IMPACT OF MOHANPURA PRESSURIZED IRRIGATION PROJECT, MADHYA PRADESH, INDIA

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ABSTRACT

Madhya Pradesh is one of the largest states of India having agriculture as the most dominant economic activity. Till the year 2014, the total Irrigation potential created (IPC) through open canal system in the state was 3.3 million hectares. The observed water use efficiency (WUE) of the projects ranges between 35-50% (Madhok AK, CWC). The Government of Madhya Pradesh embarked on an ambitious programme to improve water use efficiency, by providing pressurized irrigation network (PIN) in all the new projects to the tune of 2.5 million hectares with the objective to increase WUE to 70-80%. The paper attempts to capture the dire need for Mohanpura Irrigation Project located in the semi-arid and economically backward region of Rajgarh district in Madhya Pradesh India. This piece tries to encapsulate the earnest attempt to ensure water-security for agriculture demands of the region where most of the farmers were forced to migrate to nearby Rajasthan towns of Kota, Tonk and Jaipur as labourers thereby denying a permanent home to their families and education for their children.

The paper demonstrates through observations in Mohanpura-Right Bank sub-project, of size 25,600 ha irrigated area, that it is possible to double the water use efficiency through adoption of PIN from reservoir to farm level (1.2ha) instead of conventional gravity-based projects. It also tries to showcase how state-of-the-art and modern irrigation projects can contribute to higher water use efficiency, sustainable livelihood and economic prosperity of a region.

Keywords: Water use efficiency, pressurized irrigation network, smart communication technology.

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1. Introduction

Mohanpura Irrigation Project (MIP) is located in Rajgarh District of Madhya Pradesh State of India on river Newaj in Chambal River Basin which originates from Sehore district and confluences in Chambal River after travelling 220 km. Newaj sub-basin has a drainage area of 4290 km^2 which is 7.2% of the drainage area of Chambal basin in Madhya Pradesh. The location of Mohanpura dam within Chambal basin and Newaj sub-basin is shown in Fig-1.

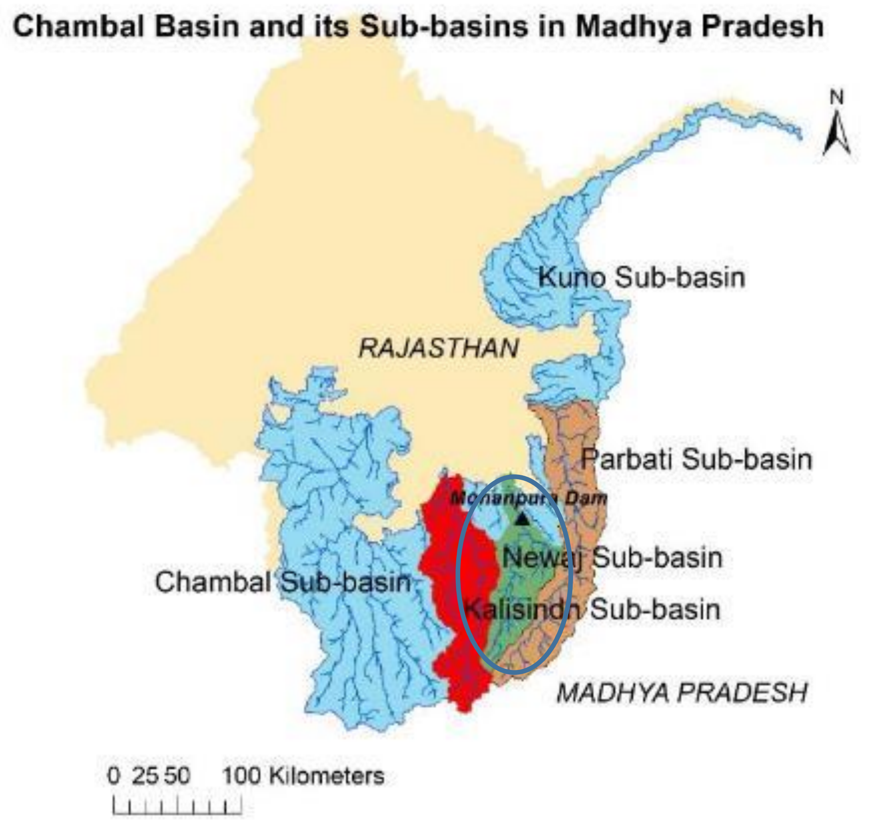


Fig-1

The need for MIP arose from the Newaj sub-basin's agriculture demand and that of adjoining Parbati and Kalisindh sub-basins (as shown in encircled area in Fig-1) for irrigating about 210,000 ha farms which would require 877 Mm^3 water for agriculture. The actual availability of water has shown that only 616 Mm^3 gross storage could be techno-economically created with 572.96 Mm^3 live water storage through the construction of Mohanpura dam utilizing an intercepted catchment area of 3825 km^2. Of this only 510 Mm^3 could be made available for agriculture with which it was possible to irrigate only 87,000 ha fields conventionally. Given the higher demand of 877 Mm^3, it became imperative to ensure efficient use of water in agriculture by adoption of PIN upto the farm level. With PIN, MIP is designed to serve 145,661 ha in Rajgarh district and also cater to the drinking, environment & industrial water needs.

With this background, in order to ensure the highest possible levels of water use efficiency, MIP was designed to ensure micro-irrigation ready irrigation supply with pressurized irrigation network (PIN). It was also necessary to couple the PIN with sophisticated yet resilient communication and control systems which allowed for automated as well as manual operations. The implementation of different sub-projects of MIP are in different stages of progress. Among these, Mohanpura Right Bank system is a sub-project of MIP that has been recently commissioned and the first integrated pressurized irrigation network with SCADA to get operational in the Madhya Pradesh. It is designed to serve the semi-arid belt of Tanwarwad in and around Kalipeeth area of Rajgarh district. The paper is limited to the study of this sub-project area. The location the various sub-projects are depicted in Fig-2.

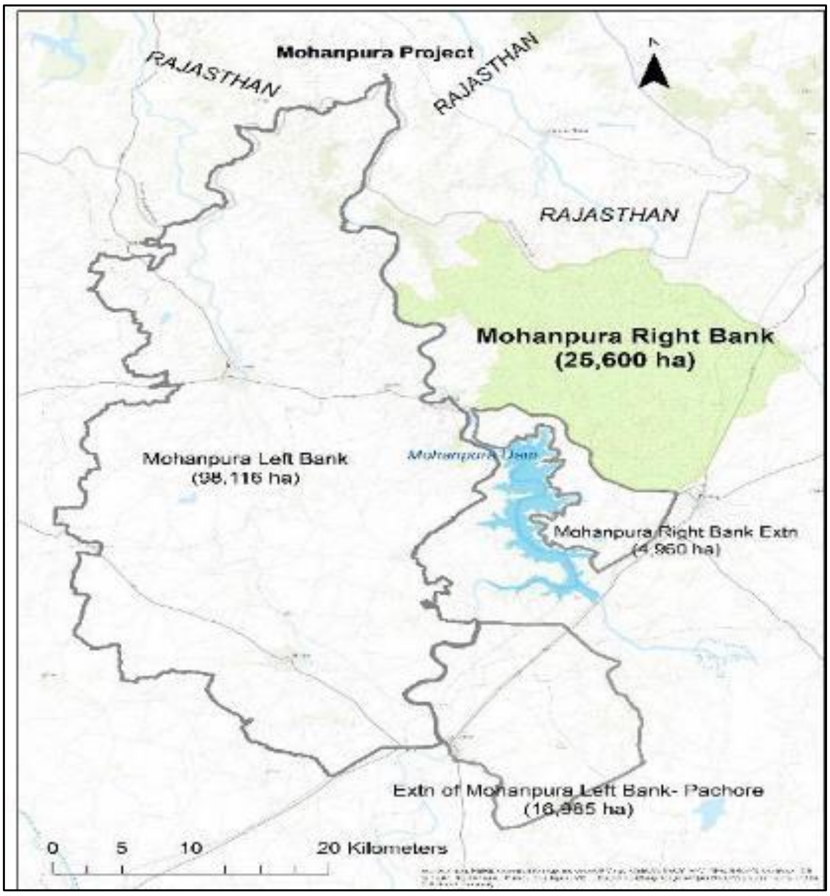
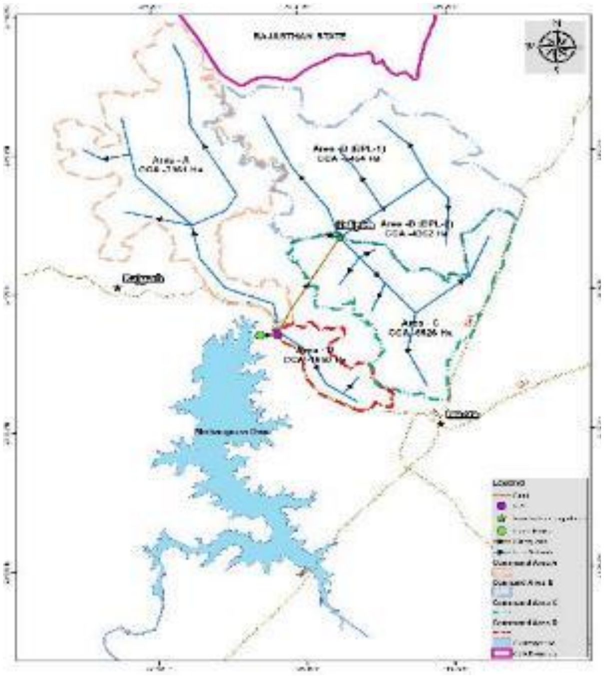


Fig-2

2. About Mohanpura- Right Bank PIN

The features of the sub-project are described in this section for a better understanding. The main objective of this sub-project is to provide adequate irrigation water with pressure (2 bar or 20 mwc) at farm level (1.25 hectares) through PIN in 25,600 ha of command area in 168 villages of Rajgarh district by lifting 8.7 m^3/s of water from Mohanpura reservoir. The system is coupled with smart and advanced communication technology, that in an autonomous way, control and monitor the operation of entire irrigation system up to 5 ha level using SCADA communication based on Resource to Root concept.

The command area of this sub-project is mainly divided in 5 parts and the command layout is depicted in Fig-3.



Area	CCA/IA (Ha)	No. of Beneficiary Villages
Area A	6,708	60
Area B (BPL 1)	6,454	34
Area B (BPL 2)	4,262	31
Area C	6,526	28
Area D	1,650	15
Total	**25,600**	**168**

Fig-3

The major components of the sub-project are pumping station, rising main, break pressure tank (BPT), gravity mains, branch lines, distribution network, controlling and regulation systems, etc. for supply of water for irrigation under pressure up to 1.25 Ha.

The water is drawn from reservoir to pump house by intake channel. Total 5 nos (4 Working + 1 Standby) of Vertical Turbine Pumps are installed at Intake Pumping station with each having capacity of 2.175 m^3/s and pumping head of 72 m to pump water to BPT. Additionally on-line booster pumping stations are installed at two locations i.e., part of Area D (1 Working + 1 Standby Pumps) and at Kalipeeth (5 Working + 2 Standby Pumps) for areas BPL 1, BPL 2 and Area C to satisfy the pressure requirement for higher elevation zones.

Rising main of 2300 mm diameter and having length of 1.1 km of (Carbon) mild steel is laid underground from pump house to transfer the water to BPT. BPT is of capacity 1.566 million litres for the retention time of 3 minutes. The diameter of BPT is 21 m with tank height is 5.4 m and staging height of 12 m. Full Supply Level (FSL) of BPT is 450 m.

In order to deliver the equitable water to every outlet in command area the concept of pressurized irrigation network with high efficiency and smart technology was conceived. In this system water is lifted from the reservoir and delivered to the farm outlet of 1.25 Ha by closed pipeline network with control mechanism at every 20 Ha chak and remotely operated On-Off valve for every 5 Ha command area. Further the water is delivered up to farm outlet by HDPE pipeline with manual On-Off valve at every 1.25 Ha. Additionally, the air valves are installed as per the hydraulic design for effective management of air in the pipe line network.

Further to synchronize the operation of all the components of the PIN system an innovative SCADA system with radio communication network is implemented in this sub-project.

3. Key technological features

The right-bank command area is highly undulating with the average relief of 15-20 m within 3000 ha zones. The key challenge arose is to maintain the equitable flows and pressure at outlets of 20 ha. With the help of available technology, a tailor-made state-of-the-art model is designed in the PINs of State.

3.1 Systems

3.1.1 Outlet Management System (OMS)

The entire command area of 25,600 Ha is divided into 1263 nos of Chaks each of 20 Ha. In order to ensure volumetric control and data acquisition, a unique concept of OMS is introduced. OMS consists of Pressure and Flow Control Modulating Device (PFCMD), Isolation valve, Air Valve, Strainer, Controller, Solar Panel and On-Off valves. All these components are mounted in tamperproof cabinet with door-switch.
A PFCMD is a specially designed pressure and flow control valve installed in OMS. It ensures the delivery of irrigation water at desired flow rate of 0.34 lps/ha at minimum required pressure of 20 m at farm level. The PFCMDs operates using the hydraulic energy in the pipe line and having linear flow characteristics to reduce the frictional losses. The equitable distribution of irrigation water is ensured by controlling the PFCMD with the help of solenoid operated hydraulic circuit.
OMS is equipped with an IoT based controller that is compact, low-powered, wireless RTU specially designed to operate the PFCMD Valves in various control modes. The Controller incorporates embedded software with fuzzy logic to control the OMS operations. The OMS controller maintains the design flow rate by modulating the PFCMD. In addition, the flow rate can be set remotely based on varying crop water requirement. Crop specific irrigation schedule can be programmed in the controller to ensure that required quantity of irrigation water is delivered at right time for required duration. The hydraulically operated On-Off valves installed at every 5 Ha are operated remotely through OMS Controller.
Solar Photo Voltaic Panels along with battery backup are installed for powering the controller, operation of solenoid valves and to transfer the data to Web portal.

Fig-4: OMS & AMS Installation in the Distribution Network

3.1.2 Air Management System (AMS)

Air Management system is installed at each location of Air valves. Total 148 nos of such AMS units are installed in the entire distribution network in this sub-project. Each AMS unit consists of air valve, isolation valve, pressure transmitters, RTU controllers and Solar panel. All these parts are mounted in tamper proof cabinet with door switch. The main feature of AMS is continuous monitoring of dynamic pipeline pressure Alerts and generate notifications in case of leakage and water theft based on differential pressure between consecutive AMS with the help of IoT based controller for wireless communication with SCADA system.

3.1.3 Control, Instrumentation and Automation

Various instruments are installed in the system for measurement and control of key parameters of the pumping system like levels, pressure and flow and other parameters for monitoring of health of the system such as temperature, vibration etc. All these instruments are hooked to the PLC control panel and further integrated to Web SCADA for synchronization with the distribution network.

3.1.4 Communication Network

LoRa (Long Range) based Wireless Radio Frequency (WRF) is used for the data communication. LoRa® is the wireless module utilized to create the long-range communication network with low power consumption using License Free Frequency Band of 865-867 MHz.

The detailed radio survey has been carried out to identify location of Gateways in the command area. Gateways are installed with high gain outdoor Omni directional antenna on a high-altitude location typically to get the clear line of sight. These Gateways are acting as a router using 4G connectivity between distribution network and Web SCADA through Cloud server. Solar PV Panel with Battery backup is installed for each gateway Power Supply. Each OMS and AMS is installed with controller with a LoRa WAN module and communicates with LoRa Network Server via a LoRa WAN Gateway. Each Gateway can be remotely monitored through Web SCADA to check the health of the communication network. In this sub-project, there are total 6 nos of LoRa gateways under operation to cover entire command area.

3.1.5 Web SCADA

Graphic User Interface based Web SCADA is installed in the sub-project to integrate the Pumping system with distribution network. This system provides real time monitoring, controls and synchronization of pressurized irrigation remotely over the internet. It enables automation of irrigation system without human interface and provides alarms, alerts and notifications for important system parameters. In addition, it provides system security, preventing sabotage and vandalism. Mobile App (WMS and ECM) is used by users to monitor and troubleshoot network operation and maintenance issues.

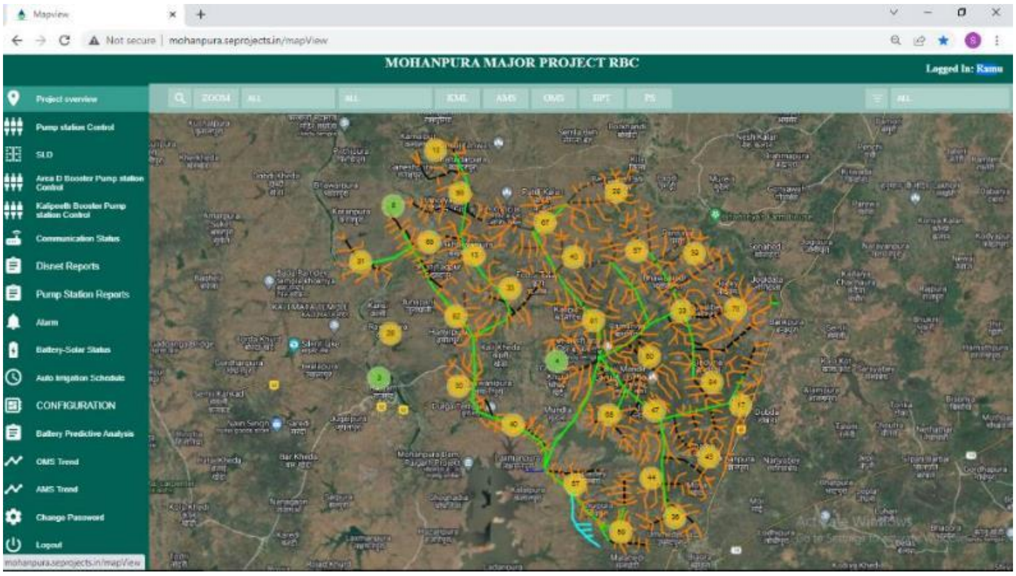


Fig-5: Web SCADA Screen of Distribution Network

3.2 Capturing Water Demand

The irrigation scheduling is designed to achieve the irrigation on rotation basis. At each OMS, two On-Off valves at 5 Ha are operated for 6 hours cycle twice in a day. Since the sub-project is designed for delivering 10 times duty i.e. 7 lps at 20 Ha chak. Hence each On-Off is delivering 3.5 lps flow rate. The detail irrigation schedule is developed depending on Chak design and programmed in the Web SCADA. The entire system can operate automatically to deliver the water according to the schedule.

Presently a call centre has been established Central Control Room to register the water demands by farmers. Based on the requirement of farmer the OMS operations are remotely controlled to satisfy these demands. However, a specially designed mobile application called Farmer Management System (FMS) is being developed so that farmers are able to register their individual water demand online using the application. All such demands are aggregated through

Web SCADA so that required quantities of crop water are delivered at each OMS. The requirement of all OMS is aggregated to operate the pumping system.

3.3 Synchronized operation for demand management

It is necessary to synchronize the operation of pumping system with variation in crop water requirement. The aggregated crop water requirement of the entire command area is fulfilled through delivery of water from BPT. In turn the same quantity of water is delivered continuously by the pumping system in the BPT. The flow rate of the pumping system varies according to intake level in the reservoir. In order to achieve the water balance and to synchronize pumping operation accordingly, Variable Frequency Drives (VFD) are provided for 50% of pumping capacity in the Intake pumping system. All the 5 pumps are fitted with Electrically Operated Butter Fly Valve (EO-BFV) with position transmitters. It is observed that, during Rabi season, crop water requirement varies from 50% to 100%. The combinations of pumps are operated using VFDs and throttling of EO-BFVs, so that overall variation in water requirement is satisfied.

4. Implementation Challenges

Among the initial and most challenging hurdle to execution and implementation to this PIN was the lack of buy-in by the senior-level engineers of the department. Most of them had the notion that investment into PIN would only yield a non-functional project. As the department consists of mostly civil engineers, multi-disciplinary projects involving civil, mechanical, electrical, control systems, electronic systems and software engineering in addition to social engineering were unthought of and hence the scepticism. To overcome this, a process driven implementation was carried out fuelled by the in-house expertise and that of the principal contractors and the private sector technological partners/ domain specialist sub-contractors. The success of the sub-project has ensured creation of a critical mass of technically competent personnel – both private and government who have gained the confidence to replicate such projects elsewhere.

The next important challenge was to overcome the scepticism of the beneficiaries who were indifferent towards the sub-project during execution as they did not believe that water would reach their farms located at higher elevations and far away from the storage. This scepticism vanished as soon as the sub-project was commissioned. The lesson learnt was that it seems less productive to sensitize and train farmers for better farm practices before really delivering water to her field. Subsequent village-level meetings and on-farm demonstrations have been very well received and also replicated with great enthusiasm.

It is perceived that active involvement of community and social mobilisation is necessary for uptake of micro-irrigation as an investment rather than a subsidy-opportunity for the utmost utilisation of PIN by the beneficiary farmers. It is also necessary to have a small yet dedicated organization of selected engineers with the key roles assigned reinforced with continuous support and belief in the team.

5. Impacts

5.1 Improved Water Use Efficiency

Since the commissioning of the sub-project in the year 2019, irrigation water has been delivered to the command area in 3 Rabi (winter) crop seasons. The year wise total irrigation water delivered along with the command area is indicated below (Table-1) and this data is derived from SCADA system of the sub-project. From the details it is observed that, actual duty/ flowrate required in the field is approximately 0.28 lps/ha as against 0.34 lps/ha for which the sub-project is designed (Table-1). This is well below the duty or flowrates adopted in open canal systems which are in the range of 0.6 lps/ha to 1.2 lps/ha. If the trend continues for a longer period of time, it would indicate that the crop water requirement calculations adopted are on a very conservative side and could require review.

Table-1

Year	Water Delivered in season (Mm^3)	No. of Days in Season	Weighted pumping duration at peak discharge (hrs)	CCA/ Irrigated area (ha)	Duty (lps/ha)
2019-20	17.30	98	1568	12,000	0.26
2020-21	40.01	120	1920	25,600	0.23
2021-22	51.71	123	1968	25,600	0.28

If similar irrigated area were to be developed using the best performing young projects in the State based on gravity based open canal system, then the water requirement at reservoir would have been in the range of 110-120 Mm^3. This comparison is shown in Table-2:

Table-2

Name of Project	**Year of commissioning**	**Storage for Irrigation (Mm^3)**	**Irrigation Area in ha**	**IA per Mm^3 of live storage**
Mahi Project	2012	123.44	28,127	228
Pench Project	2018	391.20	85,000	217
Mohanpura- Right Bank	2019	51.71	25,600	495

It may be deduced that water use efficiency for irrigation can be improved in the range of 2.1 to 2.3 times with adoption of PIN upto farm level (1.2 ha) coupled with SCADA and automation.

5.2 Surge in Crop Production

The project authorities, working closely with the district administration, came to know of a sudden spurt in crop production after the impounding of water in Mohanpura dam in 2018 and commissioning of Mohanpura Right Bank sub-project in 2019. To understand the interlinkage, government wheat procurement data for the district was obtained (of cooperative societies/markets in India where minimum support price (MSP) crops are procured). This procurement quantities are only an indicator of full production as farmers retain certain quantities for purposes of seed as well as domestic consumption.

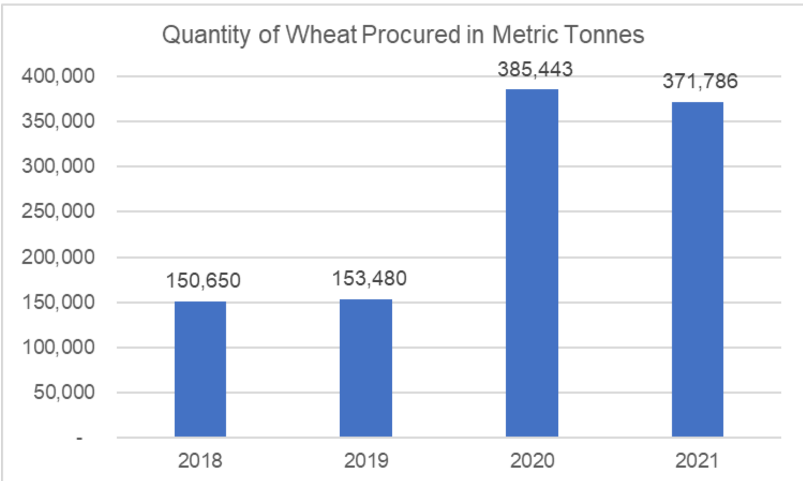


Fig-6: Government wheat procurement in Rajgarh

In Fig-6, we see a slight increase in production with increased impounding of water in Mohanpura reservoir in 2018-19 when compared to pre-project levels of production. After commissioning of the sub-project under study in 2019, there is a sudden surge in wheat procurement from 150,000 MT to more than 350,000 MT. Though not all increase may be ascribed to the sub-project, there appears a definite linkage to a combination of improved access to both surface water irrigation and improved groundwater levels due to Mohanpura reservoir. This increase is also indicative of improved water productivity.

5.3 Enhanced Access to Irrigation Services

As irrigation operators, the coverage of irrigated areas after commissioning of the sub-project was well understood and it was established that the sub-project had benefitted at least 12,000 ha and 25,600 ha in the years 2019 and 2020 onwards respectively. A study using Copernicus Sentinel (10mx10m resolution) data was conducted for NDVI and irrigated area calculations. NDVI (change detection) study plates from year 2017 to 2021 are shown in Fig-7 below.

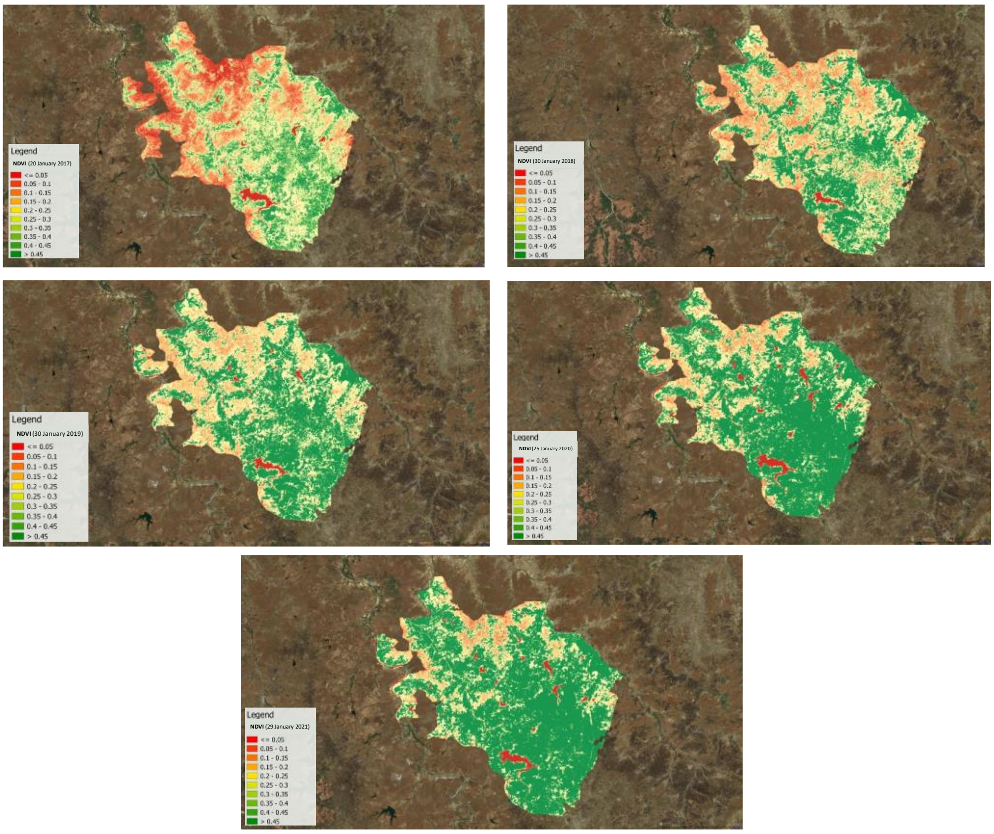


Fig-7: NDVI

The results of the calculations of irrigated area within the command boundaries of the sub-project are shown in Fig-8 as follows:

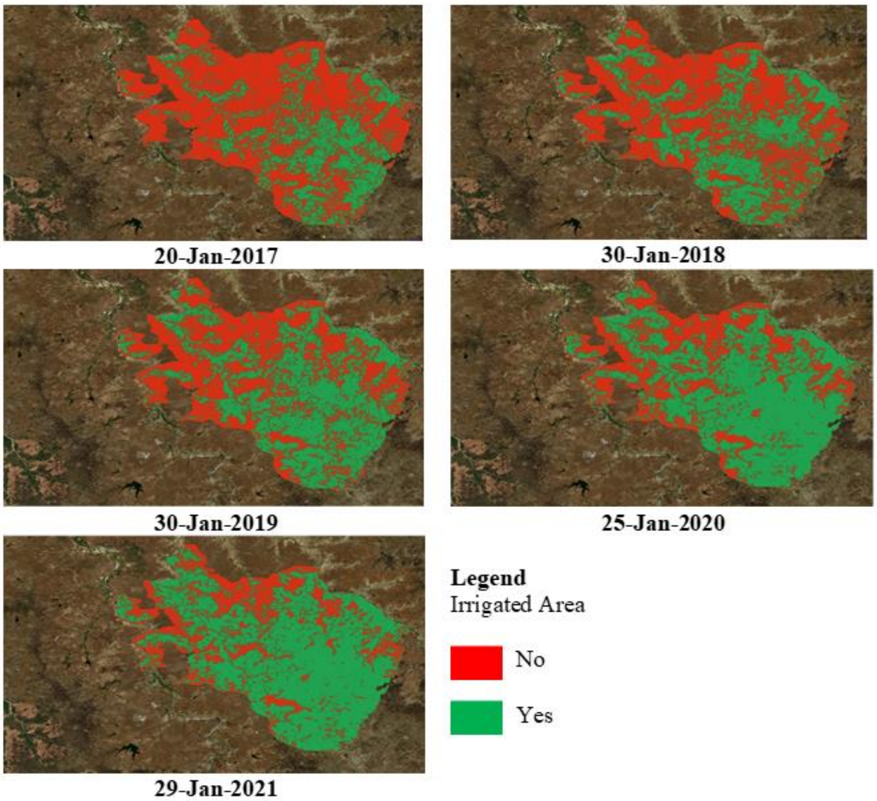


Fig-8: Analysis for Irrigated Area

The calculations of irrigated area from the satellite imageries are shown in the graph (Fig-9)

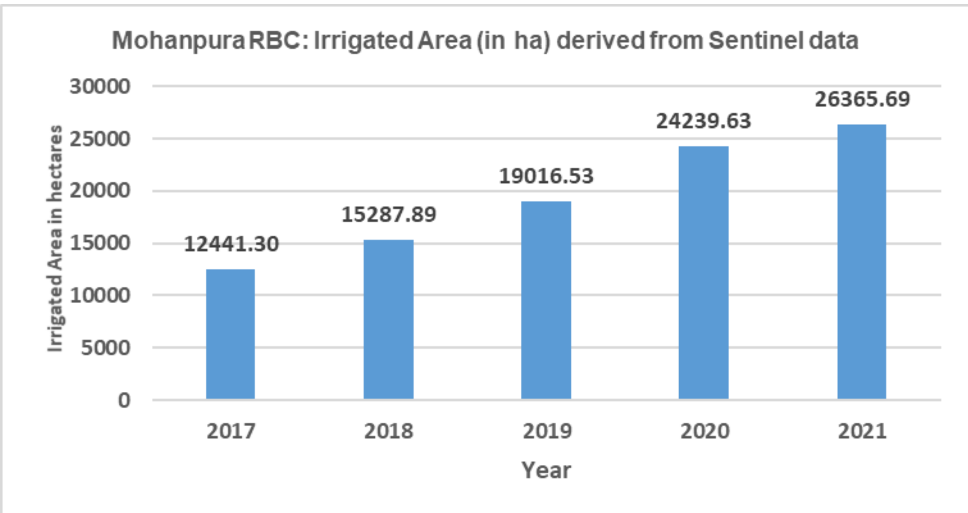


Fig-9

5.4 Energy Conservation

Centralised pumping station is provided in the sub-project to deliver the water to the irrigated area of 25,600 Ha area. Considering the large size pumps to handle large flow rates and advanced automation and control system, the overall system efficiency is higher. The power calculation for the pumping station is shown in Table-3.

Table-3

PARAMETER	UNIT	VT PUMP
VT PUMP INTAKE PUMPING STATION		
Total Head (H)	m	72
Discharge (Q)	m^3/hr	31,320.0
Pump Efficiency	%	88.0%
Motor Efficiency	%	95.5%
Power Consumption @ Motor Terminal	kW	7307.44
BOOSTER PUMPS (AREA D)		
Total Head (H)	m	16
Discharge (Q)	m^3/hr	390.50
Pump Efficiency	%	87.0%
Motor Efficiency	%	91.7%
Power Consumption	kW	21.33
BOOSTER PUMPS (KALIPEETH)		
Total Head (H)	m	26
Discharge (Q)	m^3/hr	18,190
Pump Efficiency	%	85%
Motor Efficiency	%	95%
Power Consumption	kW	1595.00
Total Power Consumption for Sub-Project	kW	8924

If farmer was supposed to arrange water on her own then she would have used the water from well or borewell. Assuming any farmer is having landholding of 1 Ha and taking water from her own borewell of 100 mtr depth, the power calculation is done using 46% efficiency of agriculture pumps as shown in Table-4. This assumption is well above the average efficiency of 27.6% (Energy Management Centre -Kerala, 2018).

Table-4

Power Calculations For 1 Ha by Individual Farmer		
PARAMETER	UNIT	VT PUMP
Static Head in Bore well	m	100
Residual Head for Sprinklers	m	20
Minor & Frictional Losses	m	10
Total Head (H)	m	130
Discharge (Q)	m^3/hr	1.22*
Pump Set Efficiency	%	46%**
Power Consumption	kW	0.73
Power Consumption for 25,600 Ha	kW	18,693

* Duty/flowrate considered same as per project

** Pump efficiencies taken as maximum efficiencies available in market but farmers predominantly use 10 to 12 years old pumps with efficiency less than 35%.

The power and energy consumption for one irrigation season of 120 days and 8 Hrs operation of pumps is shown in Table-5.

Table-5

Excess Power Consumption	kW	9,770
Number of pump operating hours in a day	Hrs	8
No. of days in Irrigation Season	Nos	120
Excess Energy Consumption in Irrigation Season	kW-hr	93,78,413

From the above calculations, it is clear that there is a saving of almost 9.38 million kW-hr energy per crop season due to centralised pumping approach.

5.5 Environmental impact and reduction in carbon footprint

Due to centralised pumping system with high efficiency, there is net reduction of 9.38 million energy (kW-hr) as shown above compared to conventional pumping system by individual farmers. This reduction in energy consumption will result it into reduced greenhouse emission equivalent to carbon foot print of 2186 metric tonnes of carbon per irrigation season (1 kW-hr = 0.23314 kg CO_2 reduction). In addition to providing required irrigation water in equitable manner to every farmer there is also substantial saving in electricity and thereby carbon footprint. There is a recurring saving in carbon footprint every season considering 30 years of project life; the total impact will be 65,580 metric tonnes. This would be equivalent to taking 14,257 passenger vehicles off-road (A typical passenger vehicle emits about 4.6 metric tons of carbon dioxide per year). Thus, the approach of having centralised pumping station alleviates the environmental impact due to agriculture activities.

5.6 Mitigation of local distress migration

Mohanpura right-bank command area was water scarce, drought-prone and lands are generally barren with little top-soil. Most of the locals had no option but to relocate to nearby Rajasthan towns of Kota, Tonk and Jaipur as labourers thereby denying a permanent home to their families and education for their children. Commissioning of the sub-project and assured availability of irrigation water in the lands of 168 villages has made the villagers to stay back and cultivate the second crop. The Sentinel data shows that about 12,000 ha got cultivated for the first time after the sub-project.

6. Conclusions

Irrigation projects in India have been marred with low water use efficiency. The demonstrated success of Mohanpura PIN with measured key parameters may initiate a new era of highly efficient and technology-driven irrigation systems. The sub-project has demonstrated the use of available technology for optimised operation to achieve higher WUE by irrigating 490 ha against the state average of 210 ha with 1 Mm^3 of water. The benchmark created could help to overcome reluctance in adopting PIN from source to farm thus initiating thoughtful replication and further refinement in new irrigation projects.

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