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Water Management in Rice-Wheat Cropping System in Indo-Gangetic Plains

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ABSTRACT

The rice – wheat rotation has turned out to be a major cropping sequence covering 45 per cent of net area sown and filled the food grain coffers of the country. Between the two eastern states, the yield of rice and wheat has increased in Bihar, but the yield of wheat in the state of West Bengal has registered a negative growth. Assured availability of irrigation water and its judicious management plays a vital role in enhancing crop productivity along with the adoption of improved cultivars, and scientific soil fertility and pest management practices. Twenty districts lay in eastern India Gangetic plains and only two districts fall in Indus plain of Punjab and Haryana. The highest surface water development in Punjab (84.0%) followed by West Bengal (77.7%), Haryana (69.4%), Uttar Pradesh (59.3%), and Bihar (49.8%). The rainwater is short of meeting the water requirement of rice field, irriagrion water is applied to fulfill the demand of water. The irrigation requirement rages from 810 mm in Bihar plains to 2000 mm in Haryana. The increase of 3.33 cm deep percolation over normal bunds of 10 cm commonly maintained in the farmer's fields. Thus, a field having 15 cm bund height effects a reduction in ground water withdrawal by 6.37 cm, and increase in deep percolation by 3.33 cm, thereby conserving a total of 10 cm water during the rice season. It also enables a more effective use of rainfall in the rice fields. In tube well command, there is considerable reduction in pumping hours resulting in saving in energy and increased life of pumping equipment.The irrigation water requirement has been observed to vary between 180 mm in Bihar plains to 360 mm in Haryana. The total water requirement for wheat has been estimated to fluctuate from 238 mm in Bihar to 400 mm in Punjab. The total water requirement of rice is estimated to vary from 1144 mm in Bihar plains to 1560 mm in Haryana. Thus, a total of 1382 mm to 1838 mm water is required for rice – wheat system at different locations in Indo-Gangetic plains. The study is an example of conjunctive and conservative management of rain and irrigation water in rice fields.

Rice-wheat is the most important cropping system in Indo-Gangetic plains encompassing an area of 7.49 million ha (M ha) our of the total rice-wheatarea of 10.5 million ha in the country. During the last two and a half decades the yield of rice in the states of Punjab, Haryana, and western UP has reached its plateau whereas that of wheat is still showing a rising trend. Between the two eastern states, the yield of rice and wheat has increased in Bihar, but the yield of wheat in the state of West Bengal has registered a negative growth. Assured availability of irrigation water and its judicious management plays a vital role in enhancing crop productivity along with the adoption of improved cultivars, and scientific soil fertility and pest management practices. As is evident from Table 1, the irrigated area under wheat varies from a low of about 88 per cent in Bihar to a high of 97 per cent in Punjab. Likewise, the irrigated area under rice ranges from 27 per cent in West Bengal to 99.8 per cent in Punjab.

Table1: Percent irrigated area under rice and wheat in the states of Indo-Gangetic plaing during 1995-1996.

Name of the State	Percent irrigated area under rice	Percentirrigated area under wheat
West Bengal	27.2	89.3
Bihar	40.2	88.4
Uttar Pradesh	62.3	92.5
Haryana	99.4	98.3
Punjab	99.8	97.1

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Source : Agricultural Statistics at a Glance, 1999, MOA, DAC. GOI

Rainfall Pattern

The rainfall distribution in different regions of Indo-Gangetic plains is reported in Table 2. It is evident from the table that the bulk of the rain occurs during the months of June to September, the monsoon season. It ranges from 75.6% of the annual rainfall in Gangetic West Bengal to 87% in Western UP. Due to sufficient availability of moisture, the rice-growing period coincides with the main monsoon season. In Indo-Gangetic plains, the winter sets in the month of November and ends by the middle of March, its duration being maximum in Punjab and minimum in Gangetic West Bengal. Because of the mild temperature requirement, wheat is cultivated during winter season. From January to March when the major wheat areas are in critical need of water, the rainfall contributes only 6.4% in eastern UP and 15% in Gangetic West Bengal. Thus, the main part of water requirement of wheat is met through irrigation from surface and ground water sources.

Table 2 Rainfall Pattern in Indo-Gangetic plains

S.No.	Name of the sub division	Annual rainfal (mm) Dec.	Percentage of annual rainfall January-February	March	May	Sept
01.	Genetic West Bengal	1425	2.7	12.4	75.6	9.8
02.	Bihar Plans	1202	2.9	6.1	85.0	6.0
03.	East Uttar Pradesh	1008	3.4	3.0	82.2	5.6
04.	West Uttar Pradesh	964	5.1	3.9	87.	4.0
05.	Panjab, Haryana and Delhi	625	8.6	7.2	80.0	4.2

METHODOLOGY

There are 22 districts in Indo-Gangetic plains where annual rainfall of 750-1250 mm favours rice-wheat cropping system with moisture availability of at least 150 days. Out of these 22 districts, 20 districts lay in eastern India Gangetic plains and only 2 districts fall in Indus plain of Punjab and Haryana (Table 3). However, in areas having less than 750 mm rainfall, rice-wheat system is prevalent on account of assured availability of irrigation water. Area receiving more than 1000 mm rainfall, very often adopt rainfed rice cultivation, while wheat is cultivated under irrigated conditions. Such areas lie in eastern India. Development of assured irrigation facility in such areas has increased they yield of rice-wheat production system.

Table 3 Districts in Indo-Gangetic plains that receive annual rainfall of 750-1250 mm

Name of the State	Name of the district
Bihar	East and West Champaran, Patna, Rohtas, Gaya, Munger
Haryana	Ambala
Punjab	Patiala
Uttar Pradesh	Varanasi, Allahabad, Fatehpur, Banda, Kanpur, Lucknow, Agra, Mainpuri, Hardoi, Bahraich, Aligarh, Lakhimpur, Bareilly, Saharanpur

RESULTS AND DISCUSSION

Water Resource of Indo-Gangetic plains

The catchment area of Indus and Ganges basins in Indian territory is 321289 sq.km 861452 sq.km, respectively. The average annual estimated surface and ground water potential in Ganges basin is 0.6095 m (Mm 3/sq km), and 0.1993 m (Mm 2/ sq km), respectively. It is estimated that there would be more availability of water resources in the down stream region of the basin on account of increased rainfall, deep alluvial deposits, and convergence of flow from upper reaches. The pH of river waters in Ganges and its tributaries have been observed to vary between 7.6 to 8.4. In the upper reaches of Ganges, the Yamuna, Ghaghra, and Gandak, HCO_3 of Ca and Mg constitute 80% of total dissolved salts. Like wise, the Indus basin possessed average annual surface and ground water potential of 0.2282 m and 0.079 m, respectively. If properly harnessed, this water is sufficient to sustain a high cropping intensity.

The state wise irrigation potential from surface water based major, medium, and minor irrigation projects is given in Table 4. The table also contains the percentage of surface water development in the states of Indo-Gangetic plains. The table indicates highest surface water development in Punjab (84.0%) followed by West Bengal (77.7%), Haryana (69.4%), Uttar Pradesh (59.3%), and Bihar (49.8%).

Table 4 Ultimate surface irrigation potential and potential created in different states of Indo-Gangetic plains.

State	Ultimate surface water based Irrigation potential-in (000, ha)			Potential created 96-97 (000, ha)			Dev. Of surface water resource
	Major & Med.	Minor Irrigation	Total	Major & Medium	Minor Irrigation	Total	%
Bihar	6500	1900	8400	2803	1378.9	4181.9	49.8
Haryana	3000	50	3050	2078	39.0	2117.0	69.4
Punjab	3000	50	3050	2518	45.5	2563.5	84.0
U.P.	12,500	1,200	13,700	7059	1063.0	8122.0	59.3
W.B.	2,310	1,300	3,610	1444	1359	2803.2	77.7

So, far, out of 171 km^3/year total replenishable ground water resource in Ganges basin, 144.96 km3/ year water is available for irrigation from which the estimated net draft is 48.59 km^3/ year leaving an utilizable resource of 96.27 km^3/ year. Thus, only 33.52 per cent of the total ground water resources has been developed in Indo-Gangeric plains so far.

Table 6 gives the state wise utilizable ground water resources and level of its development. The table reveals the highest development in Punjab (94%) followed by Haryana (84%), UP (38%), W. Bengal (24%), and Bihar (19%).

Table 6. Ground water resources and irrigation potential in Indo-Gangetic planis

S.No.	State	Ground water resources and irrigation in net term (M. ha-m/year)	Level of ground water development	(%)
01.	Bihar	2.849	2.564	19.19
02.	Haryana	0.725	0.652	83.88
03.	Punjab	1.679	1.511	93.85
04.	U.P.	7.125	6.412	37.67
05.	W. Bengal	1.923	1.766	24.18

Source. India 2000, Ministry of Information and Broadcasing, Govt. of India–A Reference Annual.

The ground water quality in Indo-Gangetic plains, leaving aside some isolated zones, is generally very good for irrigation. The major saline ground water pockets are found in Haryana, Punjab and U.P. The first approximation of estimates of farea underline by saline grouped water aquifers and annual recharge to these aquifers is given in Table 7. Development of technology for the utilization of saline waters in crop production is a major research issue that needs solution for sustaining irrigated agriculture.

Table 7. Estimates of annual recharge in areas underlain by saline ground water (EC > 4 dsm -1)

Name of state	Area underlain by saline ground water (m3/year) (sq.km)	Annual recharge
Haryana	11438	2452
Punjab	3058	1351
Delhi	140	32
Uttar Pradesh	1362	354

Water requirement of rice-wheat production system irrigation of rice

Traditionally rice was cultivated in high rainfall areas where water was abundantly available. Even though the farmers did not develop water resources for regular irrigation of the rice crop, they did utilize accumulated run off water in ponds, lakes, rivulets, or any other local depressions for irrigation the rice fields during prolonged dry spells either for field preparation or to protect the crop from withering. The income associated with the adoption of high yielding rice cultivars encouraged the farmesrs to cultivate rice in areas having assured irrigation supply. Thus, with the development of water resources for irrigation, rice cultivation spread to medium to low rainfall areas as well.

The age-old practice of puddling the rice fields seems to have evolved to aid soil submergence fro facilitating transplanting and controlling weed growth. In growing rice under continuous soil submergence, the irrigation requirement varies a great deal among different regions of the Indo-Gangetic plains on account of variation in rainfall, soil type, evaporative demand, and depth of the water table (Table 10). wherever the rainwater is short of meeting the water requirement of rice field, irriagrion water is applied to fulfill the demand of water. The irrigation requirement rages from 810 mm in Bihar plains to 2000 mm in Haryana.

Effect of intermittent irrigation on rice yield

The practice of rice cultivation under continuous submergence requires large quantity of water for its growth. In order to reduce the irrigation requirement of rice, an approach of intermittent ponding in place of continuous submergence has been studied from 1976 to 1984 all over the country under the All India Co-ordinated Research Project on Water Management. The intermittent period (number of days after the disappearance of water) has varied from 1 days to 5 days depending upon the rainfall pattern, depth of water table, and soil texture. Table 8 presents the optimum intermittent period and saving in irrigation water for different locations in India.

For most locations, a three day period appears to be permissible duration for drainage after which irrigation should be applied to rice. This schedule of irrigation, relative to continuous submergence, entailed substantial saving in irrigation water (23 to 65 percent) while yields were comparable. Significantly lower yields were obtained with the drainage period exceeding 3 days except that under some dituations such as higher-water table conditins, a longer draingage period (5 days or more) could be allowed as in case of Madhepura (Bihar). At some locations having relatively low water retentive soils, drainage period exceeding one day was not found desirable in view of significant yield reduction. But, even with one-day drainage, a condsiderable saving in irrigation could be obtained.

In absence of standing water for a large part of the irrigation interval and because of occurrence of partial desaturation during the non-ponding period, a sharp reduction in hydraulic conductivity accompanied with substantial lowering of the percolation rate is achieved. As it entails a considerable saving of water, it makes possible to irrigated a large are with a limited water supply. It also enables a more effective use of rainfall in the rice fields. In tube well command, there is considerable reduction in pumping hours resulting in saving in energy and increased life of pumping equipment.

Conjunctive use of rain and irrigation waters in rice fields

The storage of rain water in properly bunded rice fields overcomes moisture deficiency during dry spells, reduces irrigation requirements, and enhances its utilization crop production. It also induces deep percolation and ground water recharge. The amount of storage depends upon the height of dike around rice filed, quantum of rainfall and its distribution, the type of soil and its hydraulic properties, and rice cultivar. The bund height around the field should be so planned that it stores maximum amount of rain water without submerging the rice crop and reducing the yield. Mishra et. al. (1997) studied the effect of dike height on the conservation of water, soil and nutrients, and rice yield under the lateritic soil of Bhubaneswar. An exponettial relationship between rainfall excess (RE) from the rice fields and the bund height (h) was observed;

RE=121.75 e-0-181 h R2 = 0.967(1)

In which RE is rainfall excess as percentage of rainfall, and h is bund height in cm. An analysis of the equation reveals 57 per cent and 98 per cent storage of rainwater in fields having 6 cm and 22 cm bund heights, respectively. One of the objectives of storing rainwater in rice fields is to minimize irrigation water application. In the experiment at Bhubaneswar, 6 cm irrigation was applied after one day of disappearance of ponded water. Under such water regime, four irrigations were required to rice crop grown in the plots having 6 cm bund heights, and two irrigations to plots having 18, 22, 30 cm bund heights.

The high amount of rain water storage in the rice fields having bunds resulted in more deep percolation loss and ground water recharge. This fact has also been corroborated from the experiments at Ludhiana (1997-98) where 15 cm dike height around the rice field in sandy loam soil has resulted into 9.65 cm less run off , and .37 cm less application of irrigation water than field having 10 cm bund height (Table 10). It resulted into an increase of 3.33 cm deep percolation over normal bunds of 10 cm commonly maintained in the farmer's fields. Thus, a field having 15 cm bund height effects a reduction in ground water withdrawal by 6.37 cm, and increase in deep percolation by 3.33 cm, thereby conserving a total of 10 cm water during the rice season. The study is an example of conjunctive and conservative management of rain and irrigation water in rice fields.

Table 10. Effect of rain water storage in rice fields on run off, irrigation requirement, deep percolation, and crop yield.

Components of water balance, and yield	Dike height, cm		
	10	15	20
Irrigation water applied, cm	80.57	74.2	73.5
Rainfall, cm	52.3	52.3	52.3
Run off, om	11.77	2.12	0
Deep percolation, cm	67.67	71.0	72.4
Deep percolation as % of total water input	50.9	56.1	57.5
crop yield, ha	6.37	6.84	5.71

Source : Annual Report, 1997-98 AICRP Optimization of Ground Water Utilization Through Wells and Pumps, Department of Soil and Water Engineering, PAU Ludhiana, Punjab.

Water requirement of rice-wheat system

Irrigation requirement of wheat at different locations in Indo-Gangetic plains has been studied under All India Coordinated Research Project on Water Management. The irrigation water requirement has been observed to vary between 180 mm in Bihar plains to 360 mm in Haryana. The total water requirement for wheat has been estimated to fluctuate from 238 mm in Bihar to 400 mm in Punjab. The total water requirement of rice is estimated to vary from 1144 mm in Bihar plains to 1560 mm in Haryana. Thus, a total of 1382 mm to 1838 mm water is required for rice–wheat system at different locations in Indo-Gangetic plains.

CONCLUSION

Rice–wheat cropping system has been dominating in the Panjab and Hariyana . The highest surface water development in Punjab (84.0%) followed by West Bengal (77.7%), Haryana (69.4%), Uttar Pradesh (59.3%), and Bihar (49.8%). The rainwater is short of meeting the water requirement of rice field, irriagrion water is applied to fulfill the demand of water. The irrigation requirement ranges from 810 mm in Bihar plains to 2000 mm in Haryana. The increase of 3.33 cm deep percolation over normal bunds of 10 cm commonly maintained in the farmer's fields. Thus, a field having 15 cm bund height effects a reduction in ground water withdrawal by 6.37 cm, and increase in deep percolation by 3.33 cm, thereby conserving a total of 10 cm water during the rice season. It also enables a more effective use of rainfall in the rice fields. In tube well command, there is considerable reduction in pumping hours resulting in saving in energy and increased life of pumping equipment. The irrigation water requirement has been observed to vary between 180 mm in Bihar plains to 360 mm in Haryana. The total water requirement for wheat has been estimated to fluctuate from 238 mm in Bihar to 400 mm in Punjab. The total water requirement of rice is estimated to vary from 1144 mm in Bihar plains to 1560 mm in Haryana. Thus, a total of 1382 mm to 1838 mm water is required for rice – wheat system at different locations in Indo - Gangetic plains. The study is an example of conjunctive and conservative management of rain and irrigation water in rice fields.

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