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# Influence of canal water distribution system on water productivity of selected kharif crops in distributaries of Eastern Yamuna Canal (EYC) command area

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**Abstract**
Water productivity of selected kharif season crops in the three distributaries of the Eastern Yamuna Canal Command depended on the conjunctive use of canal and ground water. Present investigations were carried out to assess the effect of water distribution on the productivity of the selected crops as well as the conjunctive use practices being followed in absence of the water in Kharif Season. It was found that in the *kharif* season water availability was insufficient for transplanting and irrigating paddy in the middle and tail reaches of EYC. As a result, farmers switched over from paddy to sorghum crop, thereby loosing Rs. 3075 and Rs. 3715 per ha in the middle and tail distributaries of EYC, respectively. However, the high conveyance losses resulted into lowering of the conveyance efficiencies of the three distributaries in the range of 43-44 per cent. This indicated that there lies ample scope of increasing the water availability by properly checking the seepage and evaporation losses. The balance amount of water required by crops was replenished by the ground water sources resulting into increased pressure on stored water. The water use behavior was similar in three distributaries with varying magnitude. There is a great potential of increasing food production with assured irrigation, which is currently covers about 30% of the total arable land, contributing about 56% of the total food production of the country. Present investigation established the need for increasing the conveyance efficiencies to a great extent which will result into increased culturable commands as well as adoption of better cropping patterns in the EYC command area.

**Keywords:** Canal water distribution, Conveyance efficiency, Crop production, Economic returns, Water Productivity

## INTRODUCTION

Water being the most crucial input for ensuring stability, self-sufficiency and sustainability of food grain production apart from enhancing the water productivity; its proper distribution along various distributaries of canal command areas matter much. The tail enders have always been at the receiving end as for as the allocation of water is concerned despite that fact that elaborate roaster of water distribution and crops to be grown are designed before construction of any canal. Due to its limited availability and competing demands, it is imperative to utilize the water resource most efficiently. Like the world in India too, water is a major input in agriculture and the share of water diverted to irrigation is more than 80 per cent at the National level [1]. Water resources have multiple and competitive users [2]. Its availability on time and in proper quantity ensures stability, self-sufficiency and sustainability to food grain production. Surface water and groundwater typically have a natural hydrologic connection. Conjunctive water use is an approach that recognizes this connection and tries to utilize it to use the overall water supply more efficiently [3, 4, 5]. Some view groundwater use by individuals to supplement limited surface water supplies as conjunctive water use. Others envision conjunctive water use as large, elaborate regional water management programs that store large volumes of surface water below ground during normal and high rainfall years and then pump large volumes of groundwater from storage during drought years [6].

Conjunctive water use primarily changes the timing in the flow of existing water sources by shifting when and where it is stored and does not result in new sources of water. Conjunctive use is often incidental as water users intuitively shift between surface water and groundwater sources to cope with changes and shortages. While conjunctive use may prove successful for an individual or group of water users to manage an immediate situation, it is also possible for conjunctive use to unintentionally harm the groundwater basin and other groundwater users who are not involved in conjunctive use but are reliant on the same groundwater basin [7]. The typical hydrologic modifications caused by successful conjunctive use of ground water and surface water are depicted in Fig. 2. It is evident that the ground water extraction increases in time when there is shortage of surface water. There is a lag in the recharge of ground water due to the increased surface flow in the rivers. When the discharge in the river dwindles; due to reduction in rainfall, the dependency of the people on ground water increases which get pumped at a rapid rate causing the ground water table to fluctuate depending upon the rate of pumping or draft. Over draft is always bad which can be managed well.

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A key characteristic of conjunctive use is that it usually aims to use the very large natural groundwater storage associated with most aquifers to ‘buffer’ water-supply availability against the high flow variability and drought propensity of many surface watercourses – making it especially important for the mitigation of climate changes impacts, which in many scenarios will lead to increased intensity of droughts [8, 9]. A second important feature is that conjunctive use is often the best way to confront some of the serious problems of groundwater salinization and soil water logging on alluvial plains [10]. Adopting this rather ‘narrow definition’ excludes consideration of the artificial recharge of aquifers with surface run-off or by rain-water harvesting (without direct supply from the surface water source), the use of groundwater pumping to support river base flows (without direct supply from water wells) [11]. It is recognized that some authors include these techniques within the scope of ‘conjunctive use’, and it is not the intention here to suggest that they are not of the highest relevance for water resources management. But to maintain a sharp focus in this review on direct water-supply investments in the developing world, it was preferred not to consider them in detail here [12].

An alternative to conjunctive water use is conjunctive water management [13]. The difference between the two is more than semantics. Conjunctive water management engages the principles of conjunctive water use, where surface water and groundwater are used in combination to improve water availability and reliability [14]. But, it also includes important components of groundwater management such as monitoring, evaluation of monitoring data to develop local management objectives, and use of monitoring data to establish and enforce local management policies [15, 16]. Scientific studies are needed to support conjunctive water management. They provide important data to understand the geology of aquifer systems, how and where surface water replenishes the groundwater, and flow directions and gradients of ground water [17, 18]. There is no rigorous definition for the ‘conjunctive use’ of groundwater and surface water resources. But for the purpose of this overview it is proposed to consider only situations where *both* types of source are developed (or co-exist and can be developed) to supply a given urban area or irrigation canal-command – although not necessarily using both sources continuously over time nor providing each individual water user from both sources [19].

Potential climate change effects on aspects of conjunctive management of water resources can be evaluated by linking climate models with fully integrated groundwater–surface water models. In such a study, the objective was to develop a modeling system that links global climate models with regional hydrologic models, using the California Central Valley as a case study [20]. Supply-constrained and demand-driven linkages in the water system in the Central Valley are represented with the linked climate models, precipitation-runoff models, agricultural and native vegetation water use, and hydrologic flow models to demonstrate the feasibility of this method [21].

India has made great progress in enhancing the productivity of irrigated agricultural areas owing to large scale construction of canal networks post independence. EYC and the Western Yamuna Canal (WEC) are two branches coming out from the same head works. While the WYC receives almost about the full design discharge the EYC often gets a part of its design discharges due to several socio-economic-political reasons [20, 21]. The Eastern Yamuna Canal (EYC) and Western Yamuna Canal (WYC) take off from the River Yamuna at Tajewala in Haryana. The EYC flows through four districts of western Uttar Pradesh, namely, Saharanpur, Muzaffarnagar, Baghpat and Ghaziabad (Fig. 1). In the recent past, the EYC was modernized for 113 cumec (4000 cusec) carrying capacity and all the related works were completed during 1977 to 1980. As per an agreement made in 1994 among the basin states, a total of 11,983 billion cubic meter (bcm) of utilizable water was estimated and allocated as follows (Table 1). While the crops should get the amount of water as per their crop water requirement (CWR) [22] from either source in order to produce optimum quantities of grain or biomass. India's elaborate canal network is manned with several bottlenecks failing on many accounts. The poor conveyance, application and distribution efficiencies are among the top most reasons for poor productivity of irrigated agriculture [23, 24, 25]. If the losses of water during conveyance and application are checked and the lands are suitably laser leveled then it is not difficult to obtain higher efficiencies and the irrigated are can be increased further. To check and establish the impact of distribution system in the selected distributaries of the EYC the present study was undertaken. Present study was therefore conducted to investigate water availability and use scenario in the Eastern Yamuna Canal (EYC) command area of western Uttar Pradesh.

Materials and Methods

## STUDY AREA

The EYC main canal is 197 km long, has 934.5 km long distributaries and 445.5 km long minors. The distributaries and some of the minors directly take-off from the main canal. The total culturable command area (CCA) of EYC is 221284 hectares. The CCA of the Upper and Lower Divisions are 141634 and 79650 hectares, respectively. The CCA of the head, middle and tail reach distributaries are 3448, 4965 and 3485 hectares, respectively. The present study was undertaken in the command area of three distributaries namely, Rampuri, Badhev and Daula, respectively at the head, middle and tail reaches of the EYC. Of the three-distributaries, Rampuri belongs to the Upper Division while the other two belong to the Lower Division (Fig. 1).

For administrative facilitation, the EYC has been divided into an Upper Division and a Lower Division with their headquarters at Saharanpur and Muzaffarnagar, respectively. The total water received at the head of the Upper Division during the year 1999-2000 was 53224 (hectare meter (ha-m)). Out of this a quantity of 22727 ha-m (42.7%) was utilized while the rest was accounted for losses in leakage, seepage etc. The months that received relatively higher amounts of water were July (8329 ha-m), August (8135 ha-m) and September (7118 ha-m). Similarly, the total water received at the head of the Lower Division during the same period was 34024 ha-m. Out of this, a quantity of 30407 ha-m (89.37%) was utilized and the rest 3617 ha-m was accounted by water losses. The month that received the highest amount of water was August (8000 ha-m), followed by September (4472 ha-m) and June (3528 ha-m). The above analysis revealed that there has been considerable disparity in the water availability between the Upper and the Lower Divisions. This information provided is based on calculations done by me based on the secondary data supplied by canal authorities (Singh, 2002) Field survey had also revealed a distinct preference of the Upper Division farmers in growing rice, which was not possible by the farmers of the Lower Division due to inadequate availability of canal water. Hence, the present study was undertaken to study the canal water availability and use in selected distributaries of the

Upper and the Lower Division of the EYC command. Besides, the effect of canal water distribution on net returns in the Upper and Lower Divisions of the EYC command area was also investigated.

Water availability in the canal command through the rainfall The normal annual rainfall in the command area ranges from 950 mm at Saharanpur to 689 mm in Ghaziabad. Bulk of the rainfall is received in the monsoon season from June to September. The winter rains are much less and are normally received from December to February. The maximum and the minimum temperatures are $43^0$C during May-June and $5^0$C during December-January. The soils are generally loam in texture. There are two main agricultural seasons, namely, *kharif* (July-October) and *rabi* (November-April). Only a small part of the command area is cultivated in summer (*zaid*: April-June). The important crops grown in *kharif* season are fodder in 63932 ha (28.89% of the Gross Command Area: GCA) and Paddy in 17104 ha (7.73 % of the GCA), respectively. In *rabi* season, wheat is the most important cereal crop of the command area, occupying 46891 ha (21.19% of the GCA). In *zaid* season, pulses, vegetables and muskmelon are the important crops. Sugarcane is the most important commercial crop grown in the command covering an area of 54493 hectares (24.63 % of the GCA). Gross cropped area of the EYC command is 323445 hectares which responsible in a cropping intensity of 146 %.

**Prevalent system of canal water distribution: Warabandi / Osarabandi**

The Warabandi system of rotational irrigation water distribution has been practiced since the last century in the command areas of EYC [22]. The objective of this irrigation system, like all others in the region, is to provide extensive irrigation so that the canal system extends over as much cultivated area as possible [2]. Efficiency of water use in canal-irrigated areas has been studied from various angles. A study was conducted on wheat crop production when irrigated by various types of water sources such as canal only, hired electric pump operated tube well, self-owned electric pump operated tube well and diesel engine-pump operated tube well in the EYC command area of western Uttar Pradesh (U.P.) [23]. It was found that the lowest crop yield was registered when irrigating with only the canal water. The crop yield even for the case of hired electric tube well was higher. A study conducted [26] revealed that the irrigation water use efficiency and crop yield could be increased if land were leveled through laser leveling technique in the canal command area. State Irrigation Department in consultation with Agriculture Department publishes a roster of running of canals. The roster indicates the dates and days of running of distributaries. The canal department has the right to alter the dates of running depending upon the availability of water in the main canal. For the sake of equal distribution of water, it is necessary that distributaries draws its correct authorized full supply discharge and designed water level is maintained as otherwise at all other levels, distribution would be erratic and disproportionate [23, 26]. The selected distributaries, namely, Rampuri, Badhev and Daula have the corresponding authorized discharge capacity of 2.24, 2.38 and 2.52 cumec (80, 85 and 90 cusecs). A significant part of supplied water is lost in transit before reaching to the fields. Therefore, specific percentage allowance is made for seepage losses in canal and watercourses. This was done by assuming a canal conveyance efficiency of 80 %. To account for the losses of water during application field a application efficiency of 70 % was assumed [22].

**Survey schedule and sampling techniques**

A multistage sampling technique was adopted for the selection of study locations, namely, head, middle and tail locations and the farms in the command area of the main canal. At the first stage, the head-reach, the middle-reach and the tail-reach of the main canal were identified. At the second stage, three distributaries, namely, Rampuri, Badhev and Daula representing head, middle and tail reaches of the EYC were selected randomly (Fig.1). At the third stage, three outlets were selected from each of these distributary command areas on the basis of head, middle and tail locations of the distributary. At the fourth stage, each outlet command was divided into three locations as head, middle and tail of the outlets. At the fifth stage, 5 farmers were selected from each of the head, middle and tail locations of each of the outlet command areas. Thus, in all there were 135 farms covered under the study (3 locations along the canal, 3 locations along the distributaries and 15 farms at each location).

Information was collected on different sources of irrigation and corresponding area from each of the 135 farms unit by interviewing the farmers' personally and with the help of pre-tested questionnaire in the kharif season. In the selected distributaries the data on the amount of water supplied by the irrigation department in each distributary in various months were collected from the respective canal offices. These were multiplied by the two efficiencies as mentioned earlier, to obtain the utilizable water quantity (Table 2). The total water utilized was determined as the product of the recorded number of irrigations and the depth of water per irrigation given to the crops through different sources of irrigation. From the details of canal water releases, the utilized surface water was calculated. This was subtracted from the total utilized water to calculate the groundwater utilization.

**RESULTS AND DISCUSSION**

**Spatial and temporal variations in surface water supply**

Spatial and temporal variations in surface water supply necessitated conjunctive use of surface and groundwater to meet crop water demand. In the *kharif* season, total monthly irrigation water utilization was worked out in the selected distributary commands (Table 3).Paddy, sugarcane and sorghum (fodder) crops are sown in the same season (*kharif*) and among these, paddy requires more irrigation water during the limited period from July to October. Sugarcane is a long duration crop (May –April) but it requires lesser irrigation water than paddy. Due to uncertain/inadequate canal water availability and high cost of groundwater pumping, most farmers in the middle and tail distributaries were unable to transplant and irrigate paddy. It is seen from Table 3 that in the month of July the total water utilized was 252.51 ha-m (33.74 % groundwater), 328.69 ha-m (82.59 % groundwater) and 132 ha-m (13.18 % groundwater) respectively in the head, middle and tail distributary. Paddy sown area was almost half at the tail distributary command than that in the middle distributary command. The sugarcane-sown area in all the distributary commands was in same proportion of their total cropped area. Therefore, the farmers of the middle and the tail distributary commands switched over to sorghum from paddy Singh et al. (2004). The net return per hectare was worked for the sorghum and paddy crops in the head, middle and tail distributaries and it was found that per hectare profit reduced in the middle and tail distributaries than in the head distributary (Table 4).

The data in Table 2 revealed that the surface water supply in Rampuri distributary was maximum in the month of July, which was 298.8 ha-m (47.3 % of total supply) followed by September and August. It was minimum 23.9 ha-m (3.8 % of the total supply) in the month of October. In Badhev distributary, the maximum supply was 286.1 ha-m (39.9 % of total supply) in the month of August, followed by September and July and a minimum of 55.3 ha-m (7.7 % of total supply) in October. In the Daula distributary, maximum supply was in August 307.1 ha-m (49.3 % of total supply), followed by July and September. However, there was no surface water supply in this distributary in the month of October. Therefore, farmers were unable to transplant the paddy in the middle and tail command. It is seen in Table 3 that the total water utilization in Rampuri distributary command area in the k*harif* season was 785.9 ha -m. Out of this 353.5 ha-m (44.9 %) was contributed by surface water and 432.4 ha-m (55.0 %) by ground water. In the Badhev distributary, total water utilization was 1047.0 ha-m. Out of this 265.1 ha-m (25.3 %) was contributed by surface water and 781.9 ha-m (74.7 %) by groundwater. In Daula distributary command total water utilized was 581.4 ha-m. Out of this 240.2 ha-m (41.3 %) was contributed by surface water and 341.3 ha-m (58.7 %) by groundwater.

With respect to month-wise surface water utilization, it is seen in Table 3 that surface water utilization was highest 167.3 ha-m in the month of July in head reach distributary, 114.6 ha-m in middle and 69.3 ha-m was in the tail reach distributary, which was not sufficient for transplanting and irrigation of paddy crop in the middle and tail distributary commands of the Canal. Therefore, farmers were unable to cultivate paddy and they switched over to sorghum cultivation in lieu of paddy, as the farmer required lesser water Singh, et.al. (2004) than paddy and sugarcane. Table 4 revealed that due to shortage of surface water in the middle and tail distributary commands during transplantation season of paddy The paddy-sown area reduced from 1156 ha in the head distributary command to 329 ha and 147 ha, respectively, in the middle and tail distributary commands. Consequently, the area under sorghum followed an opposite trend.

**Water productivity of selected crops in Kharif season**

Table 4 also revealed that the net return per hectare of paddy is more than that from sorghum. Therefore, the net return per hectare is reduced due to increase in the area of sorghum in middle and tail distributary of EYC. The water productivity of paddy and sorghum was workout by considering the area irrigated, the average yield, the total yield and the total water utilized for each of the two crops (Tables 5 and 6). The water use for paddy in Rampuri is 37 cm while in Daula it is 62 cm. Thus, besides less water 1.6 times irrigation water requirement might also force the farmers to switch over.

**Seasonal distribution of canal and ground water utilization**

The seasonal distribution of canal and ground water utilization for Rampuri distributary is depicted in Fig. 3 a and b. The canal water supply in the Khrif season was low as compared to the actual demand which was met by the extraction of ground water. However, it was noticed that the canal conveyance efficiency was very poor which can be improved that will ease out the burden on the ground water sources. Similarly the seasonal distributions of canal and ground water utilization for Rampuri, Badhev and Daula distributaries have been depicted in Fig. 4 (a & b) and Fig. 5 (a & b) respectively. In these distributaries too the similar behavior of canal and ground water availabilities has been observed with slight change in quantities.

Table 1. The annual allocation of Yamuna water (in Billion Cubic Meters, bcm) among the basin states.

| ***State*** | **Months** | | | **Annual (%)** |
|---|---|---|---|---|
| | **July to October** | **November to February** | **March to June** | |
| Haryana | 4.107 | 0.686 | 0.937 | 5.730 (47.81) |
| Uttar Pradesh | 3.216 | 0.343 | 0.473 | 4.032 (33.65) |
| Rajasthan | 0.963 | 0.070 | 0.086 | 1.119 (9.34) |
| Delhi | 0.580 | 0.068 | 0.076 | 0.724 (6.04) |
| Himachal Pradesh | 0.190 | 0.108 | 0.080 | 0.378 (3.15) |
| *Total* | 9.056 | 1.275 | 1.652 | 11.983 |
| % allocation to EYC | 35.52 | 26.90 | 28.63 | 33.65 |

*Source: Annual Records. Office of the Chief/Executive Engineer, Upper Division EYC Command Office, Saharanpur, Uttar Pradesh.*

Table 2. Total water release at distributary's heads, utilizable quantities received at the water courses, conveyance and evaporation losses and conveyance efficiency of the water delivery system in different distributaries of EYC system.

| M | Rampuri Distributary | | | | Badhev Distributary | | | | Daula Distributary | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | U | L | CE | S | U | L | CE | S | U | L | CE |
| *Jul* | 298.79 (47.33) | 167.32 | 131.47 | 44.0 | 123.72 (17.72) | 69.28 | 54.44 | 44.0 | 204.66 (32.85) | 114.60 | 90.06 | 44.0 |
| Aug | 131.79 (20.88) | 73.80 | 57.99 | 44.0 | 286.08 (39.93) | 160.20 | 125.88 | 44.0 | 307.11 (49.29) | 171.98 | 135.13 | 44.0 |
| Sep | 176.78 (28.00) | 98.99 | 77.79 | 44.0 | 251.36 (35.09) | 140.76 | 110.6 | 44.0 | 111.25 (17.86) | 62.30 | 48.95 | 44 |
| Oct | 23.96 (3.80) | 13.42 | 10.54 | 43.9 | 55.26 (7.71) | 30.95 | 24.31 | 43.9 | 0.00 | 0.00 | 0 | 0 |
| Total | 631.32 (100.00) | 353.54 | 277.78 | 43.9 | 716.42 (100.00) | 401.20 | 315.22 | 43.9 | 623.02 (100.00) | 348.89 | 274.13 | 44.0 |

S= Supply at Distributaries' head, U = Utilizable quantity, L = Losses, CE= Conveyance Efficiency

Source: Executive Engineer Upper division Saharanpur and Lower division Muzaffarnagar. Figures in parenthesis are monthly supply as per cent of total supply.

Table 3. Month wise irrigation water requirement, actual canal water supplies and deficit replenished by the ground water pumping during *kharif season* in the selected distributaries of EYC command area.

| Month | Total Water Requirement (ha-m) | Actual Canal Water Supply (ha-m) | Deficit Water Supply from Canal (ha-m) | Share of Ground Water Extraction (ha-m) | Net replenishment of total water requirement through groundwater (% of Total Water Requirement) |
|---|---|---|---|---|---|
| Rampuri Distributary | | | | | |
| July | 252.51 | 167.32 | 85.19 | 85.19 | 33.74 |
| August | 141.12 | 73.80 | 67.32 | 67.32 | 47.70 |
| September | 146.84 | 98.99 | 47.85 | 47.85 | 32.58 |
| October | 245.40 | 13.42 | 231.99 | 231.99 | 94.54 |
| Total | 785.87 | 353.53 | 432.35 | 432.35 | 55.02 |
| % of Total | 100.00 | 44.98 | 55.02 | 55.02 | |
| Badhev Distributary | | | | | |
| Jul | 397.97 | 69.28 | 328.69 | 328.69 | 82.59 |
| Aug | 55.59 | 55.59 | 00.00 | 00.00 | 00.00 |
| Sept | 109.33 | 109.33 | 00.00 | 00.00 | 00.00 |
| Oct | 484.17 | 30.94 | 453.23 | 453.23 | 93.61 |
| Total | 1047.06 | 265.14 | 781.92 | 781.92 | 74.68 |
| % of Total | 100.00 | 25.32 | 74.68 | 74.68 | |
| Daula Distributary | | | | | |
| Jul | 132.00 | 114.60 | 17.40 | 17.40 | 13.18 |
| Aug | 63.25 | 63.25 | 00.00 | 00.00 | 00.00 |
| Sept | 141.27 | 62.30 | 78.97 | 78.97 | 55.90 |
| Oct | 244.89 | 00.00 | 244.89 | 244.89 | 100.00 |
| Total | 581.41 | 240.15 | 341.26 | 341.26 | 58.70 |
| % of Total | 100.00 | 41.30 | 58.70 | 58.70 | |

*Source: Annual Records for Official Use (1999).Office of the Chief/Executive Engineer Upper Division EYC Command Office, Saharanpur, Uttar Pradesh.*

Table 4. Water productivity of sorghum (green fodder) and paddy (grian) crops in the command areas of three selected distributaries of EYC.

| Distributaries | Area under sorghum crop (ha) | Average yield of sorghum crop (fodder) (t/ha) | Total yield (ton) | Total water utilized (ha-m) | Water productivity (t/ha-m) |
|---|---|---|---|---|---|
| Sorghum crop (fodder) | | | | | |
| Rampuri | 468.5 | 29.4 | 13790.8 | 49.2 | 280.4 |
| Badhev | 730.7 | 33.4 | 24433.2 | 69.8 | 350.2 |
| Daula | 1064.2 | 25.1 | 26711.2 | 95.8 | 278.9 |
| Paddy crop (grain) | | | | | |
| Rampuri | 1156 | 3.9 | 448.6 | 427.7 | 10.5 |
| Badhev | 329 | 4.6 | 151.3 | 131.6 | 11.0 |
| Daula | 147 | 4.4 | 640.9 | 91.1 | 7.0 |

Table 5. Net returns from paddy and sorghum during *kharif* cropping season the command areas of three selected distributaries of EYC.

| Row No. | *Item* | Distributaries | | |
|---|---|---|---|---|
| | | Rampuri | Badhev | Daula |
| 1 | Gross cropped area, GCA (ha) | 6058 | 8405 | 6459 |
| 2 | Area under paddy cultivation (ha) | 1156 | 329 | 147 |
| 3 | Percent of GCA under paddy (ha) | 19.08 | 3.91 | 2.28 |
| 4 | Current net return from paddy (Rs./ha) | 17455 | 14775 | 12500 |
| 5 | Area under sorghum cultivation (ha) | 469 | 731 | 1064 |
| 6 | Per cent of GCA under sorghum | 7.73 | 8.69 | 16.48 |
| 7 | Net return from sorghum (Rs./ha) | 9420 | 11700 | 8785 |
| 8 | Difference in net return between sorghum and paddy (Row 4-Row7, Rs./ha) | 8035 | 3075 | 3715 |

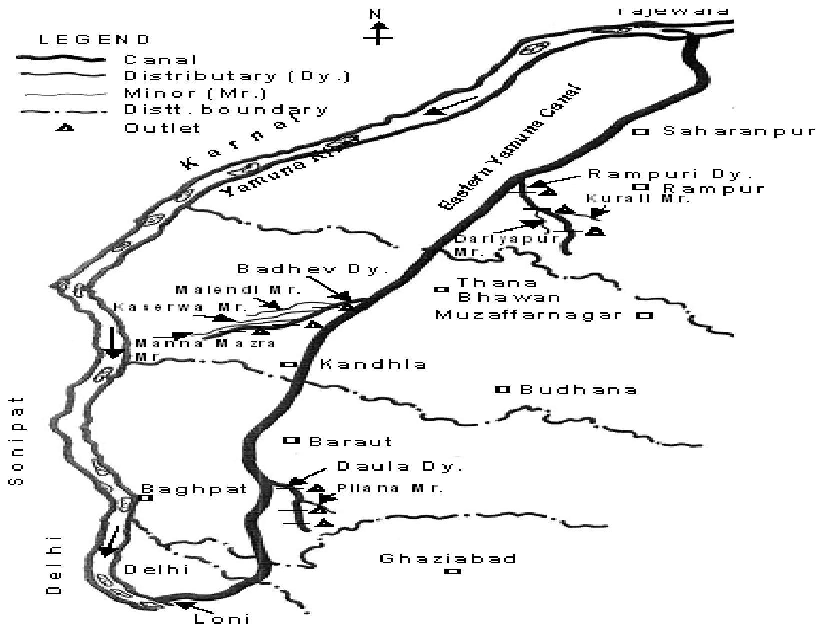



Fig 1. Location map of the selected distributaries of the Eastern Yamuna Canal (EYC) System

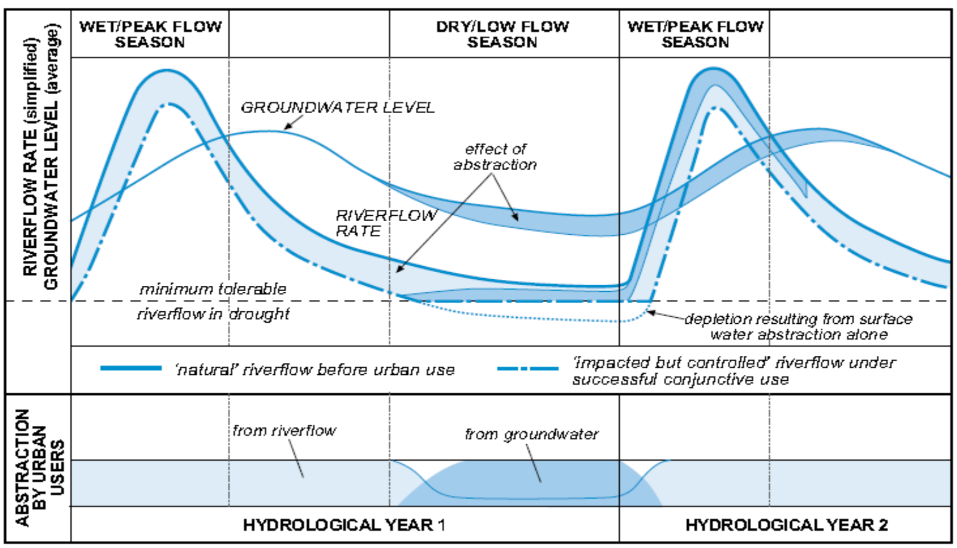
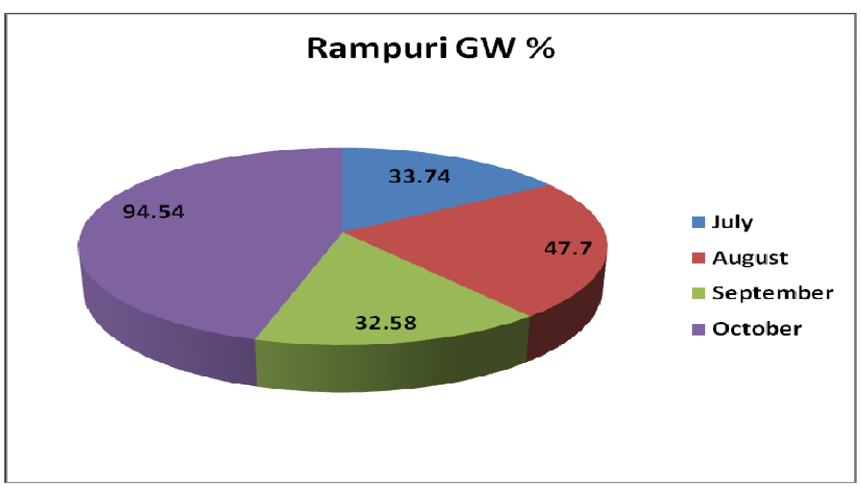



Fig 2. Typical hydrological modifications caused by successful conjunctive use of groundwater ad surface water resources for water supply (adopted from the Strategic Overview Series 2 World Bank - South Asia Region Number February 2010 with permission)



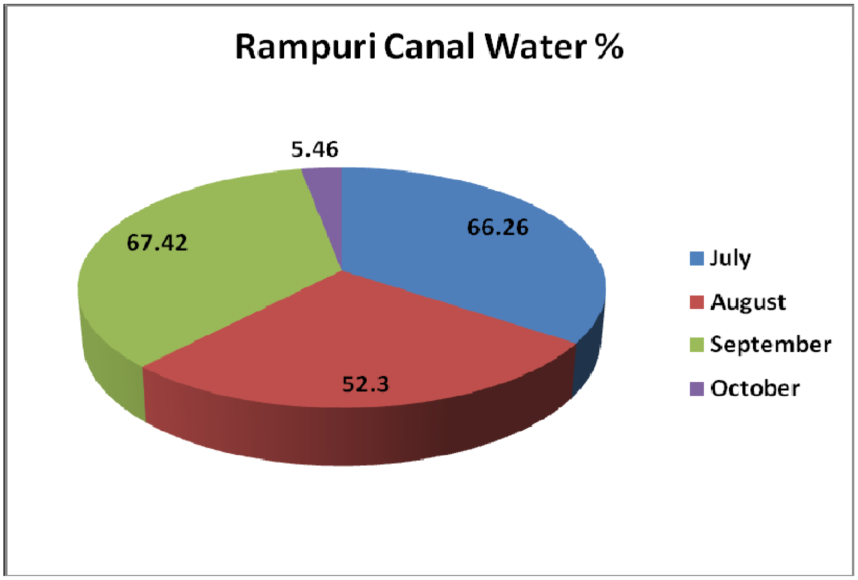
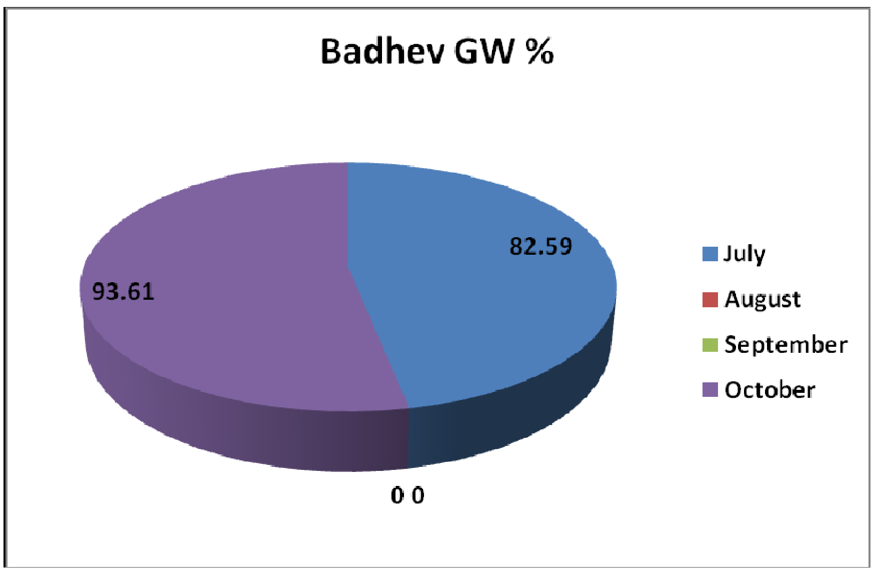



Fig 3 a & b. Seasonal distribution of the % share of canal and ground water availability in Rampuri distributary of EYC command area in Kharif cropping season



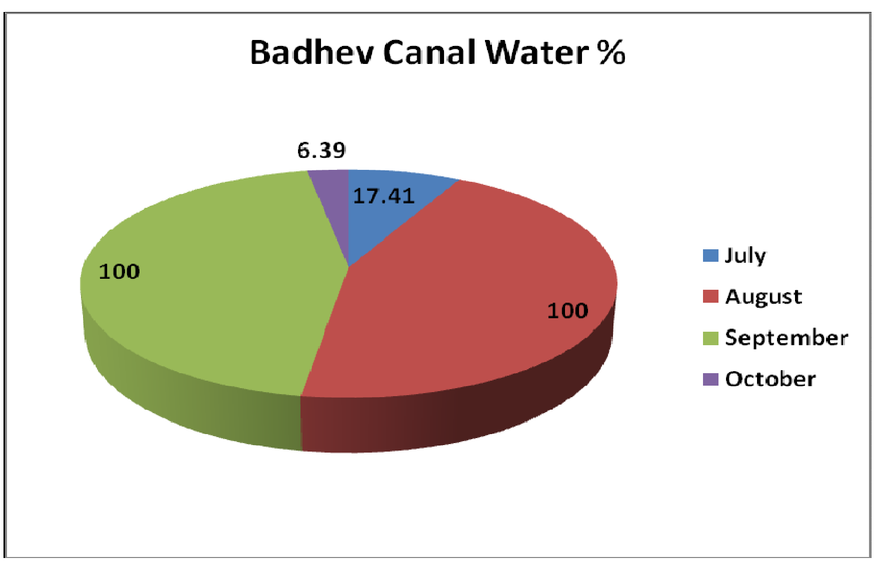
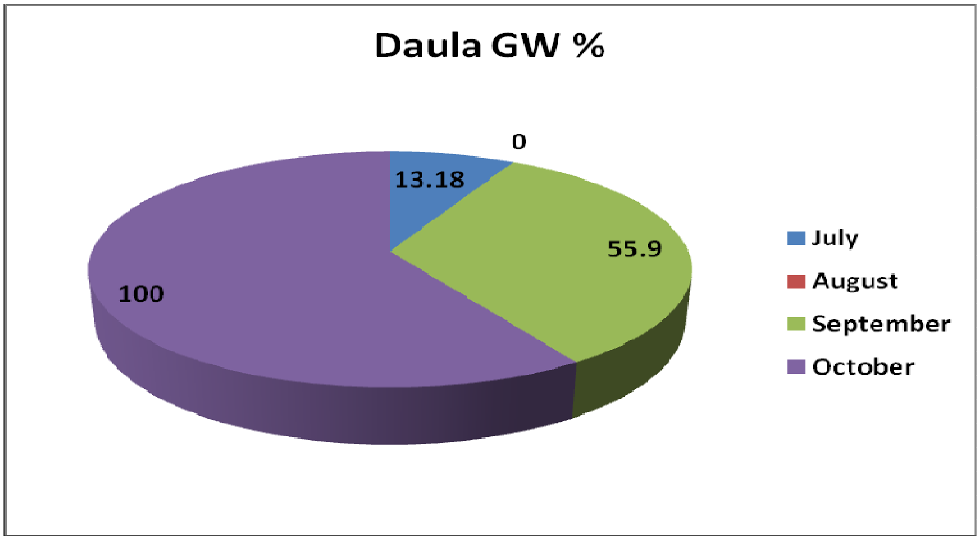




Fig 4 a & b. Seasonal distribution of the % share of canal and ground water availability in Badhev distributary of EYC command area in Kharif cropping season



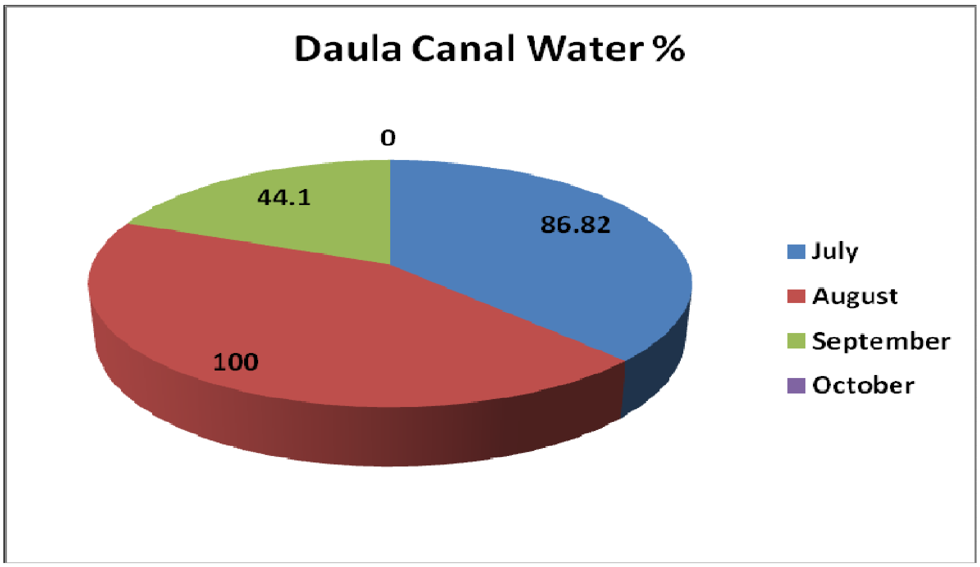




Fig. 5 a & b Seasonal distribution of the % share of canal and ground water availability in Daula distributary of EYC command area in Kharif cropping season

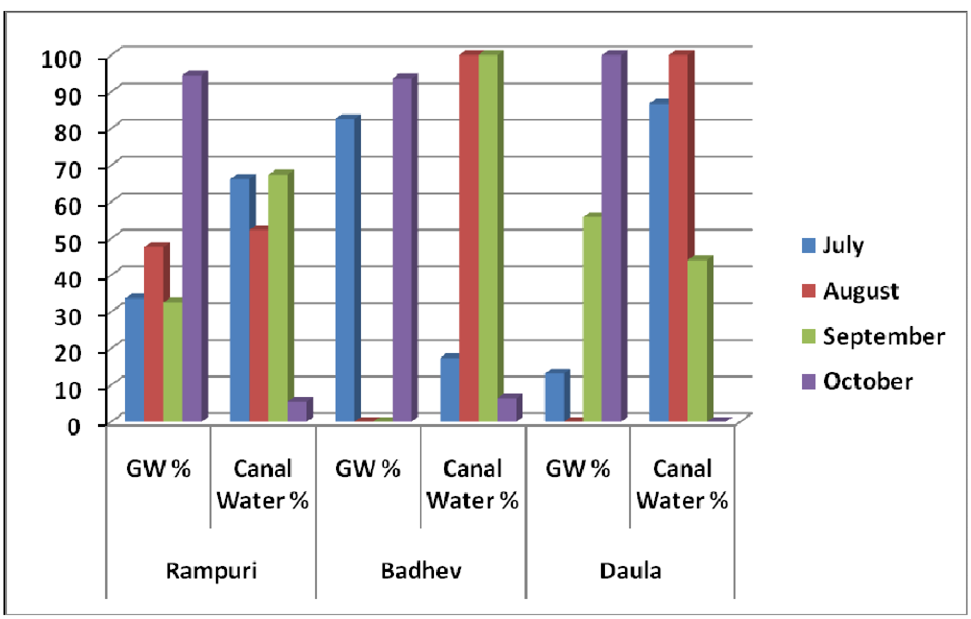



Fig 6 A. comparision of the distribution of sourceswise water availability during kharif crop growing season in three distributaries of EYC command area

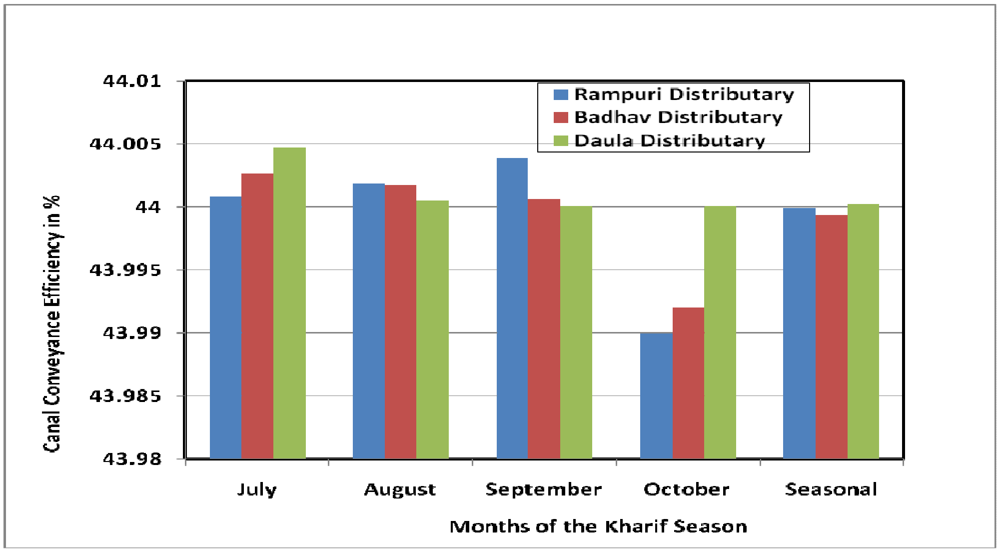



Fig 7. The canal conveyance efficiency in different distributaries of EYC in different months of the *Kharif* season

The comparative distributions of water availability in three distributaries of EYC system has been shown in Fig. 6. The share of the ground water was as high as 94 and 98 % respectively in the months of October in Rampuri and Daula distributaries. This means that the canal water was almost nil which could be replenished with Ground water sources. The conveyance efficiencies did not vary much (Fig. 7) across the distributaries and various months. This means that the seepage loesses and other pilferages have been standardized as well as the evaporation losses were also similar. Kahrif being the months of high rainfall the open water evaporation was not substantial therefore. However, the high conveyance losses warrant for adoption of lining or any other method for saving the water for being effectively utilized for crop production instead of being lost.

Successful growing of crops has been possible in Ind0-gangetic plains with the introduction of canal water [27]. Although all canals are designed for a known Gross Cultivable Area (GCA) and Culturable Command Area (CCA) which they can supplement with water and a roster of water delivery is also prepared depending on the long term hydrologic estimation of the available water for release [28, 29, 30]. However, due to a non-rigid/non-scientific/ non-strict system of the canal regulation, operation and maintenance all the canals have not been able to fulfill their designed criteria. Farmers on the other side completely transformed their erstwhile rain fed farming to irrigated farming and changed the cropping intensity, crop rotation and cropping patterns without consulting the canal engineers. This has put large unjustified demands for water on the canal which was not designed for the new crop rotation and cropping patterns. Also, there are cases where the system was brilliantly managed up to a certain time which crumbled later [31]. EYC is one such system which is suffering not on the account of misadventure of beneficiaries but due to disputes arising between two states. Such problems have also been experienced elsewhere in the world [32, 33]. It is therefore imperative that the government officials should take the necessary corrective measures to make the water available in the canal round the year and farmers to switchover to better and remunerative cropping systems [34,35] as well as modern methods of irrigation which not only save water but also improve the water use efficiencies of crop production and overall project efficiency of the canal [36,37,38].

## CONCLUSIONS

A study was conducted to investigate water availability and use scenario in the Eastern Yamuna Canal (EYC) command area of western Uttar Pradesh. It was found that in the *kharif* season water availability was insufficient for transplanting and irrigating paddy in the middle and tail reaches of EYC. The inputs costs, gross and net returns per hectare were calculated for paddy and sorghum crops in the selected distributaries. These costs were found to be Rs. 7295, 8225 and Rs. 9300, respectively, for paddy crop from head to tail reach distributaries. Similarly, these values were Rs. 7580, 5228 and Rs. 8500, respectively, for sorghum crop. The net returns per hectare (Net returns = Gross returns - Input cost) for paddy was Rs 17455, 14775 and 12500 respectively, and for sorghum, these were Rs. 9420, 11700 and 8785, respectively, in head, middle and tail reaches distributaries. Under the selected distributaries command, the canal water utilization pattern has shown considerable variation with water availability becoming gradually insufficient from head to tail distributaries in the *kharif* season. Farmers lost Rs. 3075 and Rs. 3715 per hectare, respectively, on account of switching over from paddy to sorghum in the middle and tail distributaries due to non-availability of ample amount of water. The economic returns can be increased in the EYC command, if the canal authorities take care about the equal water distribution pattern among the distributaries. Also, it was inferred from the study that not only in the command areas of all distributaries the conveyance losses were huge but also the application losses too. Therefore, if the water use efficiency could be increased then the farmers could have harnessed better yields and profits.

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