Occasional Paper
No.15-1123

For Restricted Circulation

WATER PRODUCTIVITY AND WATER SAVING IMPACTS OF LASER LEVELLING AND DEEP PLOUGHING: ANALYSIS FROM SAMBHAL DISTRICT OF UTTAR PRADESH, INDIA

Saikat Mandal, P.N.A. Vaishnavi, M.S. Prasad, K. R. Dureja, Saurabh Mathur
Binay Kumar and M. Dinesh Kumar

November-2023

INSTITUTE FOR RESOURCE ANALYSIS AND POLICY
202, Riviera, Dwarakapuri Colony, Punjagutta, Hyderabad-500082
Tel: 91-40-42617392 E-Mail: info@irapindia.org www.irapindia.org

Water Productivity and Water Saving Impacts of Laser levelling and Deep Ploughing: Analysis from Sambhal District of Uttar Pradesh, India

Saikat Mandal[1], P.N.A. Vaishnavi[2], M S Prasad[3], K R Dureja[4], Saurabh Mathur[5], Binay Kumar[6] and M. Dinesh Kumar[7]

Abstract

Efficient use of water through technological interventions can improve the sustainability of water resources. The western part of Uttar Pradesh in India is a region with intensive water use and the groundwater levels have started dropping. The CSR wing of Yara Fertilizers has been working with the farmers to implement a wide range of interventions such as Laser levelling, deep ploughing, and use of organic fertilizers for soil and water productivity improvement in the villages of Sambhal district, with the aim of improving agricultural productivity and conserve groundwater. To understand the impact of adopting those technologies, a study was conducted. The main focus of this study was to estimate the impact on yield, irrigation water use and the consumptive use of water, water use efficiency owing to the adoption of the package of treatment, and estimate the aggregate water saving.

An extensive field study involved primary data collection. The methodology involved estimation of: water application to the crops, crop consumptive use, cost of cultivation, gross income, net income, and water productivity in crop production in physical and economic terms pre and post adoption of and assessing the differences. The results showed a significant reduction in both applied and consumptive water use and substantial increase in yield, net income, and water productivity for paddy, wheat and sugarcane post-treatment. The water was 7,677 m^3/ha for kharif paddy, 3,290 m^3/ha for wheat, 10,462 m^3/ha for sugarcane (R), and 11,115 m^3/ha for sugarcane (S).

As per the estimate, the average of physical water productivity in relation to consumed water increased from 0.18 kg/ m^3 (222%) to 0.43 kg/ m^3 for Kharif Paddy, 0.43 kg/ m^3 (221%) to 0.99 kg/ m^3 for wheat, 1.85 kg/ m^3 (142%) to 3.93 kg/ m^3 for Sugarcane (R) and 1.63 kg/ m^3 (144%) to 3.28 kg/ m^3 for Sugarcane (S) post adoption. Post adoption, the average of economic water productivity in relation to consumed increased from 1.42 Rs/ m^3 (446%) to 7.72 Rs/ m^3 for Kharif Paddy, 4.86 Rs/ m^3 (739%) to 40.8 Rs/ m^3 for wheat, 2.98 Rs/ m^3 (324%) to 12.64 Rs/ m^3 for Sugarcane (R) and 2.22 Rs/ m^3 (374%) to 10.53 Rs/ m^3 for Sugarcane (S). The average water saving through the adoption of the practices,

[1] Research Officer, Institute for Resource Analysis and Policy, Hyderabad
[2] Research Officer, Institute for Resource Analysis and Policy, Hyderabad
[3] Vice President (Manufacturing), Yara Fertilizer India Pvt Ltd, Uttar Pradesh
[4] General Manager (Maintenance) Yara Fertilizer India Pvt Ltd, Babrala, Uttar Pradesh
[5] General Manager (Technical Service & Sustainability), Yara Fertilizer India Pvt Ltd, Babrala, Uttar Pradesh
[6] Senior Manager, Yara Fertilizer India Pvt Ltd, Babrala, Uttar Pradesh
[7] Executive Director, Institute for Resource Analysis and Policy, Hyderabad

considering the effect of reduction in water use and yield improvement, was estimated to be 2.068 MCM. When the effect of increase in net income was considered instead of yield, the saving was 5.398 MCM.

Key Words: Water saving, Consumptive use, Physical water productivity, Economic water productivity, Laser land levelling, Deep ploughing.

1 Introduction

The western Uttar Pradesh is one of the most intensively farmed regions in India—with a large area under paddy and an increasing area under water-intensive sugarcane. Though the region is endowed with rich alluvial aquifers with a water table at a depth of 20-30 feet, the water levels have already started depleting due to excessive withdrawals (CGWB, 2020). The CSR wing of Yara Fertilizers has been working with the farmers to implement a wide range of interventions for soil and water conservation in western UP villages for the past six years, aimed at improving agricultural productivity and conserving groundwater. Some of the interventions are: laser levelling of soils and deep-ploughing. Though the world-wide experience with these technologies is positive vis-à-vis improving the technical efficiency of use of water (in the case of laser levelling) and improving crop yields (in both cases), there are no scientific studies that evaluate the impact of these crop and water management interventions based on data from actual farmers' fields in India. The limited studies available on the impacts of such interventions used poor indicators for estimating water saving and water use efficiency, such as reductions in applied water and water productivity in relation to the amount of water applied, respectively.

2 The Conceptual Framework

Water use efficiency/water productivity is the ultimate indicator of how efficiently water is being used in crop production. However, this can be measured in many ways and at many scales. At the field scale, the most common way of measuring water use efficiency is to look at the production per unit of water applied. However, due to the chances of reuse of water (the excess irrigation that is available as return flows to groundwater), the use of such indicators can lead to the wrong assessment of water use efficiency improvements and tend to over-estimate water saving. The best indicator is the production per unit of water consumed (Allen et al., 1997), and therefore, the water use efficiency should be measured in relation to evapotranspiration from the irrigated field plus non-beneficial soil moisture depletion (if any) from the crop land (Kumar & van Dam, 2013). Further, there are several input use practices that the farmers follow (in addition to the use of technologies that change the efficiency of irrigation water use, such as fertilizer use, use of good-quality seeds, use of micro nutrients, etc.) which have implications for the cost of cultivation, and the farmer is ultimately interested in net income and not biomass output per unit of land. Therefore, water use efficiency measured in terms of biomass output per unit of water might not always be the right indicator for assessing agricultural performance. Hence, water productivity should also be measured in terms of net income per unit of water consumed.

3 Study Objectives

The objective of the study is to evaluate the impact of agricultural water management interventions in a district of western Uttar Pradesh. The following are the specific objectives:

- Estimate the yield impacts of laser levelling and deep ploughing practices followed by the farmers in the region.

- Estimate the impact of these technologies on the irrigation water use, the consumptive use of water in the field, and therefore the water saving per unit of land.

- Evaluate the water use efficiency impacts of these interventions in terms of biomass output, net return per unit of water applied in the field, and water consumed by the crops.

- Estimate the potential water saving that would have resulted from a change in water use efficiency.

4 The Approach and Methods

The approach used in the study will be eclectic. It will use primary data from the farmers who are adopting the technologies and practices for crop growing (dates of sowing and harvesting), inputs (seeds, fertilizers, labour, irrigation, pesticides, machine use), and outputs (both main and by-products) for pre- and post-adoption scenarios. For the post-adoption scenario, the cost of the package of treatments (i.e., deep ploughing and laser levelling) is added to the cost of cultivation, considering a life of three years for each and the number of seasons for which the crops are cultivated in a year. Similar data will be collected from control farms where such treatments have not taken place. This is to factor out the effects of external factors such as temperature and rainfall, which are likely to have a significant impact on crop growth and yield.

The study will also quantify the total amount of water applied (irrigation) by the farmers in the field for various crops on the basis of the well output, the number of irrigations, and the hours of watering per irrigation. It will also estimate the use of effective rainfall and evapotranspiration (ET) by using FAO's CROPWAT model. The soil moisture depletion will be separately estimated using internationally accepted methods. The net return from crop production will be estimated as:

$$INCOME_{\mathrm{NET}} = Y\ x\ P - COST_{\mathrm{CULTIVATION}}$$

Here Y is the yield of the crop in kg/ha; $COST_{\mathrm{CULTIVATION}}$ is in Rs/ha; $INCOME_{\mathrm{NET}}$ is in Rs/ha.

Water productivity will be estimated in both physical (kg/ m^3) and economic terms (Rs/ m^3 of water) by taking the ratio of the yield and net income per both the unit of water applied and the unit of water consumed, respectively.
Water applied per ha Δ = No. of irrigations (n) X Duration of Watering per ha in hours (T) X Q; where Q is the discharge in m^3 per hour

Water consumed, CU (m^3/ha) = Evapotranspiration from cropped area ET_{CROP}+ Non-beneficial soil evaporation from the field $ET_0\ X\ K_{CROP}$ after the harvest

Physical Productivity of Water in relation to Irrigation =

$$\partial = \frac{Y}{\Delta}$$

Physical Productivity of Water in Relation to Water Depleted or Consumed =

$$\partial^1 = \frac{Y}{CU}$$

Economic Productivity of Water in Relation to Water Applied Ø=

$$INCOME_{NET}/\Delta$$

Economic Productivity of Water in Relation to Water Consumed Ø′=

$$INCOME_{NET}/CU$$

To estimate the amount of water that would have actually been saved through the change in water use efficiency (in relation to ET), the amount of water that would have been consumed to produce the quantum of crop outputs that are produced now under the conventional method would be compared against the amount of water that is currently consumed.

$$\text{Total real water saving for Crop}_i = \frac{\text{Total output for crop}_{\text{i (post adoption)}}}{\emptyset_{Pre}} - \frac{\text{Total output for crop}_{\text{i (post adoption)}}}{\emptyset_{Post}}$$

The methodology used for estimating real water saving is based on Kumar, M. D. (2016).

The aggregate water saving was estimated for each crop would be estimated separately using this formula.

5 Characteristics of the Region

Sambhal district is situated in the state of Uttar Pradesh, India. It was announced on September 28, 2011, as one of three new districts in the state. It was formerly named "Bhimnagar". Sambhal is 158.6 kilometers (98.5 mi) from New Delhi and 355 kilometers from the state capital, Lucknow, towards the East. Sambhal district lies between 78˚17' E and 78˚57’ E latitudes and 28˚01’ N to 28˚51’ N longitudes. The district is bounded by Moradabad and Amroha districts on the north, Budaun and Rampur districts on the east, Bulanshahr district on the west, and Aligarh district on the south. The river Ganges forms the natural southern and south-western boundaries of the district.

The geographical area of the district is 2453.30 sq.km. According to the 2011 census, the total population of the district is 21,92,933, with 11,61,093 males and 10,31,840 females, respectively. The population density of the district is 897 per sq.km [Census, 2011]. The literacy rate in the district is 57%, and the sex ratio is 873. There are three Tehsils, eight blocks, 556 village Panchayats, and 1022 villages in the district.

The climate of this district is sub-humid. It is characterized by hot weather in the summer and bracing cold weather in the winter. The annual average rainfall in this district varies spatially from 846 to 1119 mm, as illustrated in Figure 1, with a comparatively higher amount of rainfall on the northern side and lower rainfall on the southern side of the district.

The annual average temperature of this district varies from 25.37 to 25.69 °C, which is also illustrated in Figure 2. The mean monthly relative humidity is 69%. During the south-western monsoon, the seasonal atmosphere is very humid, and for the rest of the season, it is comparatively less humid. January is the coldest month, and May is the hottest.

The district is underlain by deep alluvial soils. According to the USGS classification, the geological formation of the Sambhal district falls under quaternary sediments. The geological profile of the district is shown in Figure 3.

According to FAO classification, the soils of the district are predominantly of three types: (1) Eutric Cambisol; (2) Calcaric Fluvisol; and (3) Orthic Luvisols. In most of the areas, the soil type is Orthic Luvisols. As this district is situated on the banks of the Ganga River, the geomorphology is alluvial plain. The soil map of the district is shown in Figure 4.

According to the Statistical Diary (2020), the net and gross sown areas in this district were 193 and 373 thousand hectares, respectively. Here, a shallow tube well is the main source of irrigation. In the recent past, most wells were electrified with submersible pumps. The net irrigated area of this district was 180 thousand hectares, out of which the government and private tube wells were used to irrigate 7614 ha and 123420 ha of land, respectively (Statistical Diary, 2020). Paddy, wheat, sugarcane, mustard, maize, and lentils are the major crops cultivated here.

Paddy grown during the kharif season is irrigated. This is followed by either wheat, mustard, or sugarcane. Sugarcane is sown either in March or in October/November. The former one is an early-maturing variety and is also harvested in November like the latter one. The crop yields are reasonably high in the district, with paddy yields in the range of 4.5 to 5 t/ha. The wheat yield is also in the same range. Sugarcane yield is in the range of 90-100 t/ha.

The depth to groundwater levels in the district ranges from 5 to 20 metres. The water levels are relatively shallow in the south-western parts (in the range of 5-10m) and deeper in the north—10 to 20 m (CGWB, 2020), despite having relatively higher rainfall in that part. The discharge of shallow tube wells in the high water table areas is in the range of 20-25 litre per second. Figure 5 shows the depth to groundwater levels in the district.

Figure 1

Rainfall Isohyets of Sambhal District

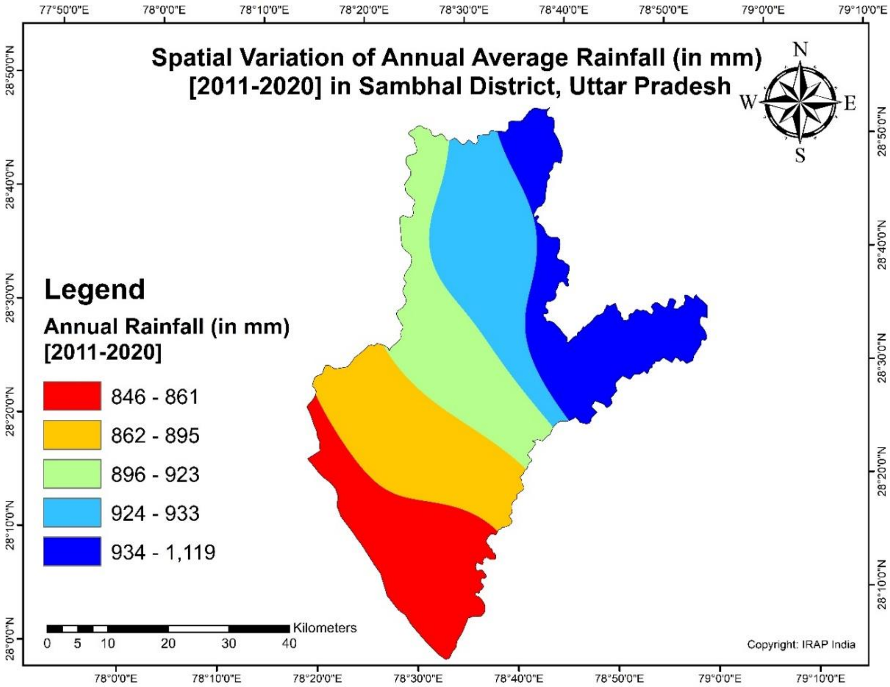


Figure 2

Temperature Isohyets of Sambhal District

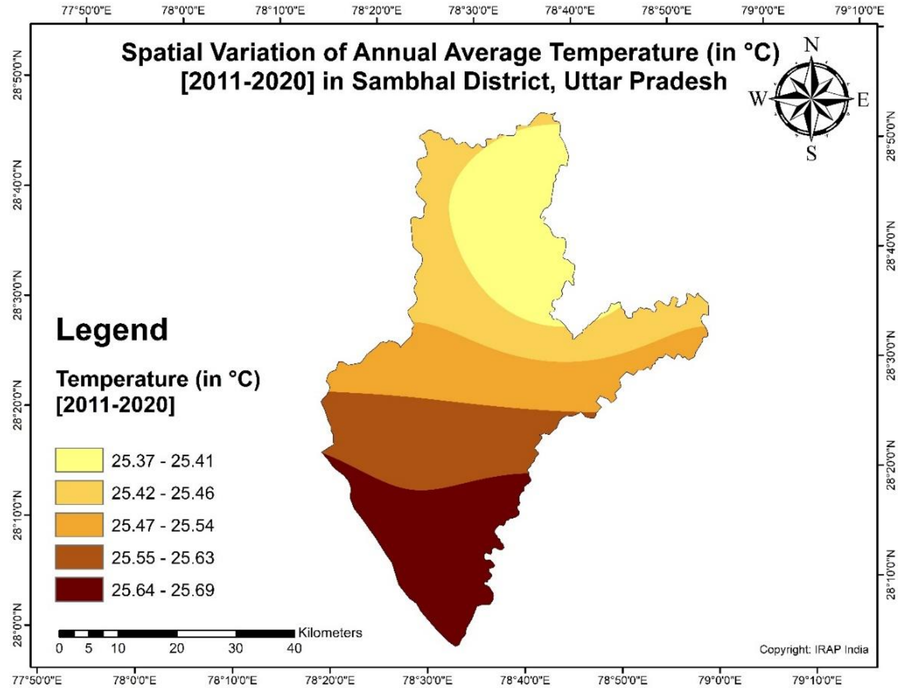


Figure 3

Map Showing the Geology of Sambhal District

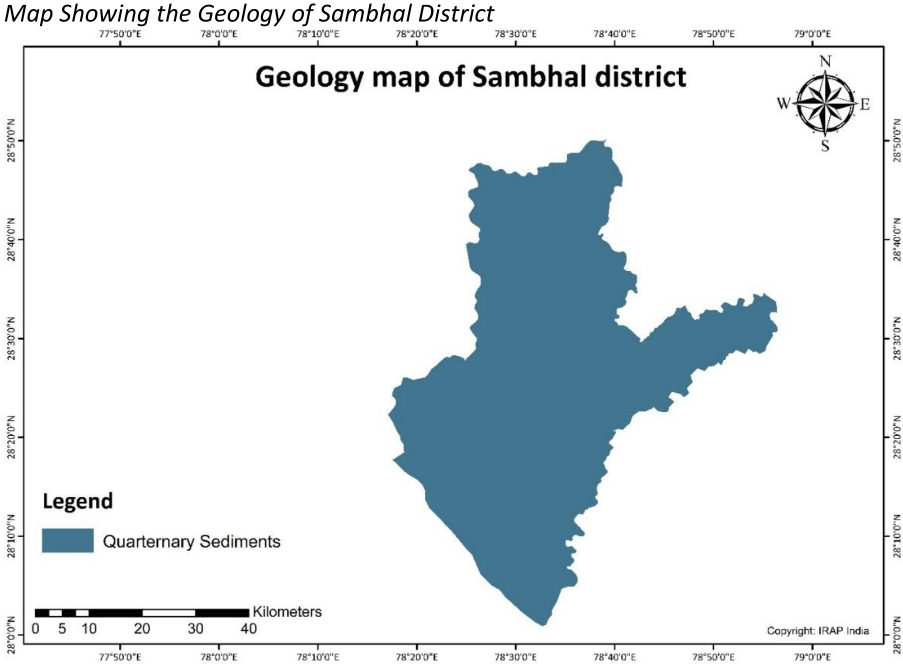


Figure 4

Soil Map of Sambhal District

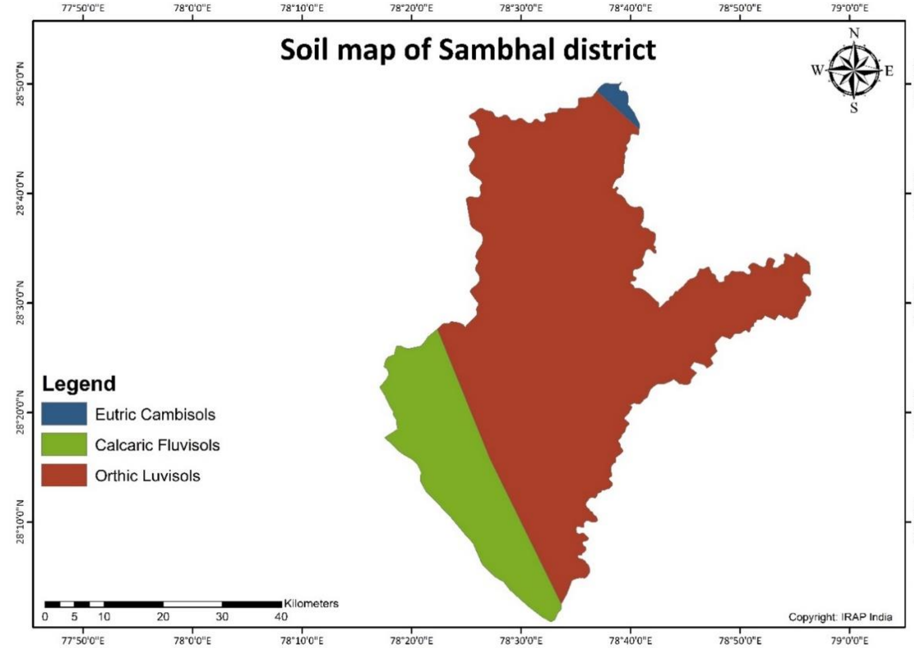
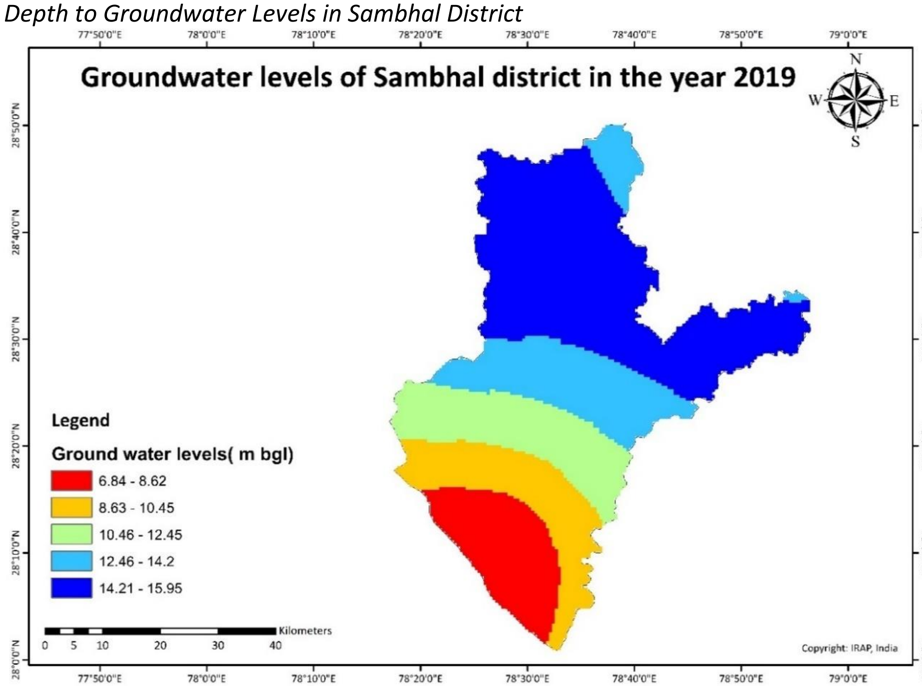


Figure 5

Depth to Groundwater Levels in Sambhal District



6 Types and Sources of Data, Sampling Plan

The types of data used are: primary data on crop inputs and outputs, growing period, and agricultural water management technology used; and secondary data on weather parameters, soils, geohydrology, and water levels.

Questionnaire was designed for collecting primary data from the farmers and was field-tested before being administered to the entire sample. Data on well output (discharge) were obtained through direct measurement of well output using a bucket and stopwatch.

Primary data from the farmers was collected through the recall method. For the post-adoption scenario, data for the most recent crop year were collected, and data for the last crop year immediately before technology adoption were used for the pre-adoption scenario. The corresponding time period was likewise employed for the control farms.

For the time period considered for the study, daily data on weather parameters such as rainfall, relative humidity, sunshine hours, maximum and minimum temperature, wind speed, and wind direction would be collected from the nearest weather station maintained by the water resources department of the state, the IMD, or the agricultural department.

The sample size was 40 for the technology combinations (laser levelling, deep ploughing, and use of organic manure), and the size of the control was 20. The study covered all the crops for which the technology/practice was introduced, and the data corresponding to the winter and summer seasons were used to obtain a correct picture of the changes in consumptive use of water from irrigation. The sampling was done in such a way that the different soil types and farm sizes, two important factors that have potential influence on water management, were adequately represented.

7 Theoretical Explanations for the Impacts

During the first exploratory field work (on August 17-19), we undertook the following activities:

1 Discussion with the officials of YARA and 'Kiran'

2 Interactions with several farmers (in small groups) during the exploratory field visit

3 Detailed discussions with five of the adopter farmers (from four villages) to determine what treatment measures they implemented in their farms, what impact they observed, and what benefits they derived, as well as the extent to which the questionnaire developed by IRAP for detailed field surveys was relevant and whether any changes or modifications were required.

4 Testing of the questionnaire to see how far the farmers are able to recall the past and respond to the specific questions.

5 Taking measurements of the discharge of the wells in the field using a drum and a stopwatch. Two wells had their discharges measured. The discharge was around 20 litres per second (lps) in the first case and 25 lps in the second case.

The exploratory field work revealed that the questionnaire developed by IRAP largely meets the requirements of the present research questions and 'points of inquiry', and only minor refinements are required (including deletion of the last table in the questionnaire) before a large sample survey is launched. The discharge of the wells in the area, which are fitted with 7.5 to 10 HP pumps, is quite high, and measurement of discharge will be quite challenging in the field conditions.

During the interviews, the adopter farmers reported substantial improvements in yield of crops, viz., paddy, wheat, and sugarcane (25-30%) and significant saving of irrigation water (30-40%) owing to the adoption of the three practices. Some farmers seem to have apprehensions about deep ploughing, indicating that it would bring to the surface all the soils from the deeper strata that are devoid of any organic matter. The farmers did not report any significant increase or change in the use of inputs, except for the cost of the treatments.

There are three different types of treatment being done, along with soil testing: 1) laser levelling; 2) deep-ploughing; and 3) use of natural fertilizers.

In the case of an unlevelled plot, excessive water application is often required to make sure that water (released from one corner of the field) reaches the tail areas of the field when there are no borders made for irrigation. This can lead to considerable evaporation from the depression storage. When borders are made inside the plot to improve distribution uniformity, a lot of land is wasted, and seepage of water through the open channels surrounding the 'small levelled borders' becomes considerably high.

Laser levelling is done to make sure that the field does not have undulations (and no positive slope in the direction in which water has to flow) and that the water can flow smoothly like a film, with much less roughness offered by the soil surface and without causing any depression storage. This ensures better distribution uniformity in water application. In spite of having 'zero' slope, laser levelling works very well in clayey loam soils and loamy clay because the infiltration capacity of the soil is quite low. However, this will not be very effective in sandy soils owing to the high infiltration capacity and the zero slope. For other soils (with high silt and clay content), laser levelling reduces the time required for irrigation as almost a uniform depth of watering is maintained throughout the field. The effect of laser levelling is in terms of a reduction in water application and uniform growth of the plants, with each corner of the field receiving an adequate amount of water.

Normally, due to the frequent use of tractors in clayey loam and loamy clay soils, the strata below the top soil (which is ploughed) gets mechanically compacted, affecting the infiltration properties of the soil and acting as a hard pan, preventing the rooting of plants and reducing the rate of infiltration of both rainwater and irrigation water. In the absence of deep ploughing (even on levelled land), the applied water remains in the first 5-6 inches, causing substantial soil evaporation during the initial stages of crop growth when the canopy cover is very low. Since the degree of saturation of the top soil (from which the crop roots take water) will be higher with water getting stored in a thin layer in the pre-treatment scenario, the rate of soil evaporation will be higher during the growing stage as well, necessitating more frequent watering to avoid moisture stress. Additionally, due to improper root development, crop growth suffers with less amount of water applied to the soil converted into transpiration and more water converted into soil evaporation. This has an impact on crop yields (since yield is a direct function of transpiration).

With deep ploughing, the hard pan below the shallow top soil is broken, and the soil becomes loose for the plants to take deep routes. Since the route zone depth increases and a greater void is created in the soil strata, the amount of water that can be stored in the soil and therefore for the roots of the plants increases. Since water can infiltrate faster into the deeper layers of the root zone, evaporation will be reduced. However, the plants can draw this water from the deeper layers of the soil. The chances of aeration of the root zone are high, with a potential positive effect on crop growth. However, it is also evident that the first watering immediately after deep ploughing takes a long time because infiltration becomes much faster and the depth of the loose soil that has more void space is large.

The use of organic fertilizer (city compost) allows enrichment of the soil from the deeper strata that come up during deep ploughing.

8 Analytical Procedure

Based on the methodology discussed in Section 6 and the observations made during the exploratory field work, we had made the reasonable assumption that with laser levelling and deep ploughing, there is no change in the deep percolation or return flow from irrigation, and the reduction in irrigation water application is due to a reduction in evaporation from the depression storage and the top soils. Let us consider the irrigation water dosage before and after treatments as Δ_1 andΔ_2, respectively. The effective rainfall is P_e. The consumptive use of water after treatment is considered equal to crop ET and there is no non-beneficial consumptive use of water in the field. Here we also make the assumption that there is no non-recoverable deep percolation, which is a very reasonable assumption in view of the fact that the soil is permeable, and the water table is very shallow.

In that case, the return flow (recoverable non-consumptive use) post treatment can then be estimated as:

Total Water Applied – Consumptive Use = $RF_{IRR} = \Delta_2 + P_e - CU_2$

The consumptive use of water in the post treatment case here is equal to ET_C

If so, then the total consumptive use of water under pre-treatment condition, (CU_1) will be,

$$\Delta_1 + Pe - (\Delta_2 + P_e - ET_c)$$

$$CU_1 = (\Delta_1 - \Delta_2) + ET_c)$$

9 Results and Discussion

The field study involved visiting the adopter and non-adopter farmers on their farms. A structured questionnaire was administered to the farmers. A total of around 45 minutes to 60 minutes were spent on each farmer to collect various data pertaining to the farming enterprise. Field observations were also made to understand the soil characteristics, crop growing methods, and irrigation practices. The data collected from the farmers who were interviewed during the field study included the following: the crops grown in different seasons; the area under irrigation for the crops grown in different seasons; the amount of inputs (seeds, fertilizer, and pesticides used) and their cost; the amount of family and paid labour used; the usage of machinery; the amount of irrigation water dosage (number of waterings and duration of watering for each irrigation); the crop yield obtained (main product and byproduct); and the farm gate price of the produce.

Well discharge measurements were performed on a total of 10 wells, 7 from sample farmers and 3 from control farmers. The measurements utilized a drum with a 220-litre capacity and a stopwatch. The measurements could not be undertaken for all the wells due to the issue of restricted power supply and load shedding. Based on the measurement of discharge for the selected wells, the pump efficiency was estimated and the same was applied for the wells for which the discharge could not be measured.

The PET values for the four crops estimated using the FAO CROPWAT model are presented in Table 1. The outputs from the analysis of the data are presented for the sample farmers (adopters) for the pre- and post-adoption scenario in Tables 2 and 3, respectively. The outputs for the control farm for the same year for which data for the post-adoption scenario were collected are presented in Table 4. For the pre-adoption scenario of the control farmers, the average values of the sample farmers were used. The key outputs are with respect to level of input use, the cost of inputs, crop yield, and gross and net return from crop production. The differences in various attributes, viz., input cost, crop outputs (yield), gross income, net income, and water productivity (both physical and economic), for the adopter farmers between pre- and post-adoption scenarios are given in Table 5.

The results show significant reductions in both applied water and consumptive water use for all three crops. In the case of paddy, the reduction in consumptive as well as applied water use was 7,677 m^3/ha. In the case of wheat, the reduction in consumptive as well as applied water use was 3,290 m^3/ha. For sugarcane (R), the reduction in consumptive as well as applied water use was 10,462 m^3/ha. For sugarcane (S), the reduction in applied water use and consumptive water use was 11,115 m^3/ha.

The results also show an improvement in the yields of the adopter farmers for all crops after the adoption of the treatment package. It also shows that the input use has slightly increased, by 14.1 kg/ha for kharif paddy and 24 kg/ha for 4.80 kg/ha for sugarcane. However, the increase in input use was much lower for the adopters as compared to the control farmers (non-adopters), in whose case the fertilizer use went up by 20.10 kg/ha for paddy, 30.9 kg/ha for wheat, and 197.5 kg/ha for sugarcane. This establishes the effect of the treatment packages: laser levelling improves the water distribution in the field; deep ploughing helps improve the aeration of the soil and thus plant growth; and organic fertilizers improve the productivity of the soils.

Following the adoption of the treatment package, the average yield obtained by the sample farmers was 4,852 kg/ha for kharif paddy, 4,583 kg/ha for wheat, 80.59 ton/ha for sugarcane (R), and 73.08 ton/ha for sugarcane (S). The yield went up by 42.9% for kharif paddy, 35.6 % for wheat, 40.8% for sugarcane (R) and 34.5% for sugarcane (S) post adoption. Whereas in the case of the control farmer, the average yield had declined during the time period considered for impact assessment for all three crops. The substantial difference in yield increase between the sample farmers and the control farmers establishes the yield improvement effect of the agricultural water management practices.

Table 1

Potential Evapotranspiration (PET) Values for Different Crops Estimated Using CROPWAT

SL No	Crop Name	Average PET Value (mm)
1	Paddy	611.93
2	Wheat	241.1
3	Sugarcane (R)	1452
4	Sugarcane	1362

Table 2

Pre-Adoption Scenario for Adopter (Sample) Farmers vis-à-vis Inputs and Outputs

Crop Name	Yield Q/ha	Gross Income Rs/ha	Net Income Rs/ha	Input Cost Rs/ha	Irrigation water applied m^3/ha	Consumptive Use, CU m^3/ha	Physical productivity of water in relation to irrigation, kg/m^3	Physical productivity of water in relation to water depleted or consumed kg/m^3	Economic Productivity of Water in Relation to Water Applied Rs/m^3	Economic Productivity of Water in relation to Water Consumed Rs/m^3
Paddy (K)	33.96	62417.76	19524.89	42892.9	18981.62	13796.8	0.18	0.25	1.03	1.42
Wheat (R)	33.81	68926.28	27717.48	41208.8	7935.11	5701.2	0.43	0.59	3.49	4.86
Sugarcane (R)	572.37	158963.82	74451.25	84512.6	30955.15	24986.5	1.85	2.29	2.41	2.98
Sugarcane	543.27	150360.58	54882.5	95478.1	33414.42	24731.0	1.63	2.20	1.64	2.22

Table 3

Post-Adoption Scenario for Adopter (Sample) Farmers vis-à-vis Inputs and Outputs

Crop Name	Yield Q/ha	Gross Income Rs/ha	Net Income Rs/ha	Input Cost Rs/ha	Irrigation water applied m^3/ha	Consumptive Use, CU m^3/ha	Physical productivity of water in relation to irrigation, kg/m^3	Physical productivity of water in relation to water depleted or consumed kg/m^3	Economic Productivity of Water in Relation to Water Applied Rs/m^3	Economic Productivity of Water in relation to Water Consumed Rs/m^3
Paddy (K)	48.52	111044.41	47248.39	63796.02	11304.1	6119.3	0.43	0.79	4.18	7.72
Wheat (R)	45.83	147005.61	98359.29	48646.32	4644.6	2410.7	0.99	1.90	21.18	40.80
Sugarcane (R)	805.92	281644.74	183575.16	98069.58	20493.2	14524.5	3.93	5.55	8.96	12.64
Sugarcane	730.77	255769.23	143303.46	112465.77	22298.8	13615.3	3.28	5.37	6.43	10.53

Table 4

Control Farmers (2021 Scenario) vis-à-vis Inputs and Outputs

Crop Name	Yield Q/ha	Gross Income Rs/ha	Net Income Rs/ha	Input Cost Rs/ha	Irrigation water applied m^3/ha	Consumptive Use, CU m^3/ha	Physical productivity of water in relation to irrigation (kg/m^3)	Physical Productivity of water in relation to water depleted or consumed (kg/m^3)	Economic Productivity of Water in Relation to Water Applied (Rs/m^3)	Economic Productivity of Water in relation to Water Consumed (Rs/m^3)
Paddy (K)	27.5	63333.3	20158.3	43175.0	17851.0	5968.5	0.15	0.46	1.129	3.38
Wheat (R)	28.95	84407.9	40133.4	44274.5	8605.5	2372.3	0.34	1.22	4.664	16.92
Sugarcane (R)	450.89	157812.5	64089.4	93723.1	42634.0	14921.6	1.05	3.02	1.503	4.295

Table 5

Overall Change in Inputs and Outputs After Adoption of the Treatment Package

Crop Name	Difference in Various Attributes After Adoption of the Treatment Package									
	Yield Increase (kg/ha)	Increase in Gross Income (Rs/ha)	Increase in Net Income (Rs/ha)	Reduction Input Cost (Rs/ha)	Saving in Irrigation Water Applied (m^3/ha)	Saving in Consumed Water (m^3/ha)	Improvement in Physical WP in relation to water applied (kg/m^3)	Improvement in Physical WP in relation to consumed water (kg/m^3)	Improvement in Economic WP in relation to water applied (Rs/m^3)	Improvement in Economic Productivity of Water in relation to Water Consumed (Rs/m^3)
Paddy K	14.56	48626.65	27723.5	20903.12	7677.5	7677.51	0.25	0.54	3.15	6.3
Wheat (R)	12.02	78079.33	70641.81	7437.52	3290.5	3290.50	0.56	1.31	17.69	35.94
Sugarcane (R)	233.55	122680.9	109123.9	13556.98	10462.0	10462.0	2.08	3.26	6.55	9.66
Sugarcane	187.5	105408.6	88420.96	16987.67	11115.7	11115.7	1.65	3.17	4.79	8.31

Figure 6.

Graphs Depicting Output for Paddy (K)

Figure 6a.

Irrigation Water Use, Consumptive Use, Yield, Input Cost, Gross and Net Income for Paddy Under Pre- and Post-Adoption Conditions

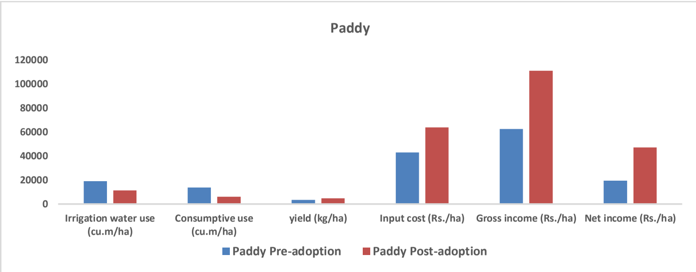


Figure 6b.

Physical Water Productivity and Economic Water Productivity of Paddy With Respect to Irrigation Water Use and Consumptive Water Use Under Pre- and Post-Adoption Conditions

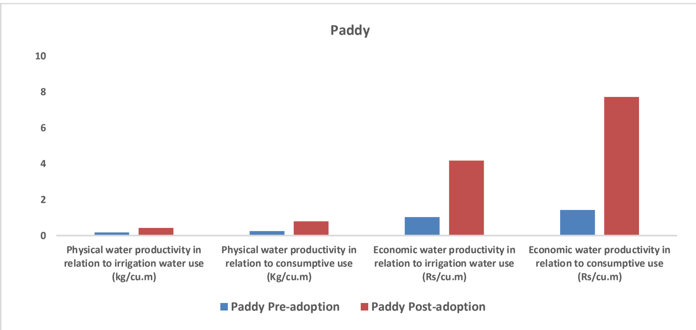


Figure 7.

Graphs Depicting Output for Wheat

Figure 7a.

Irrigation Water Use, Consumptive Use, Yield, Input Cost, Gross and Net Income for Paddy Under Pre- and Post-Adoption Conditions

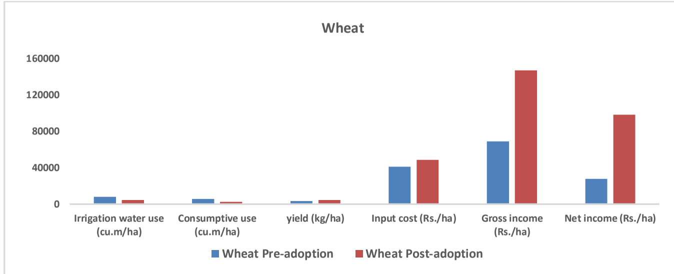


Figure 7b.

Physical Water Productivity and Economic Water Productivity of Wheat With Respect to Irrigation Water Use and Consumptive Water Use Under Pre- and Post-Adoption Conditions

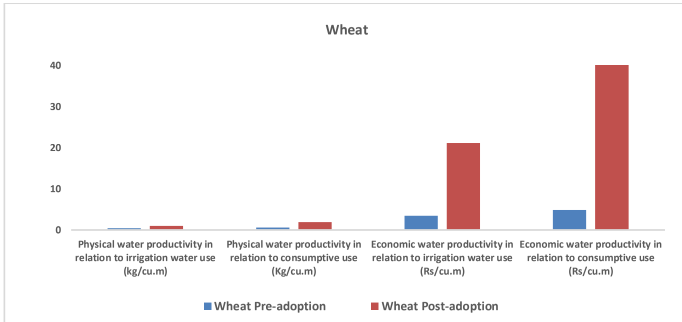


Figure 8.

Graphs Depicting Output for Sugarcane (Ratoon)

Figure 8a.

Irrigation Water Use, Consumptive Use, Yield, Input Cost, Gross and Net income for Sugarcane (Ratoon) Under Pre- and Post-Adoption Conditions

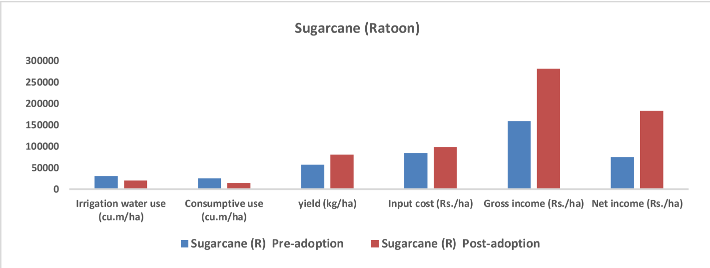


Figure 8b.

Physical Water Productivity and Economic Water Productivity of Sugarcane (Ratoon) With Respect to Irrigation Water Use and Consumptive Water Use Under Pre- and Post-Adoption Conditions

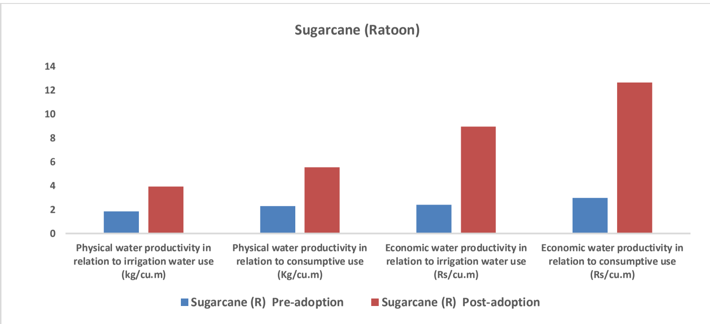


Figure 9.

Graphs Depicting Output for Sugarcane

Figure 9a.

Irrigation Water Use, Consumptive Use, Yield, Input Cost, Gross and Net Income for Sugarcane Under Pre- and Post-Adoption Conditions

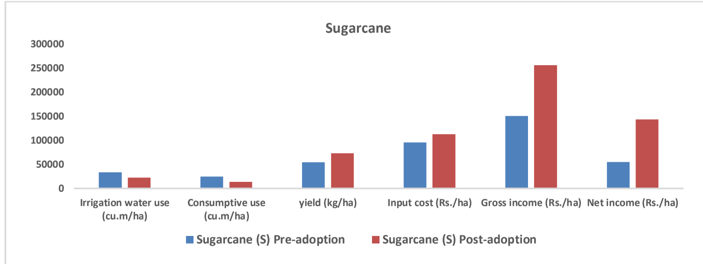
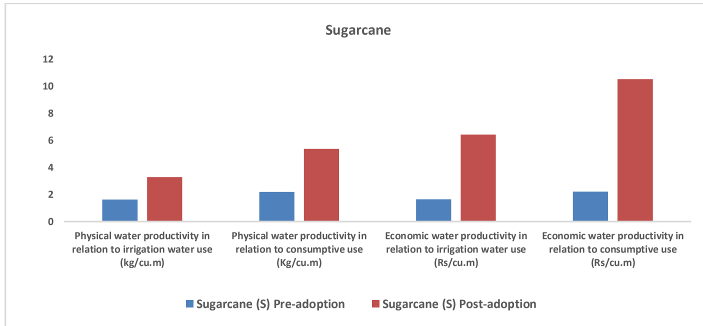


Figure 9b.

Physical Water Productivity and Economic Water Productivity of Sugarcane With Respect to Irrigation Water Use and Consumptive Water Use Under Pre- and Post-Adoption Conditions



The results show that the net income earned by the farmers had also increased owing to a substantial rise in gross income due to better output despite an increase in input costs. The average increase in net income for kharif paddy was Rs 27,723/ha, wheat was Rs. 70,642/ha, sugarcane (R) was Rs. 109,123/ha, and sugarcane (S) was Rs. 88,420. In percentage terms, it was 142% for kharif paddy, 254.86% for wheat, 146.57% for sugarcane(R), and 161.11% for sugarcane (S). While there can be an increase in income over time due to a rise in the (current) price of the produce, the analysis for control farmers show that the income growth was much lower in their case, with a 3.2% increase for paddy and negative for sugarcane. Only in the case of wheat was the income for control farmers quite high (44.8%).

The average physical water productivity in the case of the adopter farmers, expressed in kg/m^3 of applied water, was estimated to be 0.18 kg/m^3 for kharif paddy, 0.43 kg/m^3 for wheat, 1.85 kg/m^3 for sugarcane (R), and 1.63 kg/m^3 for sugarcane (S) pre adoption, whereas post adoption, it was 0.43 kg/m^3 for paddy, 0.99 kg/m^3 for wheat, 3.93 kg/m^3 for sugarcane (R), and 3.28 kg/m^3 for sugarcane (S). The average increase in WP in relation to applied water was 140% for kharif paddy, 131.6% for wheat, 101.6% for sugarcane (S), and 112.7% for sugarcane (R).

Before adoption, the average physical water productivity in the case of adopter farmers, expressed in kg/m^3 of consumed water, was estimated to be 0.25 kg/m^3 for kharif paddy, 0.59 kg/m^3 for wheat, 2.29 kg/m^3 for sugarcane (R), and 2.20 kg/m^3 for sugarcane (S), whereas post adoption, it was 0.79 kg/m^3 for paddy, 1.90 kg/m^3 for wheat, 5.55 kg/m^3 for sugarcane (R), and 5.37 kg/m^3 for sugarcane (S). The average increase in WP in relation to consumed water was 51.7% for kharif paddy, 44.7% for wheat, 45.8% for sugarcane (R), and 39.94% for sugarcane (S).

For the adopter farmers, the average economic water productivity in relation to consumed water, expressed in Rs/m^3 of water, was estimated to be 7.72 Rs/m^3 for kharif paddy, 40.8 Rs/m^3 for wheat, 12.64 Rs/m^3 for sugarcane (R), and 10.53 Rs/m^3 for sugarcane (S), whereas prior to adoption, it was 1.42 Rs/m^3 for paddy, 4.86 Rs/m^3 for wheat, 2.98 Rs/m^3 for sugarcane (R), and 2.22 Rs/m^3 for sugarcane (S). The improvement here is likewise quite substantial, owing to an increase in income and a reduction in consumptive water use. The increase in economic water productivity was phenomenal for all four crops.

The changes in various parameters of crop production between pre- and post-treatment conditions such as irrigation dosage, consumptive water use, input cost, crop yield, gross income, net income, physical water productivity, and economic water productivity (in relation to both applied water and consumed water), are depicted in Figures 6a and 6b for kharif paddy, 7a and 7b for wheat, 8a and 8b for sugarcane (R), and 9a and 9b for sugarcane (S).

Now, over the past 6 years (beginning in 2016), several farmers have adopted the treatment packages introduced by Kiran Yara Fertilizers India Pvt. Ltd. Community initiative. The total area under adoption is 35.8 ha under paddy, 135 ha under wheat, and 33.76 ha under sugarcane in the core programme area. The average water saving through the adoption of efficient land and water management practices that consider the effect of reduction in consumed water for growing the crops and improvement in yield from the crops, was estimated to be 2.068 MCM (million cubic metre) for a total area of 35.8 ha under kharif paddy, 135 ha under winter wheat, and 33.76 ha under sugarcane (R) and 8.44 ha under sugarcane (S). This basically means that had the farmers who are currently growing these crops not been using the treatment package, they would have ended up using an additional 2.068 MCM of water for irrigating the crops to produce the same level of yield. Now, if we consider the effect of a reduction in water use and an improvement in net income, the water saving amounts to 5.398 MCM.

10 Findings and Conclusions

A study was undertaken in Sambhal district of Uttar Pradesh in order to assess the physical and economic impacts of agricultural water management practices, covering a sample of 40 farmers doing various land-based treatments (laser levelling, deep ploughing, and application of organic fertilizers) and a sample of 20 control farmers who are doing normal cultivation.

The crops covered in the survey are paddy, wheat, and sugarcane. All these crops are irrigated. While paddy is grown during the kharif season, wheat is grown during the winter. Sugarcane is cultivated in two seasons in a year. One is a 12-month crop (Ratoon), and the other is a 9-month crop. The soils in the fields of the farmers who had adopted the treatment practices are mostly sandy loam and loamy sand. In a few cases, sandy soils were also encountered.

The study makes a clear distinction between the water applied by farmers in the field and the water consumed in irrigation. The real water saving in any agricultural water management practice will result from a reduction in consumed water.

The study showed that the farmers undertaking the treatment activities (sample farmers) are quite satisfied with the outcomes in terms of saving in water used for irrigating various crops, the amount of inputs used (doze of chemical fertilizers), the amount of labour spent, and the yield of crops. The details are given below.

The saving in irrigation water owing to the adoption of laser levelling and deep ploughing obtained by the sample farmers was found to be significant in the range of 1169 to 19,878 m^3/ha for paddy, 780 to 12,862 m^3/ha for wheat, 5,262 to 23,385 m^3/ha for sugarcane (R), and 7,015 to 26,309 m^3/ha for sugarcane (S). The average reduction in water use in aggregate terms was 7,677 m^3 per ha for kharif paddy, 3,290 m^3/ha for wheat, 10,462 m^3/ha for sugarcane (R), and 11,115 m^3/ha for sugarcane (S).

In percentage terms, the average reduction in water use achieved using the treatment package was 40.45% for paddy, 41.47% for wheat, 33.80% for sugarcane (R), and 33.3% for sugarcane (S). Against this, the average reduction in water use for the control farmers who have not adopted any of the treatments was found to be 5.96% for kharif paddy, 8.45%

increase in water use for wheat, and 37.7% increase in water use for sugarcane (R). Hence, except for paddy, the irrigation water dosage actually increased for the non-adopters during the time period considered.

The average reduction in consumptive use of water for irrigated production following the adoption of agricultural water management practices was estimated to be 7,677.55 m^3/ha for kharif paddy, 3,290.47 m^3/ha for wheat, 10,461.98 m^3/ha for sugarcane (R), and 11,115.66 m^3/ha for sugarcane (S).

The average increase in input use of the sample farmers owing to the adoption of agricultural water management practices was 14.1 kg/ha for kharif paddy, 24 kg/ha for wheat, 4.81 kg/ha for sugarcane (R) and 27.9 kg/ha for sugarcane (S). Against this, the average increase in input use for the control farms is found to be 20.125 kg/ha for kharif paddy, 30.88 kg/ha of reduction in input use for wheat, and 197.5 kg/ha of reduction in input use for sugarcane. Against this, no notable difference in input use was reported by the non-adopters (control farmers).

The average yield obtained by the sample farmers with treatment was 4,852 kg/ha for kharif paddy, 4,583 kg/ha for winter wheat, 80.59 ton/ha for sugarcane (R), and 73.08 ton/ha for sugarcane (S). Against this, the average yield obtained by control farmers during the same year was 2,750 kg/ha for kharif paddy, 2,895 kg/ha for wheat, and 45.09 ton/ha for sugarcane (R).

The average yield increase secured by the sample farmers post adoption of the treatment was 42.87% for kharif paddy, 35.55% for wheat, 40.80% for sugarcane (R), and 34.51% for sugarcane (S). The yield increase varied from a lowest of 14.29% to a highest of 233.33% for kharif paddy, 14.29% to 100% for wheat, 11.1% to 100% for sugarcane (R), and 16.67% to 62.5% for sugarcane (S). As against this, in the case of control farmers, the yield decrease was 19.02% for kharif paddy, 14.37% for wheat, and 21.22% for sugarcane (R). In the case of the control farmers, the average yield had declined for all three crops. The substantial difference in yield increase between the sample farmers and the control farmers establishes the yield improvement effect of the agricultural water management practices.

The average income increase secured by the sample farmers following the adoption of the treatment package was 142% for kharif paddy, 254.86% for wheat, 146.57% for sugarcane (R), and 161.11% for sugarcane (S). As against this, for the control farmers, the income increase was a mere 3.24% for kharif paddy, 44.79% for wheat, and 13.92% decrease for sugarcane. The substantial difference in income increase between the sample farmers and the control farmers establishes the yield improvement effect of the agricultural water management practices, with a rise in yield and a reduction in the cost of inputs. Hence, it can be inferred that the agricultural water management interventions are economically viable.

The average (physical) water productivity in crop production in relation to applied water was 0.43 kg/m^3 for kharif paddy, 0.99 kg/m^3 for wheat, 3.93 kg/m^3 for sugarcane (R), and 3.28 kg/m^3 for sugarcane (S) in the post-treatment condition. The physical productivity of water also showed a substantial increase post adoption of the treatment for the sample farmers. The average increase in WP in relation to applied water was 139.91% for kharif paddy, 131.58% for wheat, 101.57% for sugarcane (S), and 112.69% for sugarcane(R).

The average (physical) water productivity in crop production in relation to consumed water was estimated to be 0.79 kg/m^3 for kharif paddy, 1.9 kg/m^3 for wheat, 5.55 kg/m^3 for sugarcane (R), and 5.37 kg/m^3 for sugarcane (S) post adoption of the treatment. The physical productivity of water in relation to consumed water also showed good improvement post adoption of the treatment for the sample farmers. The average increase in WP in relation to consumed water was 222.13% for kharif paddy, 220.57% for wheat, 142.23% for sugarcane (R), and 144.33% for sugarcane (S).

The average economic productivity of water in crop production in relation to consumed water was estimated to be 7.72 Rs/m^3 for kharif paddy, 40.8 Rs/m^3 for wheat, 12.64 Rs/m^3 for sugarcane (R), and 10.53 Rs/m^3 for sugarcane (S) post adoption of the treatment. The economic productivity of water in relation to consumed water showed greater improvement post adoption of the treatment for the sample farmers as compared to the physical productivity of water. The average increase in WP in relation to consumed water was 445.6% for kharif paddy, 739.22% for wheat, 324.18% for sugarcane (R), and 374.28% for sugarcane (S). This shows the economic viability of the interventions used to save water and obtain higher crop outputs.

The average water saving through the adoption of efficient land and water management practices was estimated to be 2.061 MCM for a total area of 35.8 ha under kharif paddy, 135 ha under winter wheat, 33.76 ha under sugarcane (R), and 8.44 ha under sugarcane (S), considering the incremental yield and reduction in water use. When the incremental income is considered along with the reduction in water use, the net water saving amounts to 5.398 MCM. This basically means that had the farmers, who are currently growing these crops, not been using the treatment package, they would have ended up using an additional 5.398 MCM of water for irrigating the crops to produce the same level of income.

Hence, it can be concluded that the agricultural water management practices (laser levelling, deep ploughing, and use of organic fertilizers) promoted by Kiran Yara Community in Sambhal district are quite effective in achieving not only water saving in irrigation in real terms but also improvements in yield and productivity of land and water in both physical and economic terms. While irrigation water dosage and consumptive water use are reduced post adoption, the improvements in yield per ha, net income per ha, and water productivity in physical (kg/m^3) and economic (Rs/m^3) terms are quite substantial. With the adoption of the practices, the farmers get higher yields, higher net income, and therefore higher water productivity while being able to effectively reduce the water application and consumptive water use in irrigation.

References

Allen, R. G., Willardson, L. S., & Frederiksen, H. (1997). Water use definitions and their use for assessing the impacts of water conservation. In J. M. de Jager, L. P. Vermes, & R. Rageb (Eds.), *Sustainable irrigation in areas of water scarcity and drought* (pp. 72–81). Oxford.

Central Ground Water Board. (2021). *Dynamic Ground Water Resources Of Uttar Pradesh (2020)*. Ground Water Department U.P And Central Ground Water Board Northern Region, Lucknow, July 2021. http://cgwb.gov.in/sites/default/files/MainLinks/Uttar%20Pradseh_State_Report_Resource_2020.pdf

Kumar, M. D. (2016). Wet water saving and social benefits from micro irrigation: A study from IGNP command area in Rajasthan. In Viswanathan, P.K., Kumar, M. D., & Narayanamoorthy, A. (Eds.), *Micro irrigation systems in India: Emergence, status and impacts* (pp 91-112). Springer.

Kumar, M. D., & van Dam, J. (2013). Drivers of change in agricultural water productivity and its improvement at basin scale in developing economies, *Water International*, *38*(3), 312-325. https://doi.org/10.1080/02508060.2013.793572

Statistical Diary. (2020). Economics And Statistics Division State Planning Institute Planning Department, Uttar Pradesh. http://updes.up.nic.in/esd/reports/dbank_march21/Diary%202020(English).pdf

Registrar General of India, Ministry of Home Affairs, Government of India. (2011). *Census 2011*. https://censusindia.gov.in/

List of Other Occasional Papers

1. Kumar, M. D., Narayanamoorthy, A., and Sivamohan, M.V.K. 2010. Pampered Views and Parrot Talks: In the Cause of Well Irrigation in India. IRAP Occasional Paper, No. 1-0410, March 2010.
2. Kumar, M. Dinesh, Narayanamoorthy, A, Singh, O.P, Sivamohan, M.V.K, Sharma, Manoj K. and Bassi, N, 2010. Gujarat's Agricultural Growth Story: Exploding Some Myths. IRAP Occasional Paper, No. 2-0410, March 2010.
3. Bassi N. & Kumar, M. D. 2010. NREGA and Rural Water Management in India: Improving the Welfare Effects. IRAP Occasional Paper, No 3-0910, September 2010.
4. Kumar, M. D., Sivamohan, M.V.K., Vedantam, N. & Bassi, N. 2011. Ground Water Management in Andhra Pradesh: Time to address Real Issues. IRAP Occasional Paper, No 4-0211, February 2011.
5. Kumar, M. D., Bassi N., Venkatachalam, L., Sivamohan, M.V.K and Vedantam, N. 2012. Capacity Building in Water Resources Sector of India. IRAP Occasional Paper, No. 5-0112, January 2012.
6. Vedantam, N. and Srinivasu, VK. 2012. Small Water Harvesting and Artificial Recharge interventions in Singoda River Basin, Coastal Saurashtra: Hydrological and Socio-Economic Impacts. IRAP Occasional Paper, No 6-0512, May 2012.
7. Kumar, M. D., Foster, D.J., Saleth, R. M., Singh, O.P., and Sivamohan, M.V.K, 2014. Human Development, Inclusive Growth and Poverty Alleviation through Water Security: Global Evidence. IRAP Occasional Paper, No. 7-0314, March 2014.
8. Sivamohan, M.V.K. 2015. Agrarian Crisis in India: Where it is heading. IRAP Occasional Paper, No.8-0315, March 2015.
9. Kumar, M. Dinesh, Saleth, R.M., Prathapar, S.A, Ratna Reddy, V., Narayanamoorthy, A. and Bassi, N. 2016. Mihir Shah Committee Report (2016) on Water Reforms in India: A Critique. IRAP Occasional Paper, No.09-1216, December 2016.
10. Sahasranaman, Meera. 2016. Future of Urban Agriculture in India. IRAP Occasional Paper, No.10-1216, December 2016.
11. Chattopadhyay, S. 2017. The Solar Fiasco: An Analysis of the Techno Economic Viability of Rooftop Solar PV Systems for Powering India's Economy Shourjomoy. IRAP Occasional Paper, No. 11, March 2017.
12. Kumar, M. D., Bassi N., Singh, OP., Ganguly, A and Chattopadhyay, S.2017. Assessing Global Water and Food Challenges: Time to Rethink on Methods?. IRAP Occasional Paper, No. 12, June 2017.
13. Sahasranaman, Meera and Ganguly, A. 2018. Waste Water Treatment for Water Security in India. IRAP Occasional Paper, No.13-0418, April 2018.
14. Kumar, M. D., Bassi. N., Ganguly. A., and Sivamohan. M. V. K. 2020. How Does Rainfall Influence Annual Agricultural Growth Rates in India?. IRAP Occasional Paper, No.14-0120, January 2020.

INSTITUTE FOR
RESOURCE ANALYSIS AND POLICY

Institute for Resource Analysis and Policy is a non-profit organization undertaking research, consultancy and training in the field of natural resource management. Its goal is to promote sustainable management of natural resource and their related services, particularly land and water resource, for improved food security, livelihoods and environment. The organization undertakes inter-disciplinary and multi-disciplinary research and consultancy projects. Its administrative office is located in Hyderabad, India.

Office Address:
202, Riviera, Dwarakapuri Colony, Punjagutta, Hyderabad-500082
Tel: 91-40-42617392 E-Mail: info@irapindia.org www.irapindia.org

Rs.100/-