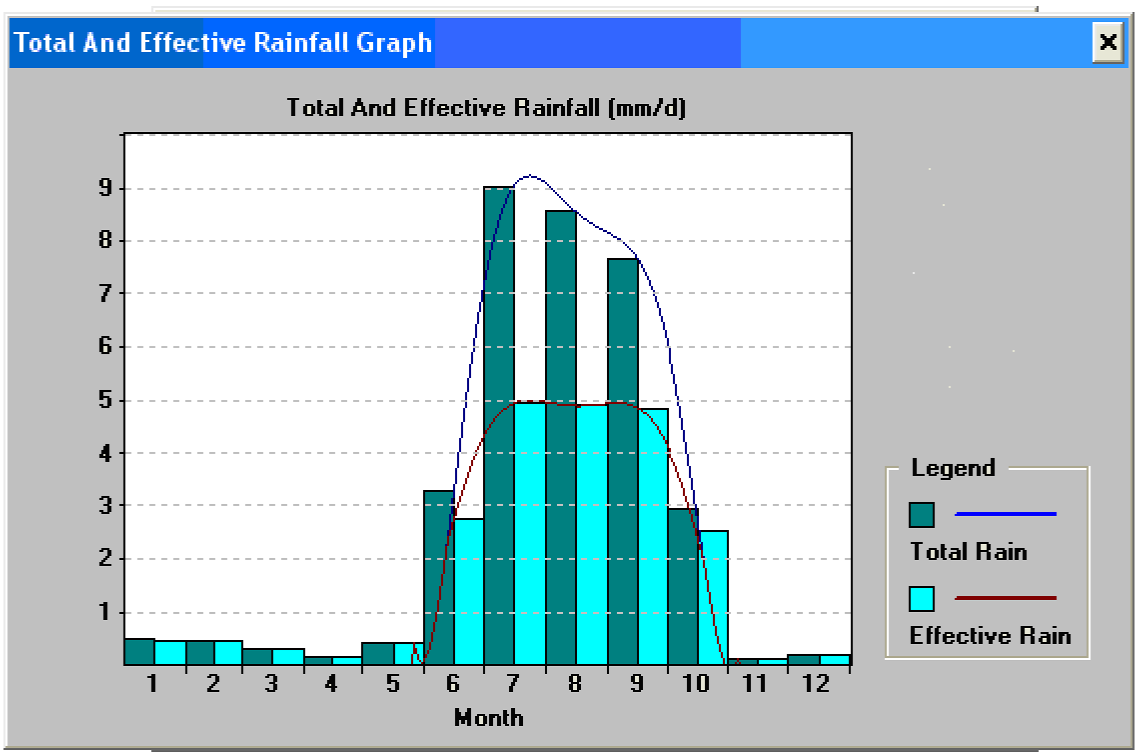


Figure2. Total and effective rainfall distribution.

The CCA of the basin is 3.23 lakh ha and the cropping intensity is 177%. For each crop: sowing dates, irrigation period, Kc stages, duration and coefficients, root full depth and time to full depth, allowable depletion, maximum height and yield response factor to water deficit factors were considered. Duration of the crop is also considered for computational purpose.

Soil type for each crop: field capacity, wilting point, initial percentage of available water, initial root depth, saturation capacity, bare soil evaporation parameters and exposed soil fraction were used according to soil type. At this stage uniform soil water holding capacity parameters of 33% and 18% for field capacity and wilting points respectively, were taken into consideration. These parameters are representative of the majority of the soils in the Sub-basin which are silty-clay-loams.

Irrigation data for each crop: field application efficiency, irrigation scheduling criterion, irrigation interval if applicable (in accordance with the irrigation criterion), the minimum application depth for gravity irrigation methods and technical irrigations. At this stage a uniform field application efficiency of 60% was applied. The suitable irrigation scheduling criterion to simulate the present situation was determined as fix interval of two to three weeks. For most of the crops, full CWR or a deficit with reasonable reduction of the yield could be accomplished with two to three week intervals. In the cases that CWR was less than full, the deficit was considered acceptable as long as the average yield reduction was less than 15%[i]. A sowing / pre-sowing technical irrigation depths which varied between 40 to 60 mm for the Rabi season depending on the crop and the sowing dates, depths of 100 mm for the Summer and the Kharif sowing dates and depth of 40 mm for first irrigation of the ratoons started in the monsoon time (all the above depths were net irrigation depths, excluding field losses).

To measure the requirement of irrigation water in the particular area, the first and the foremost task is to study the cropping pattern of that area. The cropping pattern helps to calculate the amount of water required at a particular point of time. The use of irrigation water during an irrigation season is influenced by the difference between the optimal water input for a crop and rainfall during the growing season. As a productive input, it is valued for its contribution to farm outputs, rather than as a commodity for final consumption. The relationships between irrigation farm inputs are complex and seldom linear. Some inputs are essentially fixed in the short run (such as land), while others are variable (such as fertilizers). Because some inputs are fixed, at some point, diminishing returns occur such that the continued addition of variable inputs eventually yields smaller and smaller additional units of output. This phenomenon is applicable for water also. Too less or too much both reduces the productivity of the crop, hence appropriate quantity of water should be allocated to the crop for maximum productivity (optimum productivity). This can be done by calculating crop water requirement. Next we can use this demanded quantity of water to be balance with the available water quantity. The supply side has ground water as well has surface water to meet crop water demand.

Following the CROPWAT approach of Smith [1992], the net irrigation requirement per unit irrigated area during the growing season is computed as the difference between the crop-specific potential evapotranspiration and the effective precipitation. The irrigation model uses monthly climatic data in CROPWAT. A brief sketch of the model is given below:

The water content in the effective root zone is estimated by using the water balance equation:

$$WC_t = WC_{t-1} + IRR + RAIN - AET - DP \qquad (1)$$

where:

WC_t= Soil water content today (inches), WC_{t-1}= Soil water content yesterday (inches),

IRR= Irrigation depth since yesterday (inches),

RAIN= Rain since yesterday (inches), AET= Actual ET (inches), and DP= Deep percolation (inches).

The model calculates the Crop Water Requirements (CWR) using the equation:

$$CWR = Eto * Kc * \text{area planted} \qquad (2)$$

where:

Eto: reference crop evapotranspiration in millimetres per time

Kc: average values of crop coefficient

To evaluate the effect of crop water deficit on yield decrease through the quantification of relative evapotranspiration (ETc-adj/ETc), FAO undertook an analysis of research results from a large amount of crop water studies. The findings were published in the FAO I&D No. 33 (FAO 1979) in which a linear crop-water production functions was introduced to predict the reduction of crop yield when crop stress was caused by a shortage of soil water according to the following relationship:

$$(1 - Ya/Ym) = Ky(1 - ETc\text{-}adj/ETc) \qquad (3)$$

where:

Ky is yield response factor

ETc-adj is adjusted (actual) evapotranspiration (actual evapotranspiration ETa)

ETc is crop evapotranspiration for standard conditions (no water stress) (maximum evapotranspiration ETm)
Ya is actual crop yield
Ym is maximum expected or agronomically attainable crop yield under no biotic or abiotic stress.
Ky is a factor that describes the reduction of relative yield according to the reduction in ETc caused by soil water shortage.
Ky values are crop specific and vary over the growing season according to growth stage

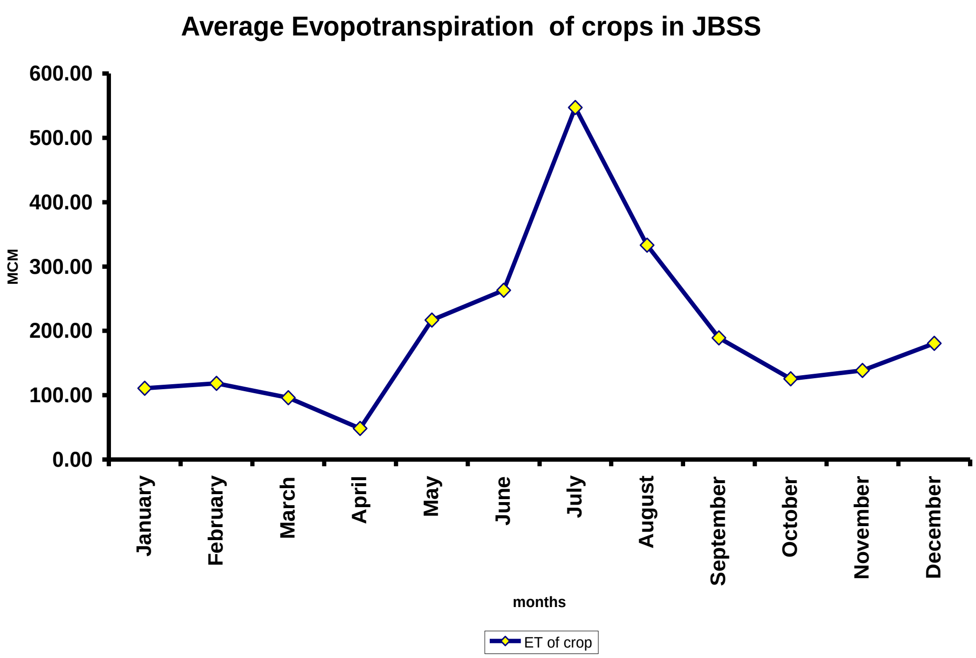


Figure3. The graph given below shows the monthly Evopo-transpiration of the crops grown in the JBSS.

The gross irrigation water requirement was calculated on monthly basis by using leaching effect and irrigation efficiency of 60%. The net irrigation water requirement so obtained is balanced with the rainfall of that area. The effective rainfall of the basin is calculated by using CROPWAT. The difference between the effective monthly rainfall and the monthly crop water requirement is the amount of irrigation water required in the particular basin needed to be supplied by either surface water or ground water.

The Surface water or the canal water supply is recorded through roster on the monthly basis. This information is collected from Irrigation department Uttar Pradesh. Though the canal was design with the discharge capacity of 123.2 m^3/sec., but presently it is running with the capacity of 86.5 m^3/sec (approx). The field application efficiency is about 30-40% only.

RESULT & CONCLUSION

Results of water demand and supply assessments are summarized in Table-2 and displayed in Figure 4.These results provide a spatial and temporal comparison of water requirements of the crops. However, it must be stressed that they are computed on average monthly climate data only. Annual climate variation (affecting time of planting, length of growing period etc) will result in ranges of ET and water use around the year through. The following Table-2 and Figure 4 clearly portray the irrigation requirements for crop groups in the three seasons. Kharif crops, apart from rice, have only minor irrigation requirements (based on the average climatic data). Rabi crops have greater irrigation requirements. Wheat, being the largest Rabi crop, will command the bulk of the water for irrigation during the Rabi season. Jaayad crops have a higher irrigation requirement, but given the small areas planted under current cropping patterns, this is unlikely to be significant. Further, many of these crops will be cut for fodder prior to reaching maturity, so their CWR will be less than calculated. Sugarcane, which occupies 7% of the cropping area on average, has a high water requirement that extends over most of the calendar year.

Table2. Water Demand and Supply in the sub-basin

					MCM	
Month	ET of crop	Gross Water Requirement	Effective rainfall	Net Irrigation requirement	Available canal Water (2003)	Deficit
January	110.91	221.82	47.16	174.66	76.56	98.10
February	118.56	247.12	41.02	206.09	107.88	98.21
March	96.19	266.51	28.75	237.76	98.60	139.16
April	48.32	96.65	12.92	83.73	64.96	18.77
May	216.69	455.37	41.02	414.35	8.12	406.23
June	263.21	568.43	266.80	301.63	131.08	170.55
July	547.19	1323.39	494.19	829.20	199.52	629.68
August	333.33	676.66	489.35	187.31	161.24	26.07
September	188.99	377.97	469.64	-91.67	145.00	0.00
October	125.45	253.91	251.29	2.61	196.04	0.00
November	138.43	276.85	9.69	267.16	68.00	199.16
December	180.63	362.11	19.06	343.05	158.92	184.13
Total	**2366.90**	**5126.78**	**2170.88**	**2955.90**	**1415.92**	**1539.98**

Units: million cubic meterts

The following findings emerge from the exercise of water balancing as given below:

- The canal water is deficit almost all around the year excluding two months VIZ: September and October.
- The deficit surface water can be supplemented with the existing ground water in the mentioned basin (2367MCM)
- The cropping intensity of 177% can be increased to about 200% and even more.
- The canal is running at 1/3rd of the design discharge which should be rehabilitated.

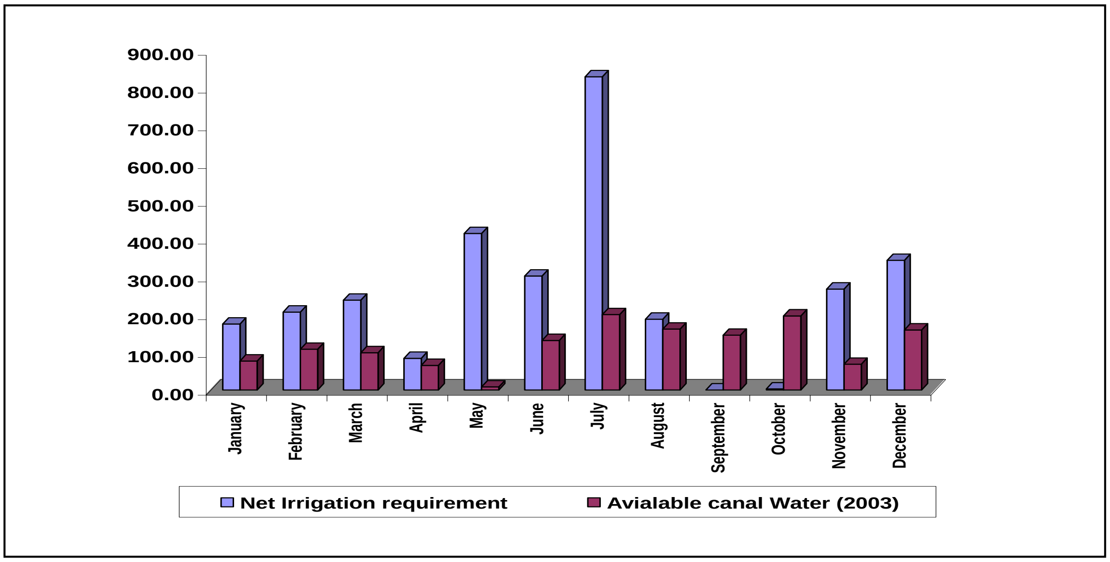


Figure4. Net irrigation requirement Vs available canal water in JBSS

Paddy covers 79%,of the total kharif area and wheat 72% of the total Rabi area. Hence this is Rice-Wheat based dominating cropping system which is water demanding in nature. There is abundant ground water which can be harnessed through deep tube wells, shallow tube wells and open wells. In addition, the districts are served by a number of branch canals and distributaries of Jaunpur Canal system, irrigation system.

- Farmers normally have no control on the amount of water they receive, when they receive it and even whether they will receive it at all. Consequently formation of Water Users Associations (WUAs) to manage Irrigation water distribution system at minor level was stipulated. As the channels are under performing, it was considered appropriate to restore the channels to their original design characteristics before the maintenance and management of minors is transferred to WUAs. To make the use of irrigation water economical / efficient, volumetric system of water flow has been introduced in form of Warabandi. Forming the WUAs and turning over the minors to them would allow decision making at lowest level and by main stake holders- the water users themselves. They will take better care of the minors than a distant bureaucracy. Cost recovery is normally synonymous with improved O&M. The main objective of proposed Participatory Irrigation Management (PIM) is to secure the participation of farmers in equitable distribution of water among themselves, ensuring efficient use of canal water for agriculture intensification, operation and maintenance of given minors, drainage of waste / surplus water and other aspects of irrigation management as assigned to them.

State Government shall give grant-in-aid for maintenance of minors.

The following benefits are expected to accrue with the transfer:

- The maintenance cost will reduce.
- Works will be executed expeditiously.
- Irrigation intensity will increase due to equitable water distribution.

- Discrimination between head and tail farmers will reduce.
- Silt clearance will be done in each minor.

RECOMMENDATION

- Improved budgeting of the available water resources in the river basin through water balance approach
- Improved management of available water resources for irrigation, domestic and industrial water supply
- Improved agricultural productivity by providing a timely, adequate, reliable and equitable supply of water through efficient roaster management.
- Planning for supply of irrigation water mandated with conjunctive use ensuring the water balance within the alternative options and opportunities
- The development of optimal cropping strategies for utilization of water logging soil along the canal network – a mix of strategy incorporating aquaculture.
- Harnessing the water recourses framework including groundwater through development of water aquifer system
- Optimization of the water use through intervention of institutional mechanisms (WUAs) targeting to improve the water productivity (efficiency)
- Innovating a new crop matrix defining a cropping system (farming system) ensuring the judicious management of water resources through optimization of water balance
- Improved system monitoring and analysis
- Improved system operation and maintenance

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- FAO (Food and Agriculture Organization), 1998. Crop evapotranspiration : Guidelines for computing crop water requirements. Authors, Allen RG, Pereira LS, Raes D & Smith M. Irrigation and Drainage Paper 56. Rome, Italy.

[i] *The indicator of the yield reduction, the relative yield which was calculated in accordance with the method presented in the FAO Irrigation and Drainage Paper No. 33, Yield Response to Water and was incorporated into the simulation in accordance with the method presented in the FAO Irrigation and Drainage Paper No. 56, chapter 8.*