

Effectiveness of Group Micro Irrigation Model and Package of Agricultural Practices in Enhancing Climate Resilience in Semi-Arid Regions of Maharashtra, India

An Action Research Study

WOTR Working Paper

Authors - Arun Bhagat and Upasana Koli

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Abstract

India is the most groundwater-dependent country on earth. Despite its vast significance, groundwater resources are heading for a crisis in many regions mainly due to farmers' dependency on ground-water-based irrigation for their livelihood and to serve the economy's vast food demands. Farming being the primary occupation, especially for the small and marginal farmers, the increasing demand for water across regions invites unequal access to its use, putting stress on the already depleting water resources. Also, it has been expected that climate change will pose a significant threat to groundwater resources in the future caused by fewer and sporadic precipitation events, due to which dependence on groundwater-based irrigation is presumed to increase even more. Therefore, to control the situation, WOTR's new approach to Group Micro Irrigation (GMI) focuses on enhancing agriculture productivity targeted at a group of smallholder farmers with particular attention to efficient water use. The GMI approach also considers water as a common good rather than privately owned. This viewpoint helps to manage scarce water resources judiciously and equitably. The approach comprises four main components: groundwater management on the supply and demand side, promotion of CRA practices, facilitation of market linkages, and integration of applied research in the form of small methods or tools to support farmers. This paper assesses the effectiveness of three GMI models implemented in Maharashtra, viz, Tigalkheda, Ranmala, and Bhangadewadi. The assessment revealed that the GMI approach had a significant impact in addressing issues related to the sustainable use and equitable sharing of water resources, and the barriers to adopting both micro-irrigation and climate-resilient farming practices. Also, it enabled an attitude of cooperation rather than competition, helped strengthen inter-personal relationships through constant and effective coordination and lowered individual investment.

Additionally, it provided equal access to water, easy access to subsidies and water-efficient technologies like micro-irrigation systems for those who otherwise could not afford it within the group. It perpetuated risk-taking abilities to indulge in experimenting with varied and advanced agricultural techniques and technology and provided sufficient bargaining power for their outputs. At the field level, a rise in cropping intensity with diversified crops of high economic value and increased yield and water productivity resulted from this approach's effectiveness.

Keywords:

Group Micro Irrigation (GMI), Climate Resilient Agriculture (CRA), Cost Benefit Analysis, Crop and Water Productivity

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Abbreviation

Avg.	:	Average
CRA	:	Climate Resilient Agriculture
GIZ	:	Deutsche Gesellschaft für Internationale Zusammenarbeit
GMI	:	Group Micro Irrigation
GoI	:	Government of India
GoM	:	Government of Maharashtra
FPO	:	Farmer Producer Organisations
FYM	:	Farm Yard Manure
mha	:	Million hectares
ha-mm	:	Hectare millimetre
kgs.	:	Kilo grams
mgbI	:	Meter below ground level
NABARD	:	National Bank for Agriculture and Rural Development
NGOs	:	Non-Governmental Organizations
ODK	:	Open Data Kit
PWP	:	Physical Water Productivity
qt	:	Quintal
RS	:	Rupees
Viz	:	Namely
WP	:	Water productivity
WUE	:	Water use efficiency
W-CReS	:	WOTR Centre for Resilience Studies
WOTR	:	Watershed Organisation Trust



1. Introduction

Groundwater is one of the primary sources of irrigation for food production in many countries of the world (Dalinet. al., 2017), and India, which significantly contributes to the food supply for countries, is the most groundwater-dependent country on earth (Mali et al., 2021; Everard, 2015; Mukherjee et al., 2015). Despite their importance, the resources are heading for a crisis in many regions, mainly due to their enormous exploitation to increase production to feed the growing population (Dhawan, 2017). Climate change, it is anticipated, will pose an additional significant threat to groundwater resources in the future (Shahid et al., 2017; Salem et al., 2018). Studies conducted in different parts of the world show that increased temperature and changing rainfall patterns due to climate change would negatively affect groundwater recharge and accessibility (Meixner et al., 2016). India's water scarcity issue is only escalating with time, induced by increasing food demand due to rising population, natural and human-induced imbalance in the distribution of resources, etc.; therefore, making efficient use of water very crucial (Kumar et al., 2020). Climate change has affected agricultural practices to the extent that farmers have increased the use of synthetic fertilizers and agrochemicals to protect themselves from the damages caused by the change. It has endangered farmers' livelihood, resulting in a high rate of land degradation and increased cost of cultivation, making agriculture costly and unfeasible to continue (Singh et al., 2019; Lal, 2020).

In India, Agriculture is a sector characterized as being dominated by small and marginal land owners (Dev, 2012). Over the years, the division of agricultural land among extended families has led to many fragmentations. As a result, 85 percent of farmers now own less than 2 ha. of land, and within this, 60 percent own less than one hectare (Ministry of Agriculture and Farmers Welfare, 2015). Alongside, the aggregate cost of production has been witnessing a steady rise. The constant demand for chemical fertilizers and pesticides is gradually raising the market prices. The negative and inelastic demand for these agricultural inputs has sharply impacted the overall production costs. Also, as retail inflation increases, the human labour costs get affected, which requires a considerable agricultural investment. This increasing cost of production and the relatively lower growth in crop output is substantially affecting the farmer's budget and lowering the income rate (Srivastava, Chand, & Singh, 2017). Given these reasons, individual farming has become unviable.

In India, Maharashtra is the third largest state that faces severe water scarcity, both spatially and temporally (Joseph et al., 2020). Almost 80% of the rural population and nearly 30% of the urban population depend on groundwater for drinking and domestic use. In the agricultural sector, of the total irrigated area, 60 percent of the water is supplied through groundwater (WRD-GoM, 2019; Khanna & Gupta, 2018). And according to the Water Resource Department of the Government of Maharashtra in its 2019 report Water Conservation and Saving in Agriculture (Initiatives, Achievements, and Challenges), the annual per capita water available in the state stands at 300 m³, which is much lower than the international convention of 1000m³. Therefore, looking at the challenging water scenario, the government has

been stressing about increasing the efficient use of water, especially in the agricultural sector. In response to the challenge, adopting water-efficient strategies such as micro-irrigation and pipe distribution in command areas is being promoted at a large scale. Apart from these, the government is also providing financial assistance to invest in those technologies and equipment that would reduce flood irrigation but still secure optimal agriculture production (WRD-GoM, 2019; Bwambale et al., 2022; Kumar, 2016). However, despite the numerous schemes, technological inputs, and new methods of productivity enhancement, it has scarcely addressed the water problem in its entirety. While water problems persist, increasing production costs and a steady decline in crop yields are pushing farmers to unsustainable practices or abandoning agriculture altogether, especially the smallholder farmers (Ceballos et al., 2020; Raju et al., 2016; Bhan & Behera, 2014; Shiferaw et al., 2009). There is deprivation in the necessities of agriculture, such as lack of water resources, technical knowledge, institutional linkages, etc. (Cosgrove & Loucks, 2015; Levidow, 2014). Access to government schemes is low among smallholder producers, even where subsidies are as high as 90%, as is in the case of micro-irrigation (Bizikova et al., 2020; Mahendra, 2014). A study on micro-irrigation (MI) adoption across states in India found that only about 10 percent of the overall MI potential in the country is achieved (Jain et al., 2019; Palanisami et al., 2011). The adoption rate is low for several reasons, including high initial investment costs, lengthy application procedures, and operational and maintenance-related problems farmers face (Chand, Kishore, Kumar, & Srivastava, 2020). However, keeping aside the farmers with water resources, the major challenge remains in providing micro-irrigation facilities to those who do not have access to water resources, i.e., the rainfed farm owners. Farmers who adopt micro-irrigation as a technology to expand agriculture have flourished (Kapoor, 2022; Sivanappan et al., 2016); however, many continue doing rainfed farming; sometimes limited to the Kharif/monsoon season only. Though many rainfed farmers have adopted modern agricultural techniques to increase productivity, their financial status has remained stagnant because of limited water availability (Kumar, 2022). Considering these reasons, we have been witnessing an increasing gap between farmers with established water resources and technology and farmers dependent on rainfall.

To address these issues and challenges, Watershed Organisation Trust (WOTR) undertook an action research project - the Group Micro Irrigation (GMI) approach, devised to enhance agriculture productivity for a group of smallholder farmers with special attention on efficient water use. Water is considered a common good rather than privately owned in this approach. This viewpoint is to help manage scarce water resources judiciously and equitably. The GMI approach comprises four main components: groundwater management on the supply and demand side, promotion of CRA practices, facilitation of market linkages, and integration of applied research in the form of small methods or tools to support farmers. Under this project, GMI models, i.e., a group of farmers who would be the beneficiaries of the approach, were formed in the semi-arid regions of Maharashtra and Telangana. In this report, we have studied the effectiveness of three GMI models based in Maharashtra, viz, Tigalkheda, Ranmala, and Bhangadewadi.

2. Objectives

The primary objectives of the study are:

- To assess the impact of GMI on the participants' farmlands by evaluating the crop area, irrigated area, cropping intensity, and crop and water productivity of the farmers in the pre- and post-project years
- To assess the economic viability of the model's approaches

3. Methodology

This section provides information about the GMI approach, study area, GMI models, data collection, and methods followed to assess the effectiveness of GMI.

3.1 Working of Group Micro Irrigation (GMI) Model

The GMI approach comprises four main components: groundwater management on the supply and demand side, promotion of CRA practices, facilitation of market linkages, and integration of applied research by providing small methods or tools to support farmers. In the first component of GMI, measures such as harvesting rainwater and construction of soil and water conservation structures to recharge groundwater are taken to support the supply side. And to support the demand side, accumulating private groundwater resources and distributing water through a common-drip-irrigation system are the measures taken. The second component of promoting Climate Resilient Agriculture (CRA) as a package of practices is a measure undertaken to boost soil health and plant resilience to ensure a harvest in the face of weather and environmental challenges. These practices include undertaking seed treatment, following crop geometry, intercropping & trap cropping, applying Farmyard Manure (FYM), vermicompost, and compost, and making use of organic inputs like Amrutpani, Jeevamrut, Vermiwash, Bio-pest management practices like the use of pheromone traps, light traps, and bio-pesticides like Dashparni ark, and Neemark. The third component involves encouraging market linkage through Farmer Producer Organisations (FPO), giving access to better prices. And the fourth component is about integrating applied research to develop tools and methods to support farmers in evaluating their agricultural performance so that they can make informed agricultural decisions about the following seasons based on the assessed performance. The assessment also provides research-based evidence on the impact of various measures undertaken. The applied research tools and methods include maintaining field books by farmers, crop water budgeting, and assessing groundwater availability by testing pump discharge.

3.2 Study Area

The project was implemented in the Tigalkheda village of Bhokardan block in Jalna district, Bhangadewadi village, and Ranmala hamlet of the same village in Parner block of Ahmednagar district in Maharashtra. These study areas come under the

semi-arid region that faces acute water scarcity every other year. The location map of the study areas is shown in figure 1.

Jalna district is located in the central part of Maharashtra state and is 400-450 km away from its coastline to the west. It belongs to the Marathwada region and is known for its frequent drought events (9 droughts occurred since 2000). The physiography of the district is of four types, i.e., Ajantha Hill range, Undulating plateau, Denudational slope, and older flood plain. The topography of the Bhokardan block, where our study village of Tigalkheda is located, lies on a dissected, undissected, and weathered plateau. The first section of the aquifer also called an unconfined aquifer, is of weathered/ fractured basalt form at a depth of 5m to 30m, while the second aquifer of jointed/fractured basalt form goes 35m to 145m deep (CGWB, 2016). A small portion to the north and west of the block is covered by Ajanta and Satmala hill ranges and plateau region, and the rest of the area is covered by denudational slope in the central & south and older floodplain to the southeast. Raighol, Jui, Khelna, Girja, and Banganga and Purna are the main rivers flowing through Bhokardan, which is a part of the Godavari River Basin. Rainfall in the region ranges from 400-600mm. The prominent soils found here are Clayey and Loam soils. The principal crops grown are cotton, cereals, pulses, and citrus fruits. The GMI-I (Group 1) model has an area of 32.05 acres of land belonging to 14 farmers in the village of Tigalkheda in Bhokardan Block of Jalna district. The land area of each farmer ranges from 0.45 to 6 acres.

Ahmednagar is the largest district by area coverage in Maharashtra, spanning 17196 sq. km, i.e., 5.54% of the total state area. It is to a distance of around 200 - 250 km from the coastline to the west. The physiography of the district has four major landforms consisting of hill and ghat sections (7.6% area), foothill area (19.4% area), plateau (3.71% area), and plains claiming the majority of the land area at 69.30%. Parner block is one of the 14 blocks in Ahmednagar district in which our 2 study villages, namely; Bhangadewadi and Ranmala hamlet of Bhangadewadi, are located. The Parner block is situated in the central plateau region of the district, with hillocks at certain places. The unconfined aquifer is present in the range of 20-40 mbgl (meter below ground level) and beyond starts the confined aquifer (GoM, 2020). Godavari and Bhima are the main rivers flowing through the district. Bhima river originates from the Pune district to the west and forms the Sina, Kukadi, and Ghod distributaries which flow through Parner and other neighboring blocks of Shrigonda and Karjat located to the southeast of the district. The nearest water bodies to the study villages are the Kalu River and Bhalwani lake. Parner receives 500-700 mm of rainfall annually and falls in the rainfall scarcity zone, being located in the rain shadow region with the Western Ghats to its west. The region faces drought every three years. The soil in the central plateau of the district, where Parner lies, has an admixture of lime suitable for producing numerous Rabi crops. Major crops taken in the region are pearl millet, pulses, groundnut, cotton, Onion, and pomegranate. The GMI-II (Group 2) model is in Ranmala hamlet, located 6 km from Bhangadewadi village. In this model, water is extracted from a dug well owned by one of the six farmers and supplied to all holding 1 acre each. The GMI-III (Group 3) model is located in the village of Bhangadewadi in Dhawalpuri Grampanchayat in Parner Taluka. This group comprises 47 farmers, with a combined 65.5 acres of the land

area allocated for the model. They use surface water lifted from a check dam (weir) constructed downstream of the Kalu dam. Water is transferred into a farm pond through a pipeline connected to the check dam, which is 7-9 km long. The water is distributed to farmers through an automation system installed at the farm pond site.

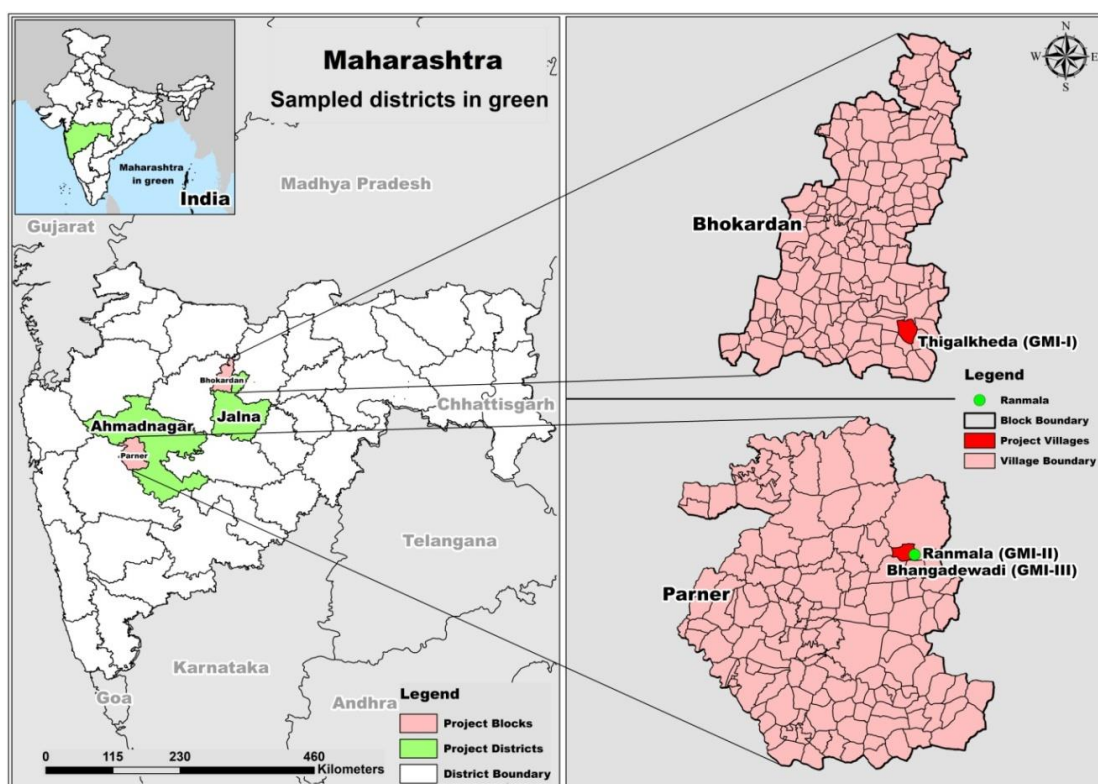


Figure 1 Location map of the study area

3.3 GMI Models

For this report, the three GMI models located in the villages mentioned above were studied, and their details are given in Table 1.

The GMI-I model, located in Tigalkheda village of Bhokardan block in Jalna district, was established in April-May 2018 and has been operating since 2018-19. The model area has three dug wells that tap into the same aquifer. This model uses a single source (dug-well), thereby restricting groundwater extraction from dug-wells owned by others in the same aquifer. This group comprises 14 farmers who belong to the same extended family.

Table 1 Details of GMI models (GMI-I, II, & III)

GMI Model	Location	No of Farmers	Year of establishment	Area (Acre)	Water Source
GMI-I	Tigalkheda, Bhokardan	14 Farmers	April-May, 2017	32.45	Dug well
GMI-II	Ranmala, Parner	06 Farmers	May, 2020	06	Dug well

GMI Model	Location	No of Farmers	Year of establishment	Area (Acre)	Water Source
GMI-III	Bhangadewadi, Parner	47 Farmers	April-May, 2020	65.5	Farm pond (water lifted from Check dam)



Photo 1 Pumping house and automation system of GMI-I (Photo Credit- WOTR)

The GMI-II model, located in Ranmala hamlet of Bhangadewadi village of Parner block of Ahmednagar district, was established in May 2020 and has been fully workable since 2020-21. The group shares water from one dug-well owned by one of the group members. Their fields are adjacent to each other. Unlike Tigalkheda, the farmers do not have familial relationships with each other but are known to each other for long as they belong to the same village. The well was renovated, and the automation and fertigation system of water distribution was established after due approval was taken from the dug-well owner to share his water source with the other 5 farmers. This GMI-II model has a total of 6 farmers owning 6 acres (01 acre each).



Photo 2 Water source and automation system of GMI-II (Photo Credit- WOTR)

The GMI-III model is located in Bhangadewadi village of Parner block of Ahmednagar district, which was established in April-May 2020 and operating since the year 2020-21. As mentioned in the study area section, this GMI-III model has 47 farmers with a land area of 65.5 acres. They use surface water lifted from a check dam, stored in the farm pond, and distributed to each farmer's field through the automation system.



Photo 3 Water source and automation system of GMI-III (Photo Credit- WOTR)

3.4 Data Collection

A detailed questionnaire in English and Marathi was prepared in Word format. The Word file was then converted into a digital format in the Open Data Kit (ODK) software. Finally, our internal team and data collectors tested the questionnaire with multiple scenarios before starting the data collection. The field surveyors were given extensive training on using the ODK application. The data collection and the training for it was conducted in two phases: baseline and post-intervention. During the data collection process, the data surveyors were closely monitored, and the necessary inputs and clarification were given to them as and when they were raised. The details of data collection are shown in Table 2.

Table 2 Details of data collected

GMI Model	Years	
	Pre-intervention (Baseline)	Post-intervention
GMI-I	2017-18	2018-19, 2019-20
GMI-II	2019-20	2020-21
GMI-III	2019-20	2020-21

3.5 Method of Assessment

A quantitative assessment was conducted to evaluate the effectiveness of the GMI models established in the semi-arid area of Maharashtra. The parameters considered for the evaluation were cropped and irrigated area, cropping intensity and pattern, and crop & water productivity. Also, a Cost and Benefit analysis was done to evaluate the impact water efficient usage has had on the agricultural outputs. To conduct this analysis, each farm's costs of agricultural inputs and market sales revenue were recorded. The details were recorded from one year before the project started until 2020. This analysis is expressed in monetary terms.

The cropped and irrigated area was calculated with data collected on the total land area allocated, the quantity of production, and irrigation details. Cropping intensity refers to cultivating more than one type of crop on the same field during one agricultural year. The agricultural input details containing information on the type of

crops grown by each farmer in their GMI area helped to calculate cropping intensity. A cropping pattern refers to the proportion of land under the cultivation of different crops at different times. Crop productivity is the quantitative measure of crop yield in a given field area, and water productivity is about crop yield per cubic meter (m³) or hectare-millimetre (ha-mm) of water consumption including adequate rainfall and water diverted from water systems.

4. Results

This section discusses the impacts of the GMI approach on the models in Tigalkheda, Ranmala, and Bhangadewadi villages through quantitative observations. The region where these villages come under is heavily dependent on monsoon water and surface & ground water for irrigation. This section shows how the usage of this water, through the adoption of micro irrigation and improved climate-resilient practices, has resulted in a positive impact. The GMI approach has increased area under crops and irrigation, effected change in cropping patterns, increased cropping intensity, and enhanced crop productivity and water productivity of the participating households. It has also positively impacted yields, lowered input costs, and increased incomes.

4.1 GMI-I

As explained in the above section, this GMI model has an area of 32.45 acres of land belonging to 14 farmers in the village of Tigalkheda in Bhokardan Block of Jalna district. The source of irrigation is a common dug well.

4.1.1 Seasonal Change in Area under Crops

In the Bhokardan area, it is observed that various food and non-food crops (commercial) are cultivated in the three main cropping seasons of Kharif, Rabi, and Summer (Zaid). Table 3 shows the seasonal changes in the cropping area before and after the project period, revealing that about 44% of the land area has increased under various crops annually. A significant change can be observed in the Rabi season, where the area under certain crops has almost doubled compared to the pre-project cropped area. But in the summer season, total GMI land has remained fallow due to the lack of water supply for irrigation for the whole season. However, farmers have assured water for the season's household usage; and enough water to grow some fodder crops for livestock. Overall, the land area under seasonal fallow land has reduced due to the development of an assured water source for irrigation through the GMI approach. Figure 2 shows a comparison of seasonal changes in pre and post-intervention cropped areas in GMI-I.

Table 3 Seasonal change of cropped area in GMI-I

GMI	Total GMI area (Acre)	Cropping Season	Pre-intervention cropped area (Acre)	Post-intervention cropped area (Acre)	Change in cropped area (%)
Tigalkheda (14 Farmers)	32.45	Kharif	29.47	32.45	10.11
		Rabi	15.7	32.45	106.69
		Summer	0	0	0
		Total	45.17	64.9	43.68

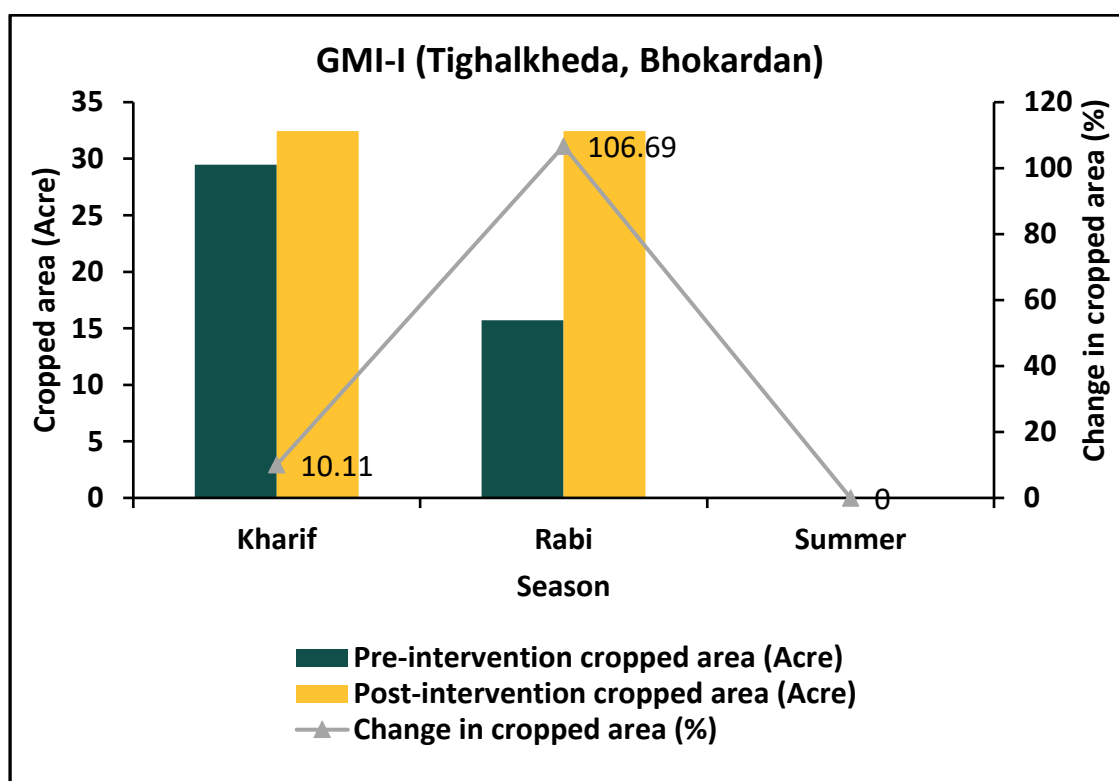


Figure 2 Comparison of seasonal change in pre and post-intervention cropped areas in GMI-I

4.1.2 Change in Cropping Intensity

It refers to cultivation of several crops on the same field during one agricultural year, which is essential for improving food production and safety at the local, regional, and national scales. Table 4 reveals that the cropping intensities in pre-intervention and post-intervention are 139.20% and 200%, respectively. There is an almost 60% rise in cropping intensity in the GMI area. Fig. 3 shows a comparison of change of pre and post-intervention cropping intensities in GMI-I.

Table 4 Change of cropping intensity in GMI-I

GMI	Total GMI area (Acre)	Pre-intervention		Post-intervention		Rise in cropping intensity (%)
		Annual cropped Area (Acre)	Cropping Intensity (%)	Annual cropped Area (Acre)	Cropping Intensity (%)	
Tigalkheda (14 Farmers)	32.45	45.17	139.20	64.9	200	60.80

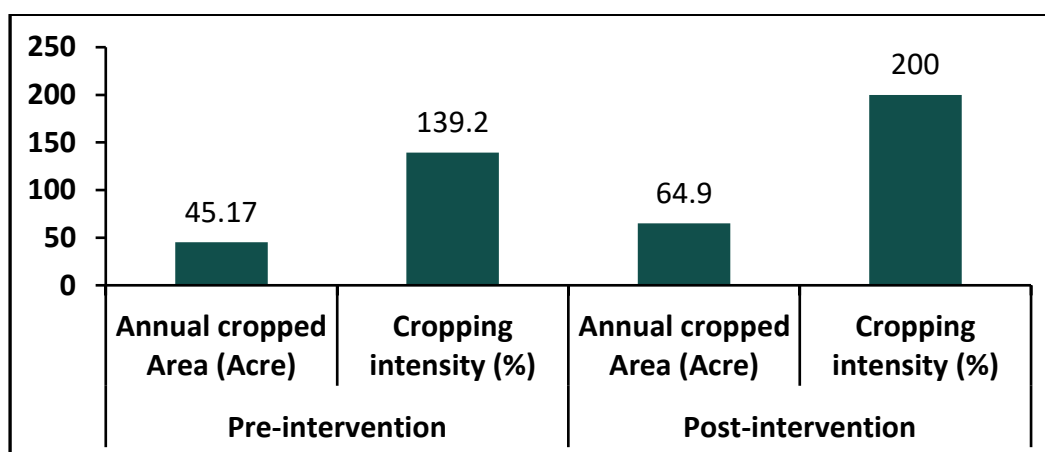


Figure 3 Comparison of change in pre and post-intervention cropping intensities in GMI-I

4.1.3 Seasonal Change in Irrigated Area

Irrigation helps to grow crops in places that have sparse or seasonal rainfall. It also helps crops that cannot sustain without irrigation. An assured water source and a well-designed irrigation system ensure the proper amount of water for the crops. Table 5 reveals that about 45.17 acres of land area was under partial irrigation in the pre-intervention period, which was converted into land with complete irrigation with the addition of 19.73 acres. A total of about 64.9 acres is under complete irrigation with equitable water distribution as per the land holding of farmers in GMI. Fig. 4 shows a comparison of the change in pre- and post-intervention irrigated areas in GMI-I.

Table 5 Seasonal change in irrigated area of GMI-I

GMI	Total GMI area (Acre)	Irrigation Status	Pre-intervention irrigated area (Acre)			Post-intervention irrigated area (Acre)			Change in irrigated area (%)		
			Kharif	Rabi	Summer	Kharif	Rabi	Summer	Kharif	Rabi	Summer
Tigalkheda (14 Farmers)	32.45	Full	0	0	0	32.45	32.45	0	100	100	0
		Partial	29.47	15.7	0	0	0	0	-100	-100	0
		Rainfed	0	0	0	0	0	0	0	0	0

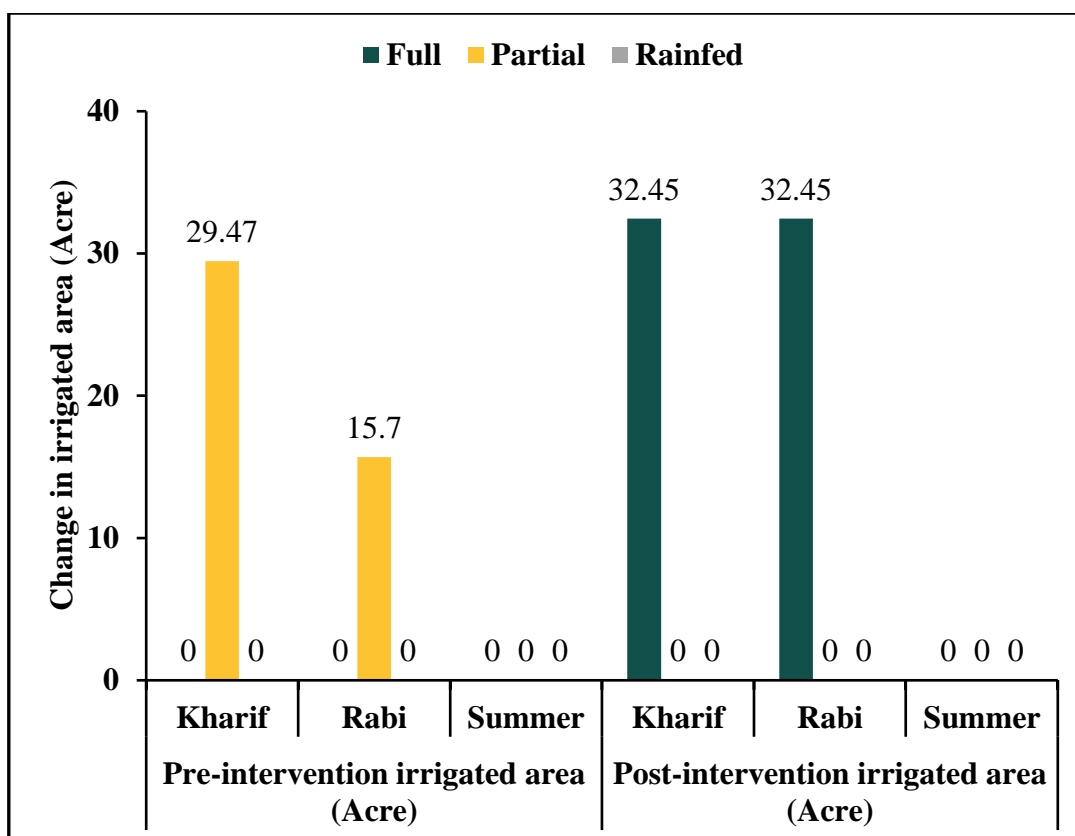


Figure 4 Comparison of change in pre and post-intervention irrigated areas in GMI-I

4.1.4 Change in Cropping Pattern

Understanding cropping pattern refers to analysing the proportion of land under cultivation of different crops at different times. Cultivating multiple crops at a given time helps maintain and improve soil health. Table 6 shows no drastic change in cropping pattern before and after the project for GMI-I model but a gradual shift from Soybean and Maize to Cotton crops in the Kharif season. Also, we can see a sizeable fallow land brought under Wheat crop in rabi season with little shift from Chickpea to Wheat. Fig. 6 shows a comparison of pre- and post-intervention cropping patterns in GMI-I.

Table 6 Change in cropping pattern of GMI-I

GMI Details		Cropping Season		
		Kharif	Rabi	Summer
Tigalkheda (14 Farmers)	Pre-intervention	1. Maize 2. Cotton 3. Soybean	1. Wheat 2. Chickpea 3. Sorghum	-
	Post-intervention	1. Maize 2. Cotton 3. Soybean	1. Wheat 2. Chickpea 3. Sorghum	-

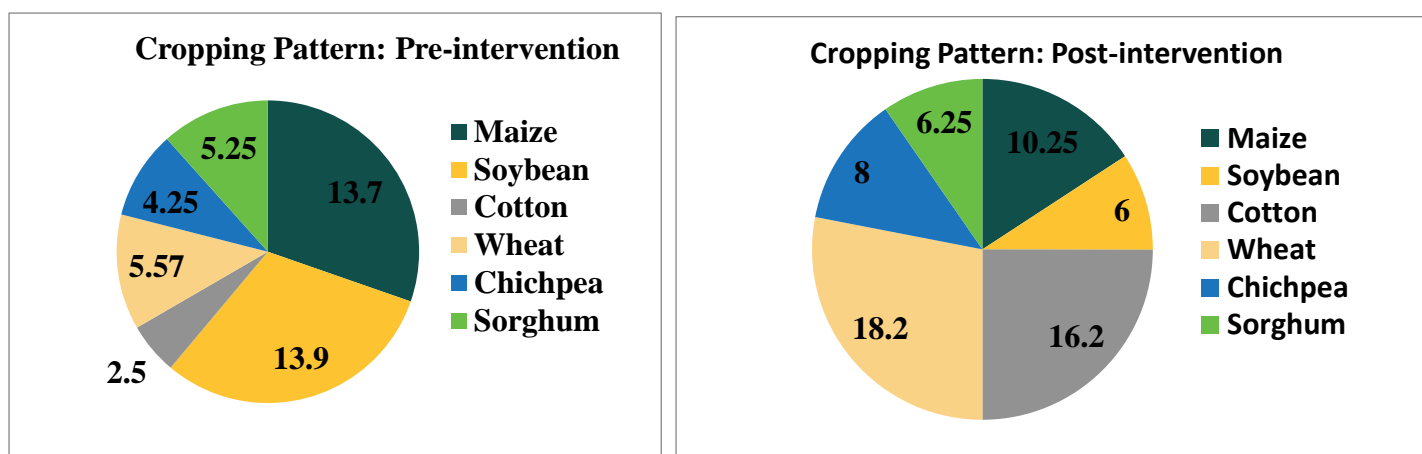


Figure 5 Comparison of pre and post-intervention cropping pattern of GMI-I

4.1.5 Production Cost and Revenue

Table 7 shows that in the pre-intervention year of 2017-2018, of the total of 14 farmers, 7 cultivated Maize, 1 cultivated Soybean, and 6 cultivated Cotton crops in the Kharif season. And in the Rabi season, 8 farmers grew wheat, 3 cultivated Chickpea, and 2 cultivated Jowar crops. In the Rabi season, two farmers did not do any crop cultivation. In the year 2018-2019, during the Kharif season, 4 farmers cultivated Maize, 6 took Cotton, and 4 took Soybean crops. And, in the Rabi season, 3 farmers took up wheat, 2 took Jowar, and 5 cultivated Chickpea. It can be seen that Maize, Soybean, Cotton, and Wheat are the primary crops taken in all the pre- and post-intervention periods. The revenue earned in 2017-2018 is more for Maize, Soybean, and Cotton in Kharif, and in the Rabi season, the revenue earned is more for Chickpea, Jowar, and Wheat. In 2018-2019, the revenue earned was more than the costs for Maize, Cotton, and Soybean for crop 1 and Cotton and Soybean for crop 2. And in the Rabi season, chickpea has earned more revenue than the costs. In 2019-2020, Cotton, Maize, and Soybean earned the farmers more revenue, thereby covering the input and transport costs. This village was less affected by the COVID Pandemic lockdowns and restrictions; however, in the absence of these restrictions, it is assumed they would have earned more than what they did owing to the market's proximity.

Table 7 Details of the cost of production and revenue from market sales in GMI-I

Pre-intervention (2017-18)									
Cost of Production					Revenue from Market Sales				
Kharif		Rabi			Kharif		Rabi		
Maize	84505	Crop1	Wheat	54875	Maize	190800	Crop1	Wheat	14400
Soyabean	19650		Chickpea	39080	Soyabean	140000		Chickpea	134000
Cotton	119933.5		Jowar	22350	Cotton	362500		Jowar	38000
		Crop2	Wheat	16500			Crop2	Wheat	24232.5
Post-intervention (2018-19)									
Cost of Production					Revenue from Market Sales				
Kharif			Rabi		Kharif			Rabi	
Crop1	Maize	96351	Wheat	33355	Crop1	Maize	181700	Wheat	30600
	Cotton	305492.5	Chickpea	79487		Cotton	435600	Chickpea	170000
	Soybean	69972	Jowar	51059		Soybean	114000	Jowar	42500

Crop2		Maize	23142			Crop2		Maize	20000		
		Cotton	69145					Cotton	125000		
		Soybean	22577.5					Soybean	36000		
Post-intervention (2019-20)											
Cost of Production						Revenue from Market Sales					
Kharif			Rabi			Kharif			Rabi		
Crop 1	Cotton	397021.9	Crop 1	Chickpea	65652.5	Crop 1	Cotton	468100	Crop 1	Chickpea	194000
	Maize	200392.5		Jowar	44779		Maize	228750		Jowar	70500
	Soybean	91607.8		Wheat	23700		Soybean	146000		Wheat	40000
Crop 2	Cotton	48337.5	Crop 2	Wheat	12145	Crop 2	Cotton	121500	Crop 2	Wheat	12000
	Soybean	18842.5					Soybean	30000			
	Maize	19200					Maize	22500			

4.1.6 Electricity Bill Costs

In the Marathwada region, owing to limited rainfall, farmers have been substantially investing in irrigation resources and infrastructure such as motor pumps, pipelines, canals, and tanks, with a view to extend agricultural operations as much as they could from surface and ground water. In Tigalkheda village, of the 14 members of the group micro-irrigation model, about 13 already had a functional irrigation system (pipeline and motor pumps) driven by electricity connectivity at project initiation. The details of electricity connections for water pumping in pre- and post-intervention of GMI-I are shown in figure 6. The project included all the 14 farmers and established an irrigation system connected with drips and pipelines to an electric motor pump automated system. In the pre-project year of 2017-2018, the total electricity bill cost incurred by the 13 farmers with a functional irrigation system in the Kharif season stood at Rs. 16,600. It drastically increased to Rs. 26,400 in the Rabi season, then simmering down to Rs. 10,400 in the summer. The irrigation system established under GMI-I supplied water to the entire agricultural area under the model. The average bill amount per person was Rs. 1,276.93 in Kharif, Rs. 2,030.7 in Rabi, and Rs. 800 in Summer. Since project commencement in 2018-2019, the electricity bill charged per person was Rs. 150 for all 14 farmers. The details of electricity charges for water pumping in pre- and post-intervention of GMI-I are shown in figure 7. As all the land area has been getting a calculated supply of water (reduction in the uncontrolled water supply), the electricity bill amount for Kharif, rabi, and summer season stood at a steady Rs. 2,000 per season, even in the seasons of the following year, 2019-2020.

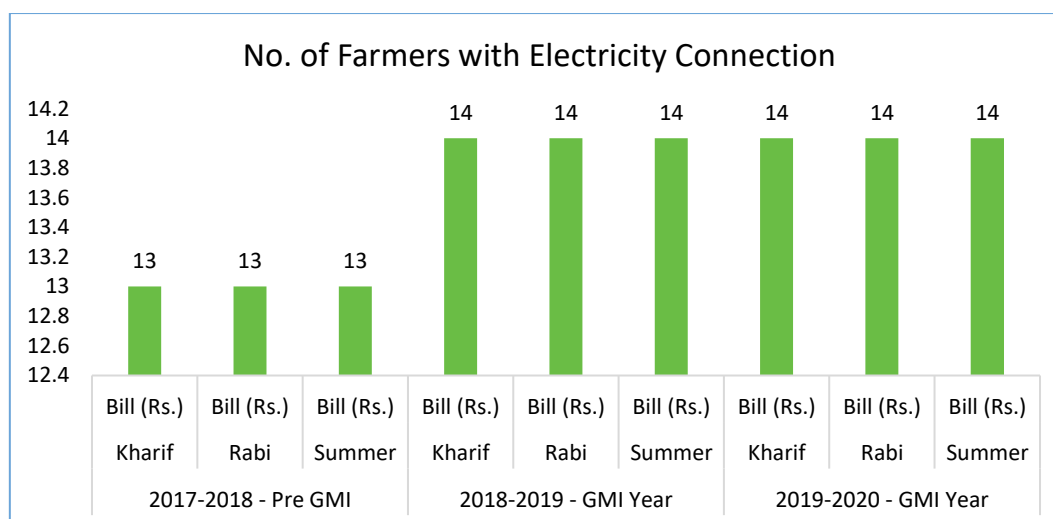


Figure 6 Comparison of pre- and post-intervention electricity connections for water pumping in GMI-I

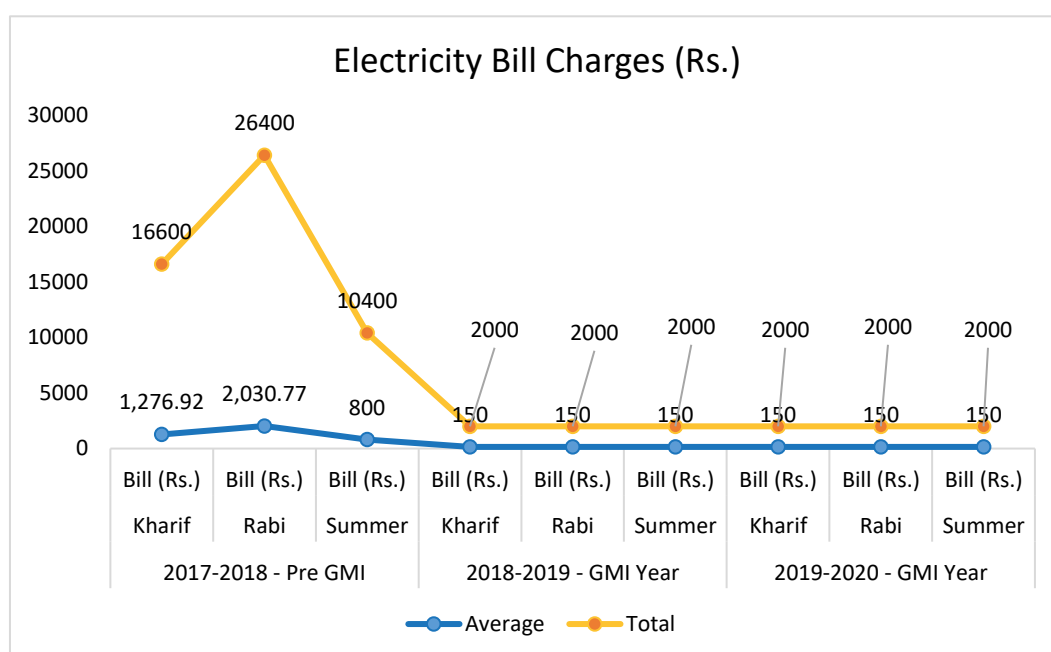


Figure 7 Comparison of pre- and post-intervention electricity charges for water pumping in GMI-I

4.1.7 Water Resources for Irrigation

Tigalkheda village has streams and rivers located far away; hence, groundwater is the only water resource for irrigation. Table 8 shows that 12 farmers of the group of 14 had tube-wells and dug-wells through which water was being supplied to their farms before the project year. The other two had no water resources but shared water from neighbouring farms' water resources. The establishment of the wells owned dates back to 1930 with the latest being constructed in 2011. The maximum investment in constructing a well was about Rs. 1,75,000 and the minimum, Rs. 1,000. The minimum cost was recorded in 1930 when the valuation was high. The farmers had also installed motor pumps for supplying water to farms. The installation of these pumps was done between the years 1980 and 2015 for which they incurred a cost of about Rs. 86,500. To increase water availability, 2 farmers,

post-construction, further deepened their wells. For one farmer, it cost less, about Rs. 4,000, while the other paid Rs. 50,000 as deepening charges owing to the complexity, depth level, etc.

Table 8 Details of available irrigation resources in pre-intervention at GMI-I

Irrigation Resources at pre-intervention			Tube Wells/Dug Wells			
			Maximum	Minimum	Average	Total
2017-2018-Pre GMI	Initial Cost	Number of Wells	1	1	1	12
		Year of Construction	2011	1930	1965	-
		Cost (Rs.)	175000	1000	34083.33	409000
	Further Deepening	First deepening cost	1	1	1	2
		Cost (Rs.)	50000	4000	27000	54000
	Motor Pump	Year of Purchase	2015	1980	2000	-
		Cost (Rs.)	15000	2500	7208.33	86500

4.1.8 Drip and Sprinklers Ownership

An environment of recurrent application of traditional practices in agriculture and irrigation existed, caused by uncertainty in water availability and hence low economic returns. Consequently, only a minuscule population had the financial ability to invest in advanced and expensive technology, partially or entirely. Table 9 reveals that, in the 14 farmers' GMI group, only one farmer had drips and sprinklers installed and operationalised in the GMI land area before the model started. The drip system has been functional since 2003, costing the owner Rs. 10,000, and the water is being sourced from an owned tube well. From 2018-2019, all the farmers have been using drips and sprinklers installed under the Group Micro Irrigation project.

Table 9 Details of drips and sprinklers in pre- and post-intervention at GMI-I

Drips and Sprinklers	2017-2018- Pre GMI	2018-2019- GMI Yr.	2019-2020- GMI Yr.
Number	1	14	-
Total Cost (Rs.)	10000	554000	-
Year Of Installation	2003	2018	-
Sources of Irrigation	Tube-Well/Dug-well	GMI-Dug-Well	-

4.1.9 Vermicompost Beds Ownership

Vermicompost beds make compost available readily at the household level and at a low cost. It supports the farmer by reducing the financial burden of investing in chemical inputs and helping him move towards organic farming which is low cost as well as beneficial for the soil. Table 10 reveals that, within this group, only 2 farmers had purchased vermicompost beds for their farming. Large enough to carry 500 kgs of compost, each vermicompost bed costed around Rs. 1,400 and were bought in 2016 and 2017.

Table 10 Details of Vermicompost beds in pre- and post-intervention of GMI-I

Vermicompost Beds	2017-2018- Pre GMI	2018-2019- GMI Yr.	2019-2020- GMI Yr.
Vermi-Compost Bed 1	-	2	-
Year of Purchase (Avg.)	-	2017	-
Size per bed (Kg. of compost it can store)	-	500	-
Cost (Total)	-	1400	-
Avg. Life of Bed (In years)	-	-	-
Vermi-Compost Bed 2	-	-	-
Year of Purchase	-	-	-
Size per bed (Kg. of compost it can store)	-	-	-
Cost (Total)	-	-	-
Avg. Life of Bed (In years)	-	-	-

4.1.10 Tankers

No farmers ordered tankers in all the seasons in the years 2017-2018, 2018-2019, and 2019-2020 for agriculture in the group micro-irrigation land area.

4.1.11 Agricultural Assets Owned

No farmers in the group have ownership of agricultural technologies such as tractors, sowing machinery, weeding machinery, harvesting machinery, threshing machinery, etc. They have been hiring these technologies each season as and when required.

4.1.12 Finance and Loans

Agricultural operations need investments to purchase inputs such as seeds, fertilisers and pesticides, hire technology services and finally for transportation of products to markets. Table 11 reveals that 13 members from the 14-member GMI group in Tigalkheda in 2017-2018 had applied for financial loans to invest in agriculture in the Kharif season, and five farmers took loans for the Rabi season. However, in the following years of 2018-2019 and 2019-2020, all 14 farmers applied for loans. It can be seen that the loans were majorly taken in the Kharif season. No loans were availed in the summer since no agricultural activities were taken up in those years. The details of loans taken by farmers in pre- and post-intervention of GMI-I are shown in figure 8. The range of loan amounts has been increasing since the last year. In the year 2019-2020, the aggregate loan availed by the farmers stood at Rs.8,04,000 compared to the loan amount in the year 2017-2018, which was Rs.3,69,500. The details of the principal loan amount taken by farmers in pre- and post-intervention of GMI-I are shown in Figure 9. All the loans were applied through banks which charged an average interest rate between 8.31 to 10.4% in all the years. The details of interest rates on loans taken by farmers in pre- and post-intervention of GMI-I are shown in figure 10. They were taken for a shorter duration of 12 months. The details of the duration of loans taken by farmers in pre- and post-intervention of GMI-I are shown in figure 11.

Table 11 Details of finance and loans in pre- and post-intervention of GMI-I

Finance & Loans			Kharif				Rabi			
			Bank				Bank			
Variables			Max.	Min.	Avg.	Total	Max.	Min.	Avg.	Total
Baseline	2017-2018	No. of Farmers who took loan	-	-	-	13	-	-	-	5
		Principle Amt (Rs.)	100000	4000	28423	369500	22500	4000	12500	62500
		Interest rates (%)	11	4	8.31	-	11	8	10.4	-
		Duration of Loan (Months)	12	12	12	-	12	12	12	-
Group Micro Irrigation years	2018-2019	No. of Farmers who took loan	-	-	-	14	-	-	-	-
		Principle Amt (Rs.)	100000	10000	50642	709000	-	-	-	-
		Interest rates (%)	14	6	8.46	-	-	-	-	-
		Duration of Loan (Months)	12	12	12	-	-	-	-	-
	2019-2020	No. of Farmers who took loan	-	-	-	14	-	-	-	-
		Principle Amt (Rs.)	100000	16000	57428	804000	-	-	-	-
		Interest rates (%)	14	6	8.89	-	-	-	-	-
		Duration of Loan (Months)	12	12	12	-	-	-	-	-

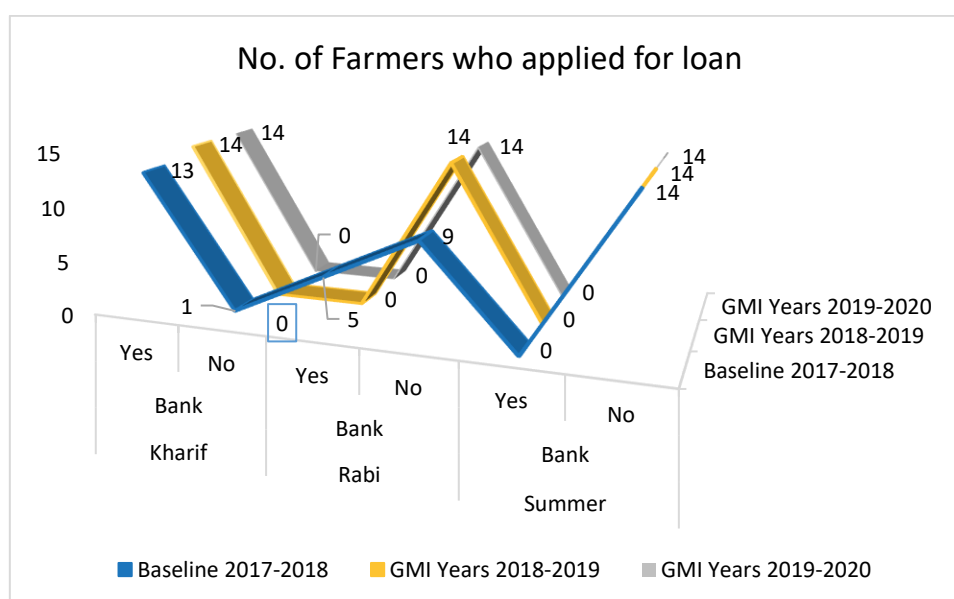


Figure 8 Comparison of pre- and post-intervention loan taken by farmers of GMI-I

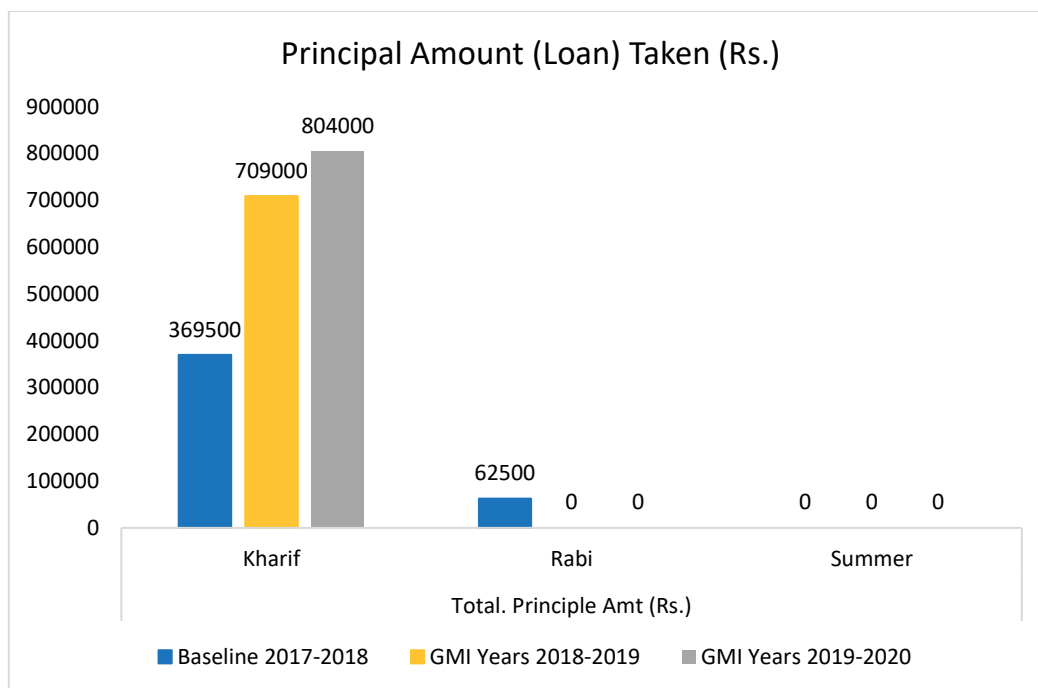


Figure 9 Comparison of pre and post-intervention principal loan amount taken by farmers of GMI-I

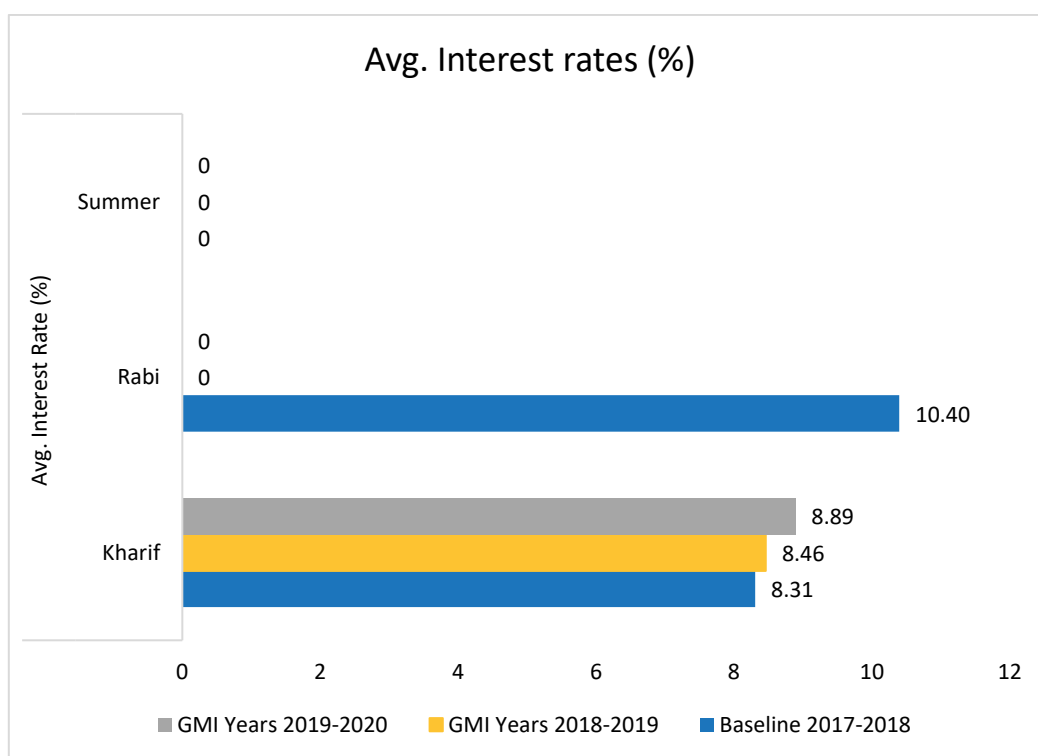


Figure 10 Comparison of pre- and post-intervention interest rate on loan taken by farmers of GMI-I

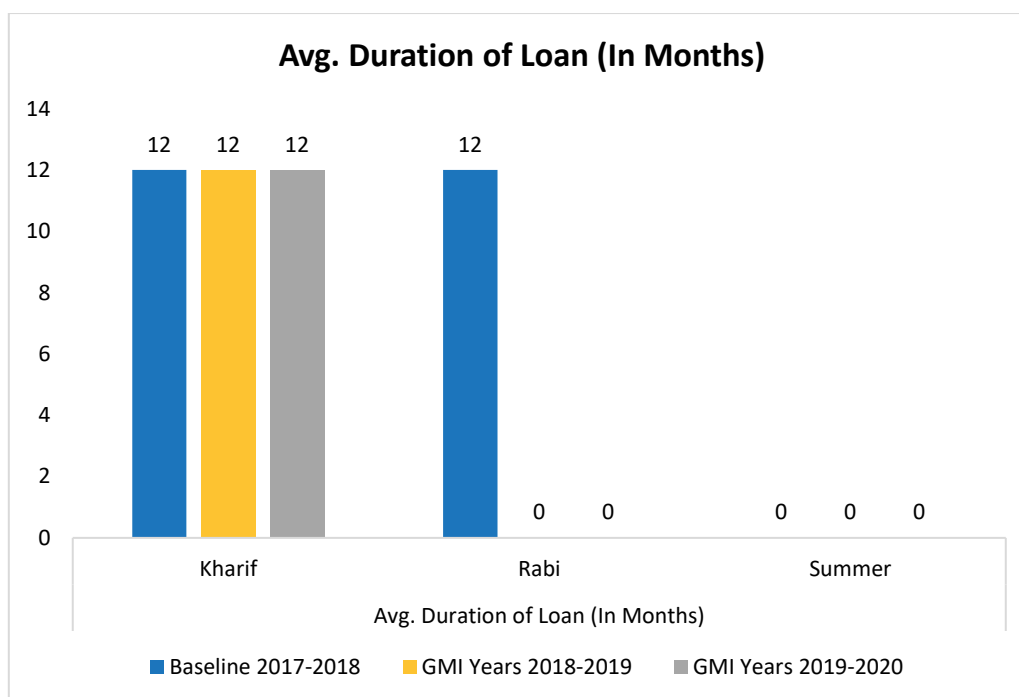


Figure 11 Details of pre- and post-intervention duration of loan taken by farmers of GMI-I

4.1.13 Change in Crop Productivity

Crop productivity is the quantitative measure of crop yield in a given measured area of the field. The four most important factors influencing crop yield are soil fertility, water availability, climate, and diseases or pests. The observed crop yield data in pre- and post-intervention were collected on a recalled basis, and after that, the change in crop productivity was calculated. Table 12 reveals that for almost all the crops except cotton, the average rise in crop productivity is about 50%, and for the Cotton crop, the increase is by 18%. The hike observed in crop productivity is distinctly noticeable. However, there is still scope for further increase in productivity by following improved climate-resilient practices, weather advisories, and operating irrigation schedules properly. The comparison of the change in pre- and post-intervention crop productivity in GMI-I is shown in figure 12.

Table 12 Change in crop productivity of GMI-I

GMI Details	Crop Details	Crop Productivity (Quintal/Acre)		Rise in crop productivity (%)
		Pre-intervention	Post-intervention	
Tigalkheda (14 Farmers)	Sorghum	2.96	4.68	158.11
	Cotton	8.38	9.91	118.26
	Soybean	6	9.1	151.67
	Wheat	6.87	10.5	152.84
	Chickpea	5.31	7.76	146.14
	Maize	14.09	22.15	157.20
	Pigeon pea	4	-	-

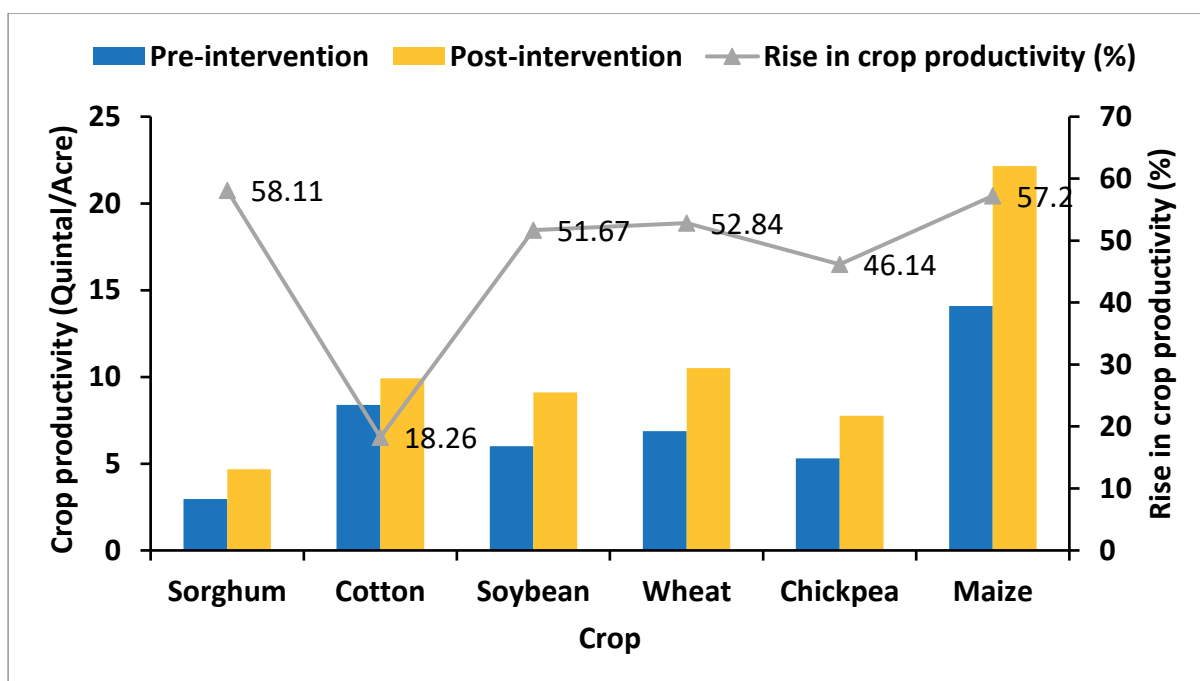


Figure 12 Comparison of change in pre and post-intervention crop productivity in GMI-I

4.1.14 Change in Water Productivity (Water Use Efficiency)

As explained in the methodology, there is no difference between water productivity and water use efficiency. Water productivity is about crop yield per cubic meter (m³) or hectare-millimetre (ha-mm) of water consumption including adequate rainfall and water diverted from water systems. This water productivity is also called physical water productivity (PWP). Similar to crop productivity, Table 13 reveals that for almost all the crops except cotton, the average rise in water productivity is about 50% and for cotton it is 18%. The hike in water productivity is due to the strict adoption of a micro-irrigation system in the GMI approach. However, there is vast scope to increase water productivity by applying the exact amount of water as per the schedule and by adopting advanced techniques like deficit irrigation to save extra water. It would also reduce nutrient loss and leaching of the root zones, resulting in better groundwater quality and fewer fertiliser requirements over full irrigation. The comparison of the change in pre and post-intervention water productivity of crops in GMI-I is shown in figure 13.

Table 13 Change in water productivity of GMI-I

GMI Details	Crop Details	Water Productivity (kg/ha-mm)		Rise in water productivity (%)
		Pre-intervention	Post-intervention	
Tigalkheda (14 Farmers)	Sorghum	1.85	2.95	59.46
	Cotton	2.67	3.16	18.35
	Soybean	3.07	4.66	51.79
	Wheat	3.12	4.77	52.88
	Chickpea	4.43	6.47	46.05
	Maize	5.87	9.23	57.24

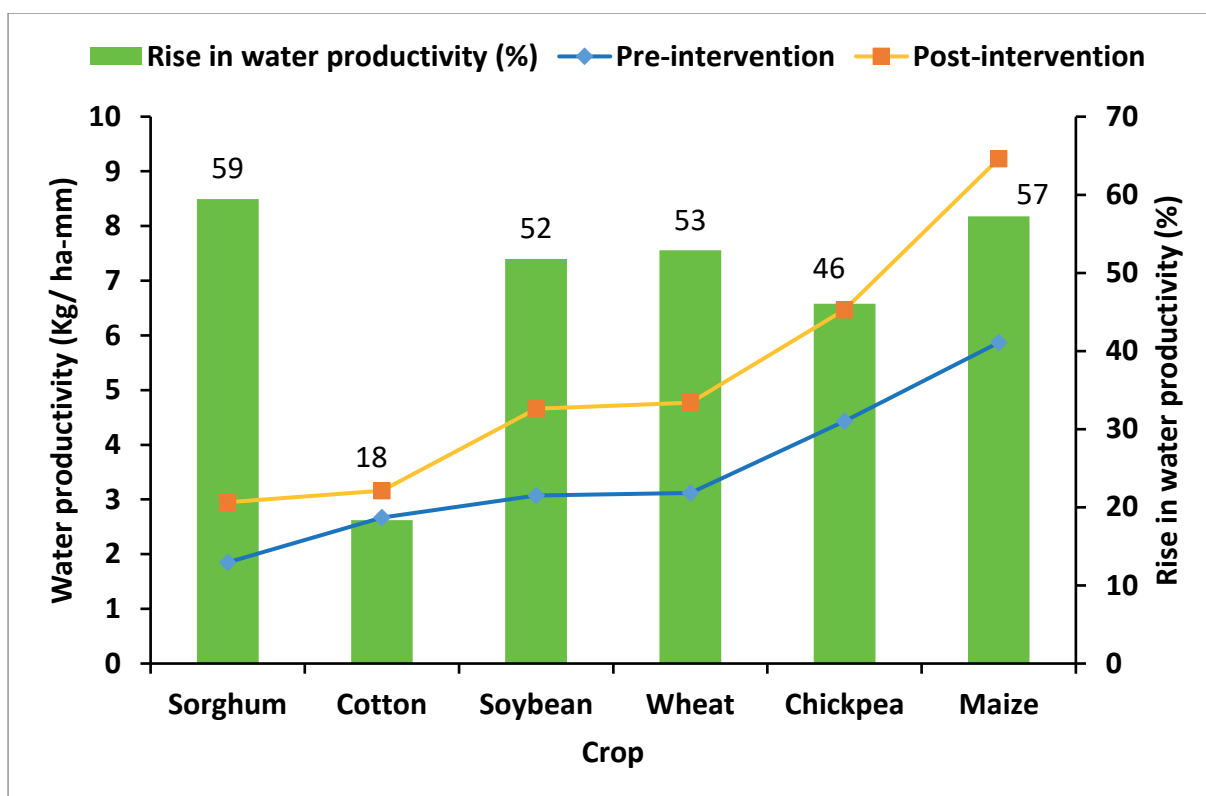


Figure 13 Comparison of change in pre and post-intervention water productivity in GMI-I

4.2 GMI-II

As explained in the methodology, this GMI model has an area of 06 acres of land belonging to 06 farmers in the hamlet of Ranmala of Bhangadewadi village in Parner Block of Ahmednagar district. The source of irrigation is a dug well owned by one of the farmers (pre-intervention) of the GMI group.

4.2.1 Seasonal Change in Area under Crops

Table 14 shows the seasonal changes in the cropping area before and after the project implementation for the GMI-II model. It reveals that the area under various crops increased by 20% in the Rabi season and by 100% in the summer season, in the following year. However, a noticeable change was observed in the area under crops in the summer. In pre-intervention, there was no area under crops (seasonal fallow land) in the summer season, but after the adoption of the GMI approach, the area under summer crops has increased to 100%. Overall, the private area under seasonal fallow land was reduced due to the development and equal sharing of an assured water source for irrigation among the GMI farmers. Figure 14 compares the seasonal change in pre- and post-intervention cropped areas in GMI-II.

Table 14 Seasonal change of cropped area in GMI-II

GMI	Total GMI area (Acre)	Cropping Season	Pre-intervention cropped area (Acre)	Post-intervention cropped area (Acre)	Change in cropped area (%)
Ranmala (06 Farmers)	06	Kharif	06	06	0
		Rabi	05	06	20
		Summer	0	06	100
		Total	11	18	61.11

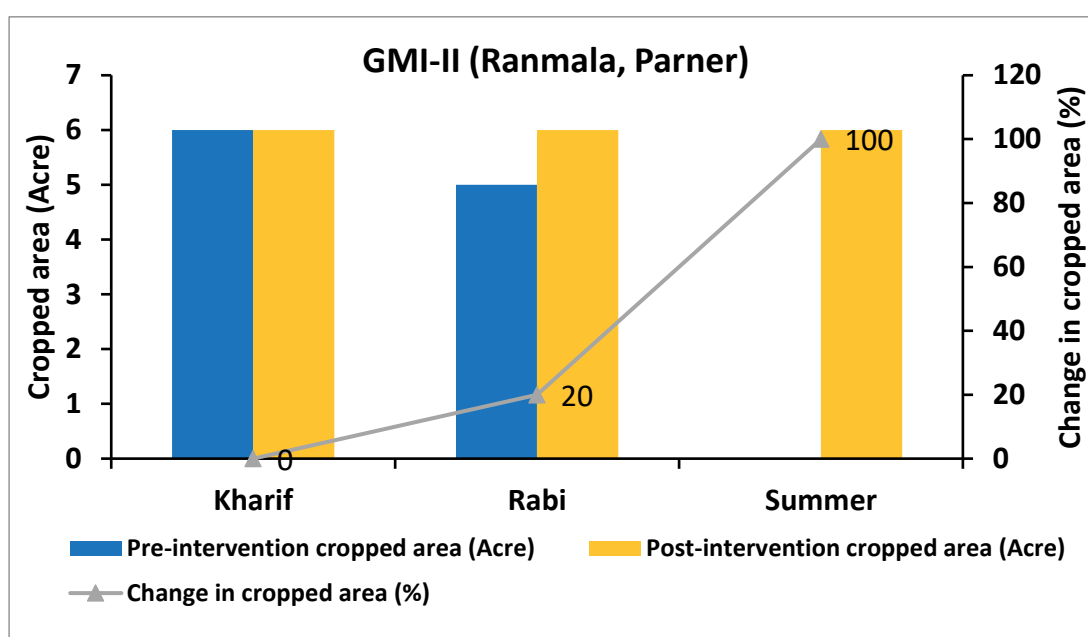


Figure 14 Comparison of seasonal change in pre and post-intervention cropped areas in GMI-II

4.2.2 Change in Cropping Intensity

Table 15 reveals that the cropping intensities in pre-intervention and post-intervention are 183.33% and 300%, respectively. There is an almost 116.67% rise in cropping intensity in the GMI-II model. Fig. 15 compares the change in pre- and post-intervention cropping intensities in GMI-II. High cropping intensity is desirable not only for fuller utilization of land resources but also for reducing unemployment in the rural economy.

Table 15 Change of cropping intensity in GMI-II

GMI	Total GMI area (Acre)	Pre-intervention		Post-intervention		Rise in cropping intensity (%)
		Annual cropped Area (Acre)	Cropping intensity (%)	Annual cropped Area (Acre)	Cropping intensity (%)	
Ranmala (06 Farmers)	06	11	183.33	18	300	116.67

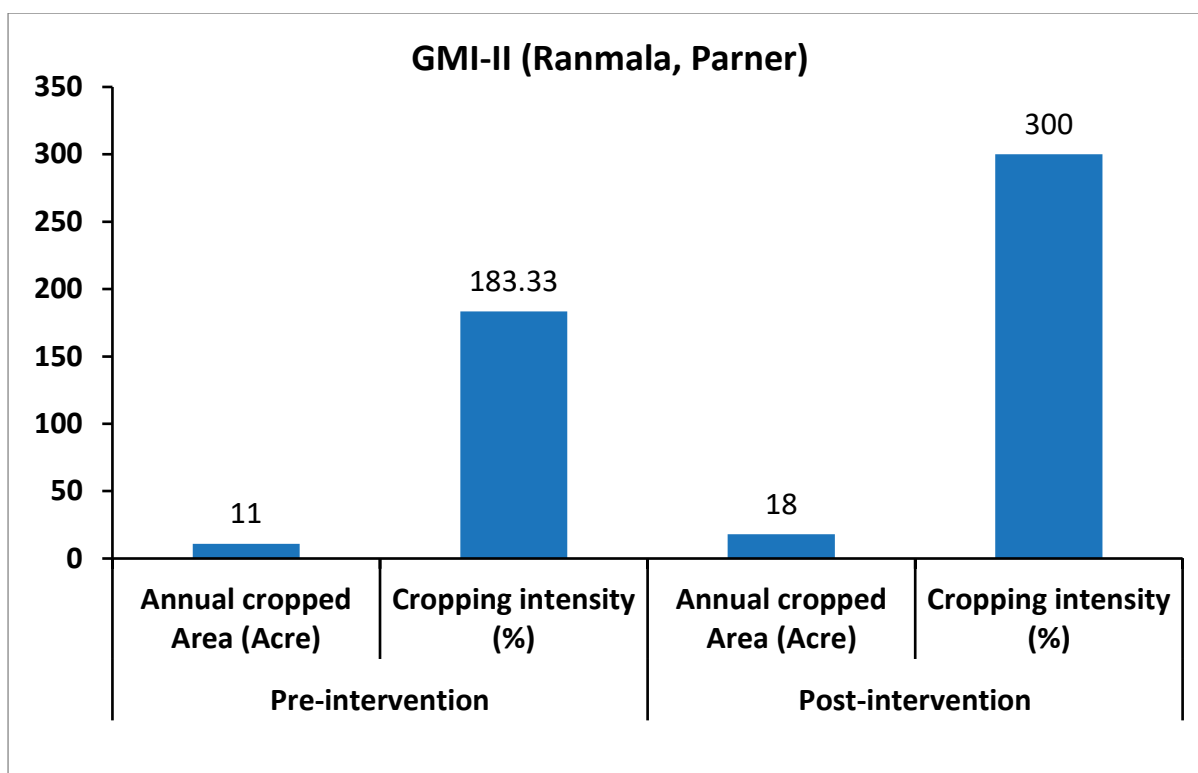


Figure 15 Comparison of change in pre and post-intervention cropping intensities in GMI-II

4.2.3 Seasonal Change in Irrigated Area

Irrigation is usually used in areas where rainfall is irregular or dry spells or drought is expected, like in the Parner block. Crops can artificially fulfill their water requirements through irrigation water. Table 16 reveals that before the project year, out of the 6-acre area, 1 acre was under partial irrigation, and 05 acres were rainfed. Post-intervention, all the 06 acres of land area came under full perennial irrigation. Fig. 16 compares the change in pre- and post-intervention irrigated areas in GMI-II.

Table 16 Seasonal change in irrigated area of GMI-II

GMI	Total GMI area (Acre)	Irrigation Status	Pre-intervention cropped area (Acre)			Post-intervention cropped area (Acre)			Change in cropped area (%)		
			Kharif	Rabi	Summer	Kharif	Rabi	Summer	Kharif	Rabi	Summer
Ranmala (06 Farmers)	06	Full	0	0	0	6	6	6	100	100	100
		Partial	1	1	0	0	0	0	-100	-100	0
		Rainfed	5	5	0	0	0	0	-100	-100	0

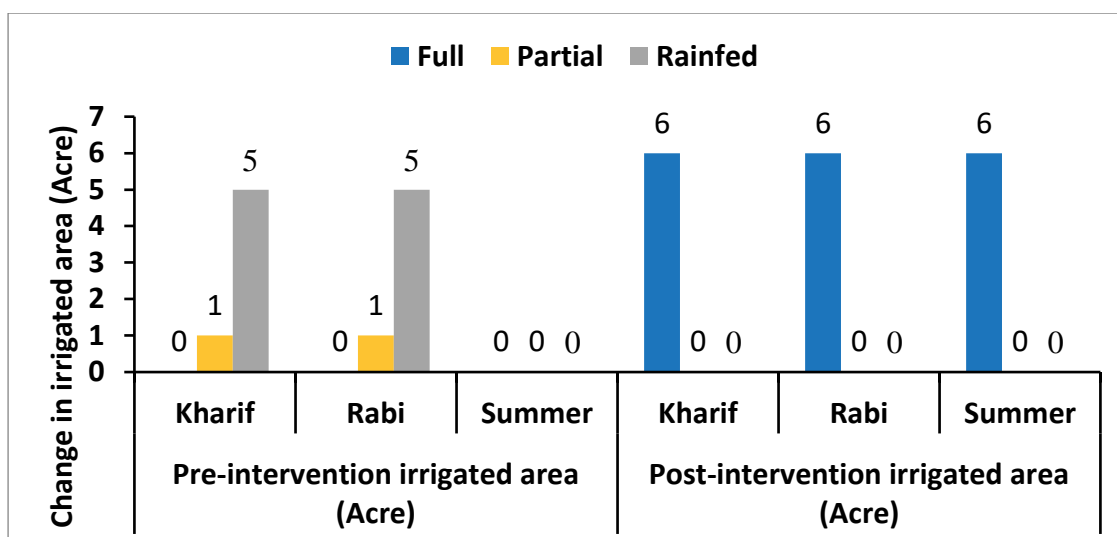


Figure 16 Comparison of change of pre and post-intervention irrigated areas in GMI-II

4.2.4 Change in Cropping Pattern

In the semi-arid area, change in cropping pattern heavily depends on the availability of an assured source of irrigation. Table 17 shows a change in cropping pattern in pre- and post-intervention of the GMI-II model. It reveals no significant difference in cropping pattern but a gradual shift from cereals to perennial vegetable crops like Drumstick etc. Also, seasonal fallow land in Rabi and summer seasons were cultivated for Onion and other crops. Fig. 17 shows the comparison of pre- and post-intervention cropping patterns in GMI-II.

Table 17 Change in cropping pattern of GMI-II

GMI Details		Cropping Season		
		Kharif	Rabi	Summer
Ranmala (06 Farmers)	Pre-intervention	1. Green Gram	1. Sorghum 2. Onion	-
	Post-intervention	Drumstick, Green Gram, and Onion		

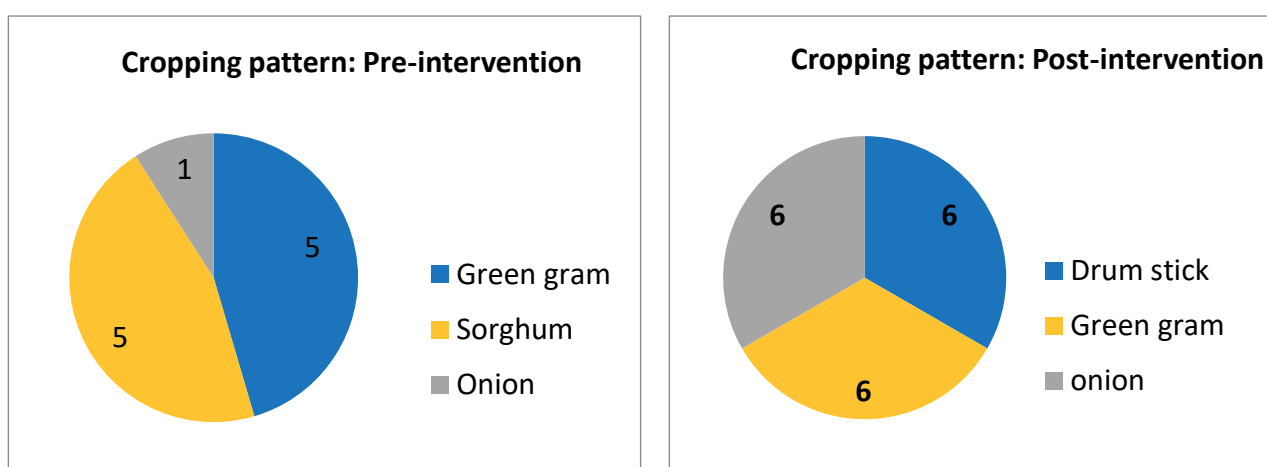


Figure 17 Comparison of pre and post-intervention cropping pattern of GMI-II

4.2.5 Production Cost and Revenue

In the pre-intervention year, 5 farmers had cultivated Moong, and one farmer, Drumstick in the Kharif season. In the following year, after the project implementation, all the farmers started cultivating Drumstick. In the Rabi season, in the pre-intervention year, the 4 farmers cultivated Jowar while one farmer grew Onion. One farmer from the group did not cultivate any crop in the Rabi season. To calculate the production costs, agricultural costs such as machinery and labour required for ploughing, harrowing, sowing & seeding, weeding, harvesting, and threshing, and input costs such as chemical fertilizers, and organic fertilizers, chemical pesticides, etc., including their labour cost were considered. The cost of production in the Pre-Intervention for Green Gram in Kharif, was Rs. 47025 and Rs. 22920 for Drumstick. In the Rabi season, the cost of production for Jowar was Rs. 45380 and for Onion was Rs. 16390. In the post-intervention year, the cost of production for the Drumstick crop was Rs. 158225. The revenue earned from Green Gram was Rs. 76000 and Rs. 12000 for Drumstick in the Kharif season before the project year. The revenue earned was Rs. 23400 for Jowar and Rs. 50000 for Onion in Rabi season before the project intervention. In the post-intervention year, the revenue earned from Drumstick was determined to be Rs. 88200. It can be seen that the revenue earned could not cover the cost of production as these years were Pandemic-affected years. The farmers had mentioned that due to the non-functioning of markets and low footfall of customers due to lockdowns and restrictions; they could sell only a limited quantity, and much of the produce was damaged.

Table 18 Details of the cost of production and revenue from market sales in GMI-II

Cost of Production							
Pre-Intervention (2019-2020)				Post Intervention (2020-2021)			
Kharif		Rabi		Kharif		Rabi	
Green-Gr	47025	Jowar	45380	-	-	-	-
Drumstick	22920	Onion	16390	Drumstick	158225	-	-
Revenue from Market Sales							
Pre-Intervention (2019-2020)				Post Intervention (2020-2021)			
Kharif		Rabi		Kharif		Rabi	
Green-Gr	76000	Jowar	23400	-	-	-	-
Drumstick	12000	Onion	50000	Drumstick	88200	-	-

4.2.6 Electricity Bill Cost

In the baseline year of 2019-20, only 2 of the 6 farmers in the GMI group were recorded to have an electricity connection. In the model implementation year, all 6 had an electricity connection as it was needed for the drips, the project's primary motive, i.e., to regulate water usage. The details of electricity connections for water pumping in pre- and post-intervention of GMI-II are shown in figure 18. The cost of electricity bills in the Kharif season of the baseline year was Rs. 2300. In the Rabi season it was Rs. 2500, and in the Summer season, it was Rs. 1200. Since the supply of water through the model was initiated, the electricity bill charges stood stagnant

at Rs. 1662 per season for a year. Each farmer paid an amount of Rs. 277 as their share of electricity usage. The details of electricity charges for water pumping in pre- and post-intervention of GMI-II are shown in figure 19.

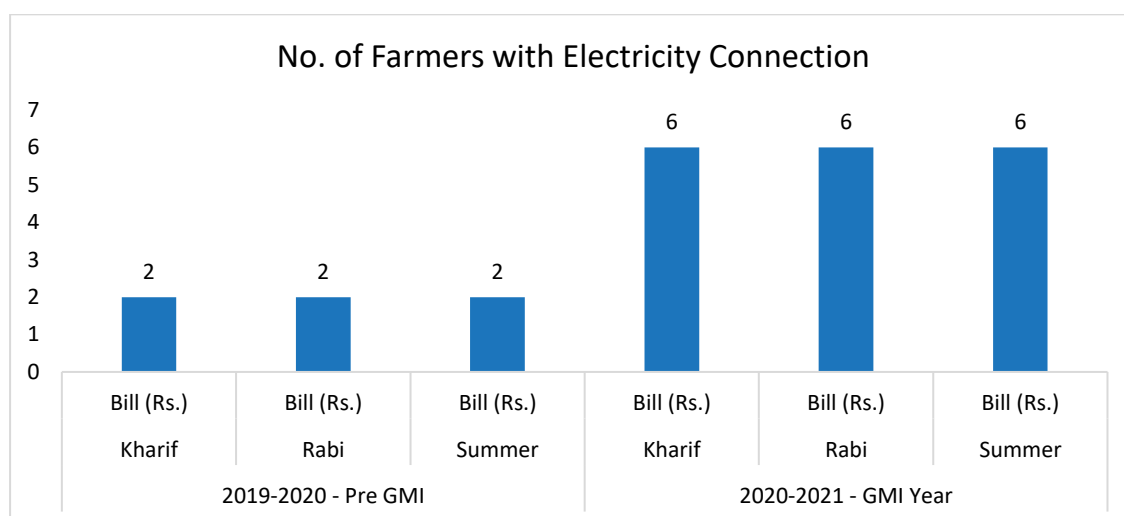


Figure 18 Comparison of pre- and post-intervention electricity connections for water pumping in GMI-II

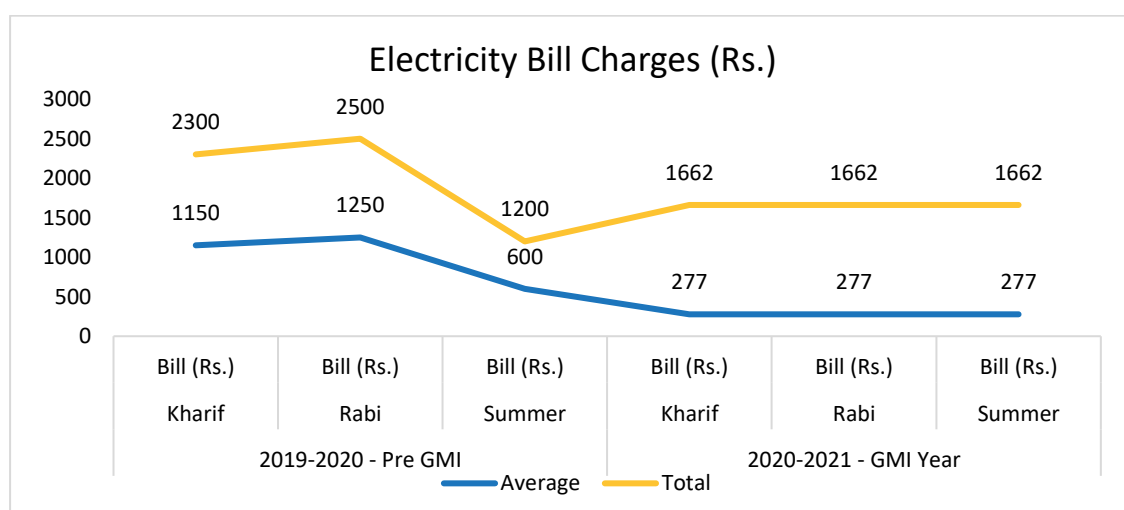


Figure 19 Comparison of pre- and post-intervention electricity charges for water pumping in GMI-II

4.2.7 Water Resources for Irrigation

Table 19 reveals that the year before the model initiation year of 2020-2021, of the six farmers, only 2 had water resources for their agricultural land. The rest of the farmers' agriculture was dependent on rainfall water. Of the two farmers who had tube-wells/dug-wells one was constructed in 1985 and the other in 2013. The cost of the one constructed in 1985 was much lower, considering the valuation in that year, while the expenses were higher for the construction done in 2013 (Rs.2,00,000). Motor pumps were purchased at the cost of Rs. 8000 and Rs. 15,000.

Table 19 Details of available irrigation resources in Pre-intervention at GMI-II

Irrigation Resources at pre-intervention			Tube Wells/Dug Wells			
			Maximum	Minimum	Average	Total
2019-2020	Initial Cost	Number of Wells	2	1	1	2
		Year of Construction	2013	1985	1999	-
		Cost (Rs.)	200000	20000	110000	220000
	Further Deepening	No. of times	-	-	-	-
		Cost (Rs.)	-	-	-	-
	Motor Pump	Year of Purchase	2014	1988	2001	-
		Cost (Rs.)	15000	8000	11500	23000

4.2.8 Drips and Sprinklers Ownership

Adopting modern agricultural technology depends on the farmer's confidence and risk-taking capacity. The level of confidence and risk-taking capacity is directly related to the weather processes, availability of resources to generate or re-generate income, etc. The volatile market rate and lack of these resources determines the confidence and risk-taking capacity. In Ranmala, in general, there is a lack of adoption of technology owing mainly to unfavourable weather, and hence a lack of earning from agriculture which is the primary source of earning in the region. Table 20 reveals that in the GMI group of 6, none of the farmers had drips and sprinklers on the GMI farms. The GMI project had these installed, which cost them about Rs. 2,70,000 overall, while the other major costs were covered under the project.

Table 20 Details of drips and sprinklers in pre- and post-intervention of GMI-II

Drips and Sprinklers	2019-2020- Pre GMI	2020-2021- GMI Year
Number	-	6
Total Cost (Rs.)	-	270000
Year Of Installation	-	2020
Sources of Irrigation	-	GMI

4.2.9 Vermicompost Beds Ownership

Table 21 reveals that only one farmer has owned a vermicompost bed among the 6 GMI farmers. It was purchased in 2018 for Rs. 1500 and held about 500 kgs of compost. The life span of the bed was for one year.

Table 21 Details of Vermicompost beds in pre- and post-intervention of GMI-II

Vermi Compost Beds	2019-2020- Pre GMI	2020-2021- GMI Year
Vermi-Compost Bed 1	1	-
Year of Purchase (Avg.)	2018	-
Size per bed (Kg. of compost it can store)	500	-
Cost (Total)	1500	-
Avg. Life of Bed (In years)	1	-
Vermi-Compost Bed 2	-	-

Year of Purchase	-	-
Size per bed (Kg. of compost it can store)	-	-
Cost (Total)	-	-
Avg. Life of Bed (In years)	-	-

4.2.10 Water Tankers

No farmer had ordered water tankers in any of the seasons in the GMI year of 2020-2021. In the 2019-2020 baseline year, one farmer called for a water tanker service to supply water for the Drumstick cultivation he had undertaken that year. The services were availed from government agencies; hence did not incur any cost for the service.

4.2.11 Agricultural Assets Owned

Table 22 reveals that only one farmer (family) owns a tractor and sowing machinery in the GMI group. The tractor and sowing machinery were purchased in the year 2007, which cost them Rs. 5,00,00 and Rs. 35,000, respectively. No other farmer has had owned such advanced technology until now.

Table 22 Details of finance and loans in pre and post-intervention of GMI-II

Agri-Assets Owned		2019-2020- Pre GMI	2020-2021- GMI Year
Tractors	Number	1	-
	Year Bought (Avg.)	2007	-
	Purchase Price (Sum)	500000	-
	Maintenance Cost in 2019-2020 (Sum)	10000	-
	Maintenance Cost in 2020-2021 (Sum)	50000	-
Sowing Machinery	Number	1	-
	Year Bought (Avg.)	2007	-
	Purchase Price (Sum)	35000	-
	Maintenance Cost in 2019-2020 (Sum)	-	-
	Maintenance Cost in 2020-2021 (Sum)	-	-
Weeding	Number	-	-
	Year Bought (Avg.)	-	-
	Purchase Price (Sum)	-	-
	Maintenance Cost in 2019-2020 (Sum)	-	-
	Maintenance Cost in 2020-2021 (Sum)	-	-
Threshing	Number	-	-
	Year Bought (Avg.)	-	-
	Purchase Price (Sum)	-	-
	Maintenance Cost in 2019-2020 (Sum)	-	-
	Maintenance Cost in 2020-	-	-

Agri-Assets Owned		2019-2020- Pre GMI	2020-2021- GMI Year
	2021 (Sum)		
Other Machinery	Number	-	-
	Year Bought (Avg.)	-	-
	Purchase Price (Sum)	-	-
	Maintenance Cost in 2019-2020 (Sum)	-	-
	Maintenance Cost in 2020-2021 (Sum)	-	-

4.2.12 Finance and Loans

No Farmers have taken loans in both baseline and GMI years to purchase agricultural inputs.

4.2.13 Change in Crop Productivity

Table 23 reveals that in pre-intervention, the crop productivity of Green Gram, Sorghum, and Onion were 2.5qt/acre, 3.2qt/acre, and 77qt/acre, respectively. But after adopting the GMI approach, farmers changed their crop to Drumstick (perennial vegetable). The productivity of the Drumstick was 75 qt/acre post-intervention. Direct comparison between productivity in pre- and post-intervention is possible in this situation. The farmers' shift from Cereal crops to vegetables also shows the availability of an assured source of irrigation. The crop productivity in pre- and post-intervention in GMI-II is shown in figure 20.

Table 23 Change in crop productivity of GMI-II

GMI Details	Crop Details	Crop Productivity (Quintal/Acre)		Rise in crop productivity (%)
		Pre-intervention	Post-intervention	
Ranmala (06 Farmers)	Green Gram	2.5	-	-
	Sorghum	3.2	-	-
	Onion	77	-	-
	Drum Stick	-	75	-

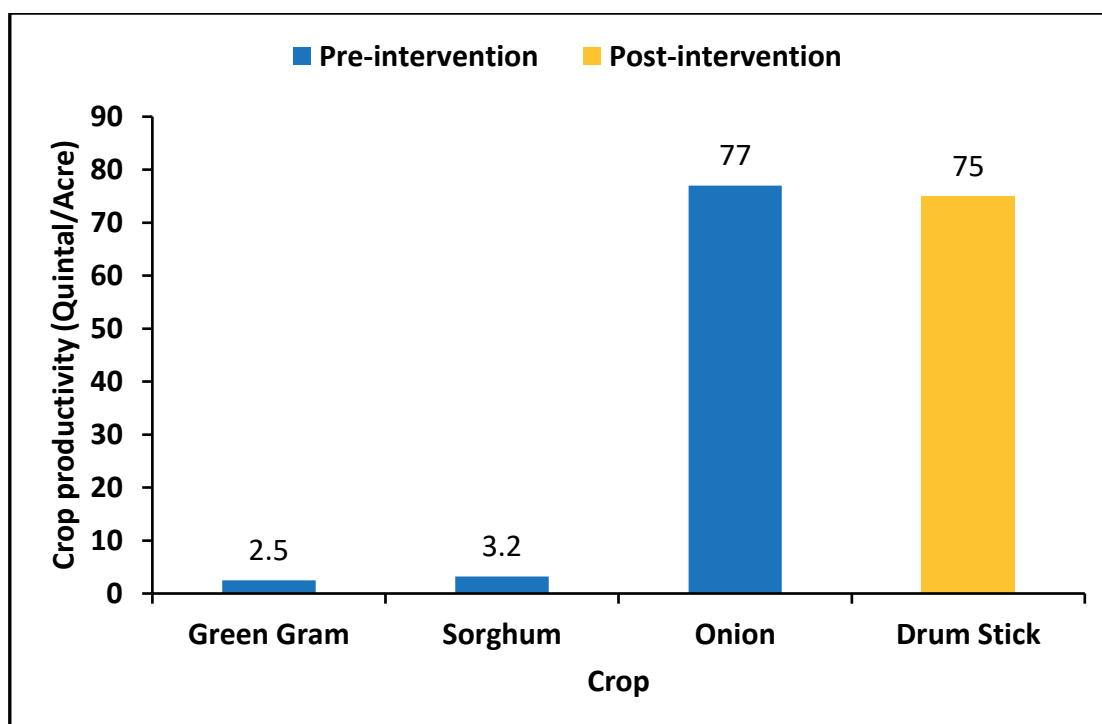


Figure 20 Comparison of change in pre and post-intervention crop productivity in GMI-II

4.2.14 Change in Water Productivity (Water Use efficiency)

Table 24 reveals that in pre-intervention, the water productivity of Green Gram, Sorghum, and Onion was 1.4 kg/ha-mm, 0.93 kg/ha-mm, and 35 kg/ha-mm, respectively, far less than the average productivity of India. After the GMI model intervention, the Drumstick's productivity is 19.41 kg/ha-mm, which is also less than the average productivity. Therefore, there is enormous scope to increase water productivity by applying the exact amount of water as per the schedule and adopting climate-resilient techniques. The water productivity of crops in pre- and post-intervention in GMI-II is shown in figure 21.

Table 24 Change in water productivity of GMI-II

GMI Details	Crop Details	Water Productivity (kg/ha-mm)		Rise in water productivity (%)
		Pre-intervention	Post-intervention	
Ranmala (06 Farmers)	Green Gram	1.4	-	-
	Sorghum	0.93	-	-
	Onion	35	-	-
	Drum Stick	-	19.41	-

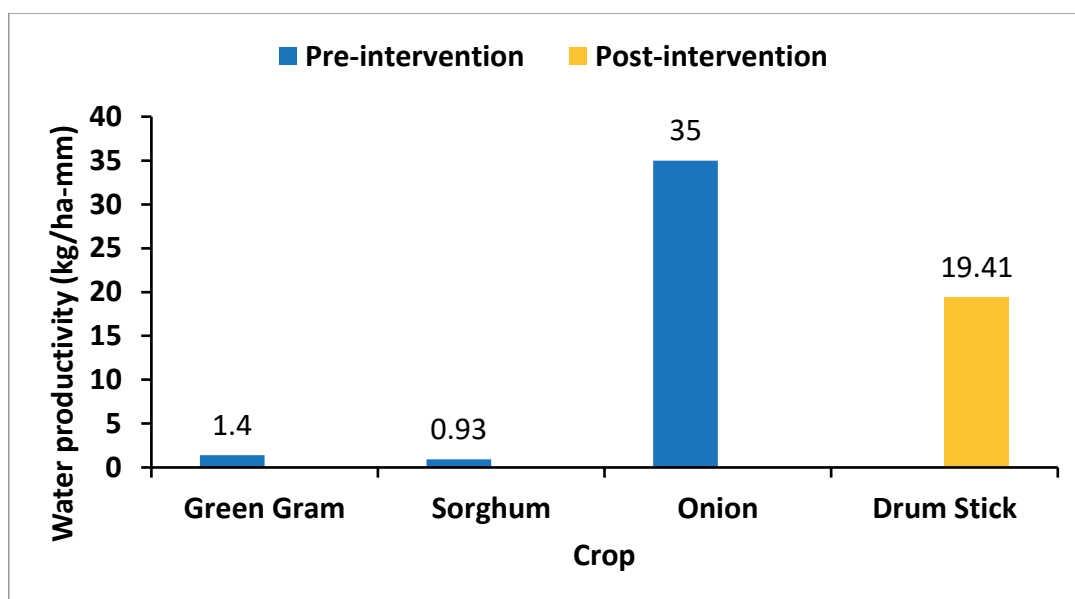


Figure 21 Comparison of change in pre and post-intervention water productivity in GMI-II

4.3 GMI-III

As explained in the methodology, the GMI-III model has an area of 65.5 acres of land belonging to 47 farmers in the Bhangadewadi village in the Parner block of Ahmednagar district. The source of irrigation is a common farm pond filled with water lifted from the check dam (store water flowed over from excess water spillway) constructed downstream of Kalu dam.

4.3.1 Seasonal Change in Area under Crops

Table 25 shows the seasonal changes in the cropping area pre- and post-intervention of the GMI-III model. It reveals that about 15.21% of the area increased under various crops on an average in the following year. The change in cropped area is not substantial but a noticeable change can be observed in the cropping pattern and irrigation status. Also, in pre-intervention, there were only 1.5 acres under the crop (seasonal fallow land) in the summer season; however, after the adoption of the GMI approach, the areas under the summer crop increased to 61 acres (98%). Overall, the private area under seasonal fallow land was reduced. The comparison of the seasonal change in pre- and post-intervention cropped areas in GMI-III is shown in figure 22.

Table 25 Seasonal change of cropped area in GMI-III

GMI	Total GMI area (Acre)	Cropping Season	Pre-intervention cropped area (Acre)	Post-intervention cropped area (Acre)	Change in cropped area (%)
Bhangadewadi (47 Farmers)	65.5	Kharif	55.25	62.5	13.12
		Rabi	50.5	61	17.30
		Summer	1.5		
		Total	107.25	123.5	15.21

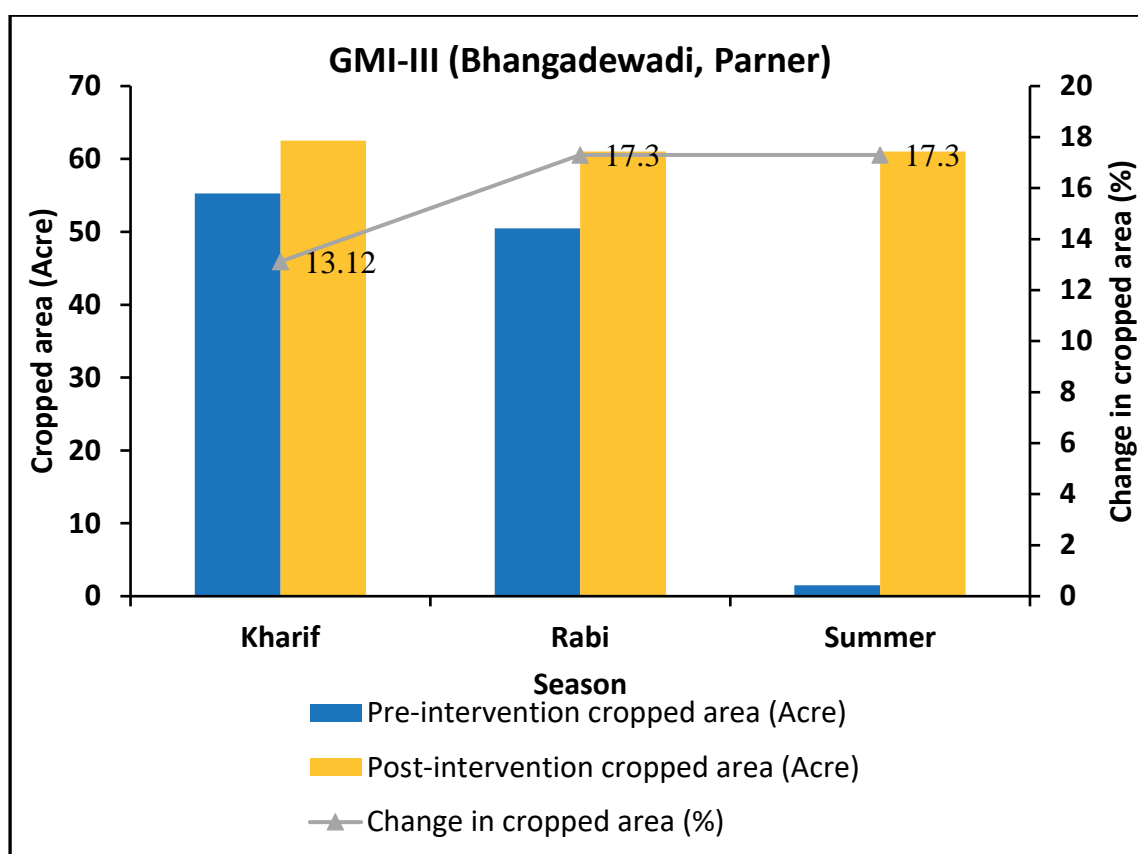


Figure 22 Comparison of seasonal change of pre- and post-intervention cropped areas in GMI-III

4.3.2 Change in Cropping Intensity

Table 26 reveals that the cropping intensities in pre-intervention and post-intervention are 163.74% and 188.55%, respectively. There is an almost 24.80% rise in cropping intensity in the GMI-III model. The cropping intensity hike is crucial because there are only two ways to satisfy the increasing food and other demands of the rising population such as drinking water and water for domestic usage: expanding the net area under cultivation and intensifying cropping over the existing area. The comparison of the change in pre- and post-intervention cropping intensities in GMI-III is shown in figure 23.

Table 26 Change in cropping intensity of GMI-III

GMI	Total GMI area (Acre)	Pre-intervention		Post-intervention		Rise in cropping intensity (%)
		Annual cropped Area (Acre)	Cropping Intensity (%)	Annual cropped Area (Acre)	Cropping Intensity (%)	
Bhangadewadi (47 Farmers)	65.5	107.25	163.74	123.5	188.55	24.80

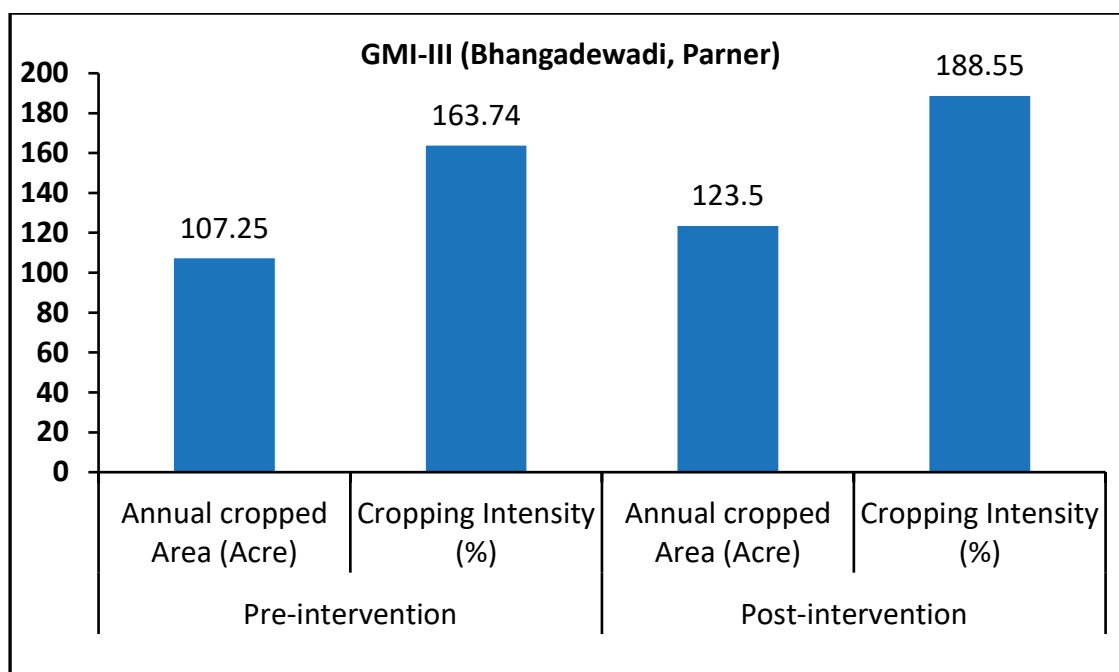


Figure 23 Comparison of change in pre and post-intervention cropping intensities in GMI-III

4.3.3 Seasonal Change in Irrigated Area

Table 27 reveals that in pre-intervention, out of the 65.5 acres, 24.25 acres were under partial irrigations and 29.5 acres were rainfed. In post-intervention, all the area (a total of 65.5 acres) came under full perennial irrigation, of which 95% area was cropped under different crops. The comparison of the change in pre- and post-intervention irrigated areas in GMI-III is shown in figure 24.

Table 27 Seasonal change in irrigated area of GMI-III

GMI	Total GMI area (Acre)	Irrigation Status	Pre-intervention cropped area (Acre)			Post-intervention cropped area (Acre)			Change in cropped area (%)		
			Kharif	Rabi	Summer	Kharif	Rabi	Summer	Kharif	Rabi	Summer
Bhangadewadi (47 Farmers)	65.5	Full	1.5	1.5	1.5	62.5	61	61	97.60	97.60	97.60
		Partial	24.25	17.5	0	0	0	0	100	100	100
		Rainfed	29.5	31.5	0	0	0	0	100	100	100

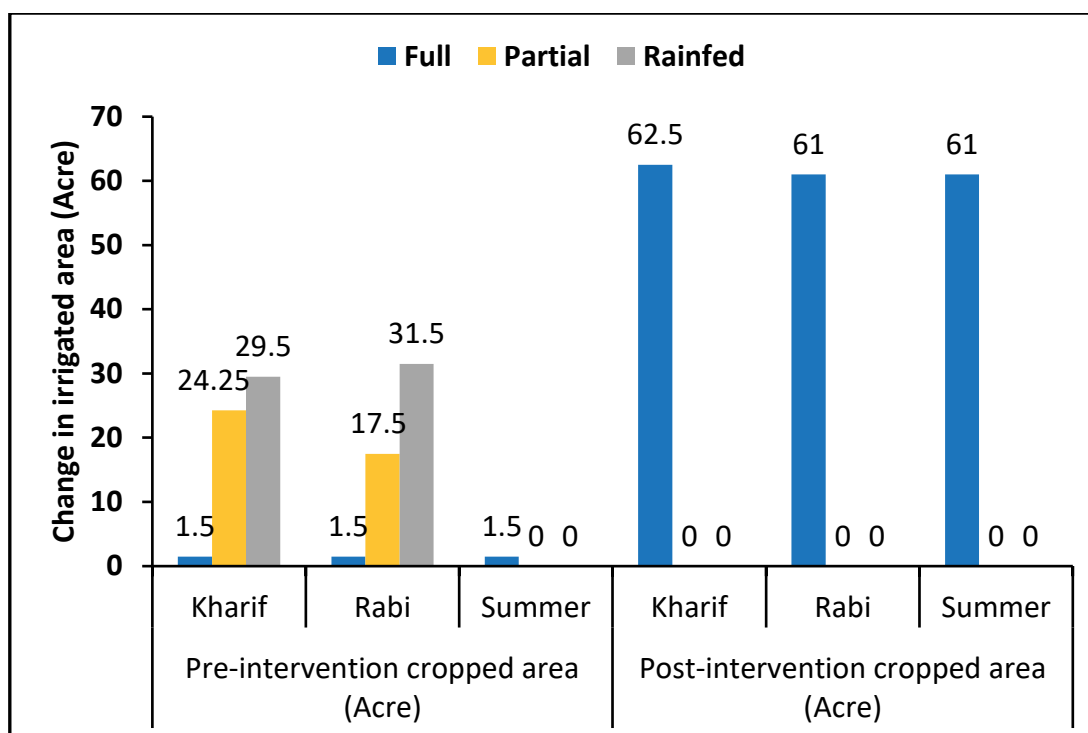


Figure 24 Comparison of change of pre and post-intervention irrigated areas in GMI-III

4.3.4 Change in Cropping Pattern

Table 28 shows a change in cropping pattern, pre- and post-intervention of the GMI-III model. It reveals a much-diversified change in cropping pattern with a gradual shift from Cereals to Vegetable crops. Also, seasonal fallow land in Rabi and Summer seasons reduced up to nil. Figure 25 shows the comparison of pre- and post-intervention cropping patterns in GMI-III.

Table 28 Change in cropping pattern of GMI-III

GMI Details		Cropping Season		
		Kharif	Rabi	Summer
Bhangadewadi (47 Farmers)	Pre-intervention	1. Pearl-millet 2. Green-gram 3. Onion 4. Pea	1. Sorghum 2. Chickpea 3. Wheat 4. Onion	-
	Post-intervention	1. Brinjal 2. Cauliflower 3. Green-gram 4. Onion	1. Cabbage 2. Cauliflower 3. Chickpea 4. Groundnut 5. Sorghum 6. Onion 7. Peas 8. Tomato	

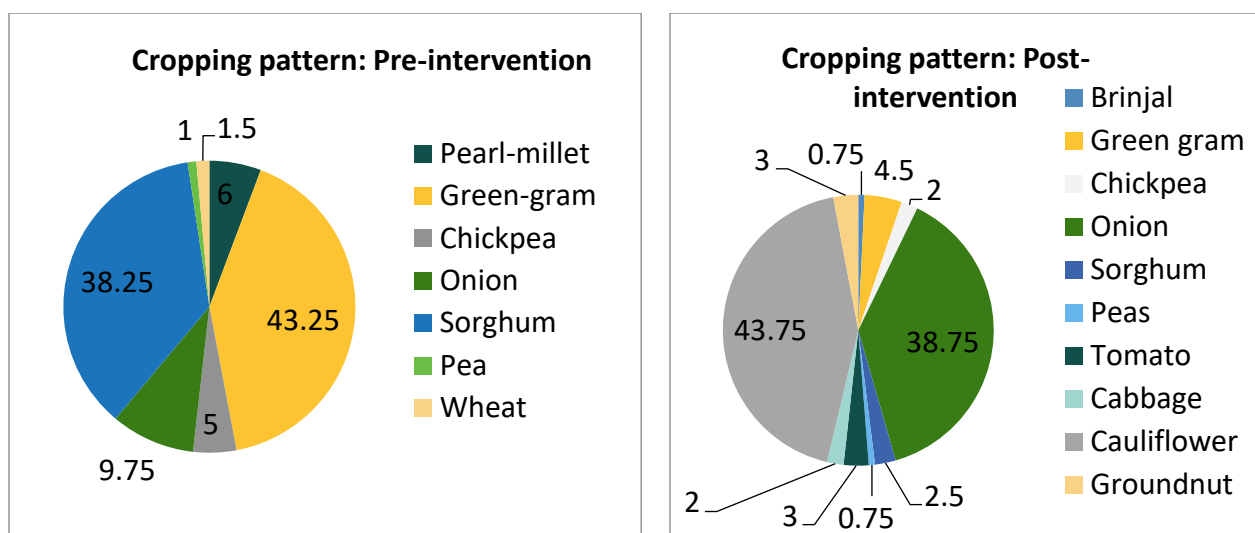


Figure 25 Comparison of pre and post-intervention cropping pattern of GMI-III

4.3.5 Production Cost and Revenue

In Bhangadewadi, in Kharif season, the primary crop cultivated in the pre-intervention year was Green Gram, followed by Bajra and Onion. About 30 of the 39 GMI group farmers cultivated Green Gram; the rest of the 8 farmers in the 47-member group did not take any cultivation in 2020. In the post-intervention year, in the same season, the number of crops cultivated included Cauliflower, Sugarcane, Tomato, Brinjal, along with the previous year's crop choices. In that year, the primary crop cultivated was Cauliflower. It was in considering the water availability connected to the GMI model that the decision to cultivate Cauliflower was made. 30 farmers cultivated this crop, while the rest cultivated the other crops. In the Rabi season, farmers increased the variety of crops by cultivating Groundnut, Cabbage, Tomato, Cauliflower, along with cultivating the previous choices of Jowar, Wheat, Chickpea, and Onion. Jowar was the primary crop chosen in the pre-intervention year where about 27 farmers of the 37 who cultivated crops in that season cultivated this crop. Green Gram earned revenue more than the agricultural input costs in the pre-intervention year, in the Kharif season. In the Rabi season, the Jowar crop could not recover the input costs, while the Onion crop recovered costs and delivered profits. In the post-intervention year, revenue was earned from all the crops, except for Brinjal. The underlying reason for this were the restrictions imposed due to COVID19, reducing options to sell the produce.

Table 29 Details of the cost of production and revenue from market sales in GMI-III

Cost of Production									
Pre-Intervention (2019-2020)					Post Intervention (2020-2021)				
Kharif		Rabi		Summer	Kharif		Rabi		
Crop 1		Crop 1		Crop 1	Crop 1		Crop 1		
Green Gram	559432	Jowar	339731	Onion	48272.5	Cauliflower	3249699.6	Onion	3858465.95
Bajra	45925	Wheat	21357.5			Onion	393830	Jowar	27650
Custard	35420	Chickpea	63384			Green Gram	243040	Groundnut	237940

Onion	459390	Onion	190437.5			Sugarcane	234800	Cabbage	91327.5
						Tomato	204282.5	Tomato	533070
Crop 2		Crop 2		Crop 2		Peas	30440	Cauliflower	88225
Green Gram	12180	Chickpea	11870	-	-	Custard	87400	Chickpea	296830
Pea	15375					Brinjal	34057.5	Peas	14195.5
						Crop 2		-	
						Cauliflower	127431.5		
Revenue from Market Sales									
Pre-Intervention (2019-2020)					Post Intervention (2020-2021)				
Kharif		Rabi		Summer		Kharif		Rabi	
Crop 1		Crop 1		Crop 1		Crop 1		Crop 1	
Green Gram	677500	Jowar	188640	Onion	90000	Cauliflower	1804500	Onion	3907600
Bajra	15000	Wheat	30000			Onion	417500	Jowar	33000
Custard	0	Chickpea	51500			Green Gram	46200	Groundnut	180000
Onion	384500	Onion	676500			Sugarcane	0	Cabbage	4000
						Tomato	80000	Tomato	45000
Crop 2		Crop 2		Crop 2		Peas	30000	Cauliflower	45000
Green Gram	17000	Chickpea	27500	-	-	Custard	0	Chickpea	17000
Pea	8000					Brinjal	90000	Peas	18000
						Crop 2		-	
						Cauliflower	110000		

4.3.6 Electricity Bill Costs

In the Bhangadewadi Group Micro Irrigation (GMI) group of 47 farmers, not all farmers have electricity connectivity at their farms. In the year before the project started, i.e.; in 2019-2020, only 21 farmers had a connection. However, since the establishment of the Group Micro Irrigation Model, i.e., 2020-2021, all farms are connected to motors, to which drips in the farms are connected for water supply. This is with the exception of one farmer who has been inactive in agriculture. The details of electricity connections for water pumping in pre- and post-intervention of GMI-III are shown in figure 26. Before the project started, we can notice a variation in the electricity costs for the three seasons. Each of the 21 farmers had to pay an average bill of Rs. 1,676.19 in Kharif, Rs. 2,342.86 in Rabi, and Rs. 1,104.76 in the summer season. The connection all the 47 farmers received through the model has incurred them a standard cost of Rs. 2,127 across each season for that year. The model has ensured all farmers get a connection and a continuous electricity supply for drip operation. The details of electricity charges for water pumping in pre- and post-intervention of GMI-III are shown in figure 27.

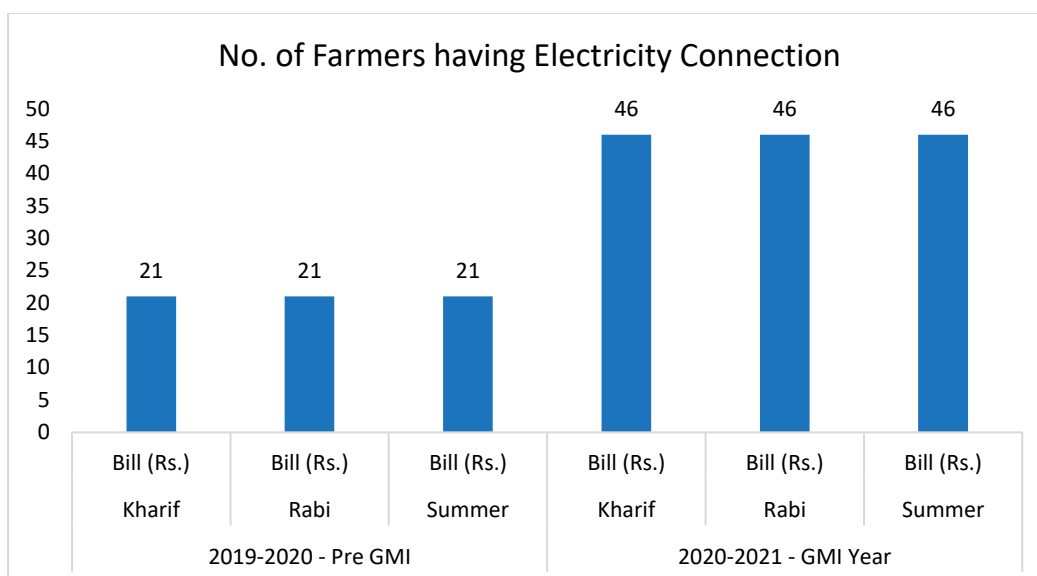


Figure 26 Comparison of pre and post-intervention electricity connections for water pumping in GMI-III

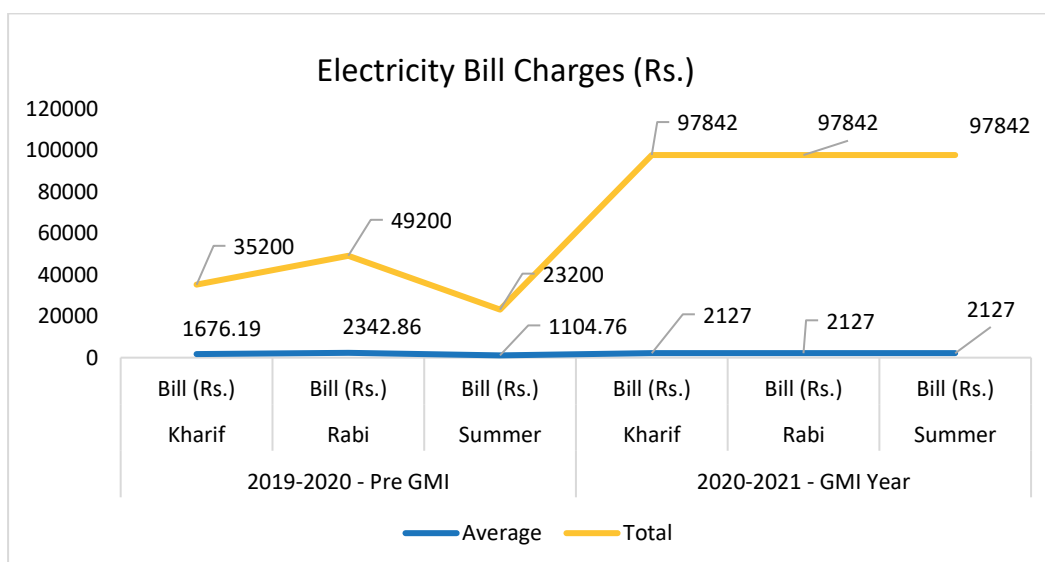


Figure 27 Comparison of pre and post-intervention electricity charges for water pumping in GMI-III

4.3.7 Water Resources for Irrigation

Lack of surface water and irrigation facilities such as pipelines compel farmers to construct structures to extract and store as much groundwater as possible for sustaining agriculture. Table 30 reveals that, of the total 47 farmers in the Bhangadewadi village, about 22 farmers had one dug-well each, except for one farmer who had 2 wells, and 2 farmers who had borewells to extract water for seasons post-Kharif. The oldest dug-well was constructed in 1965, and the newest was built in 2015. The borewells has been recently constructed between 2008 and 2011. The overall expenditure incurred as initial construction costs of dug-wells was Rs. 34,00,000. The cost for each well ranged between Rs. 5,000 and Rs.5,00,000, excluding the motor pumps costs. The overall expenditure on motor pumps was Rs.2,95,000. with each farmer spending between Rs. 3,000 and Rs.40,000. The

borewells cost the owners Rs. 46,000 in total costs while the motors incurred a total cost of Rs.34,000 for their construction and installation. On establishment of the model, all 47 farmers on the land reserved for the model had an assured supply of water provided through drips connected to the farm pond, which sourced water from a surface reserve of the Kalu dam, transferred through pipelines.

Table 30 Details of available irrigation resources in Pre-intervention at GMI-III

Irrigation Resources at pre-intervention			2019-2020- Pre GMI			
			Maximum	Minimum	Average	Total
1 st Dugwell	Initial Cost	Number	1	1	1	22
		Year of Purchase	2015	1965	1996	-
		Costs	500000	5000	154545.45	3400000
	Further Deepening	First deepening cost	150000	10000	52500	210000
	Motor Pump	Motor Cost	40000	3000	13409.09	295000
		Year of Purchase	2015	1985	2002	
2 nd Dugwell	Initial Cost	Number	1	1	1	1
		Year of Purchase	1990	1990	1990	1990
		Costs	85000	85000	85000	85000
	Further Deepening	First deepening cost	-	-	-	-
	Motor Pump	Motor Cost	10000	10000	10000	10000
		Year of Purchase	1990	1990	1990	1990
Borewells	Initial Cost	Number	1	1	1	2
		Year of Purchase	2011	2008	2010	
		Costs	30000	16000	23000	46000
	Further Deepening	First deepening cost	-	-	-	-
	Motor Pump	Motor Cost	20000	14000	17000	34000
		Year of Purchase	2011	2008	2010	

4.3.8 Drip and Sprinklers Ownership

Table 31 reveals that a year before the model installation year of 2020-2021 i.e.; 2019-2020, only one farmer had drip and sprinklers available. It was installed that year itself and cost the farmer Rs. 40,000 for the overall installation. The owner's tube-well/dug-well and drip were connected for water supply. In the model year, almost all the 44 farmers, except for 3 farmers, invested in drip and sprinklers, costing them around Rs. 13,45,000.

Table 31 Details of drips and sprinklers in pre and post-intervention of GMI-III

Drips and Sprinklers	2019-2020- Pre GMI	2020-2021 – GMI Year
Number	1	44
Total Cost (Rs.)	40000	1345000
Year Of Installation	2019	2020
Sources of Irrigation	Tube-Well/Dug-well	GMI

4.3.9 Vermicompost Beds Ownership

Table 32 reveals that limited farmers have purchased Vermi-Compost beds in this group of 47 GMI farmers. At the time of the study, there were 8 vermicompost beds available within this group. They were purchased in 2018. The average size of the beds is large enough to store about 500 kgs. of compost. A 500 kg holding-sized bed can supply compost for about 1 acre of land, once. The overall cost of all 7 beds before the model year was about Rs. 14,500. In 2020-2021, only one farmer purchased a vermicompost bed sized 1000 kg for Rs. 2000. These beds' life span is about 2-3 years.

Table 32 Details of Vermicompost beds in pre and post-intervention of GMI-III

Vermi Compost Beds	2019-2020- Pre GMI	2020-2021– GMI Year
Vermi-Compost Bed 1	5	1
Year of Purchase (Avg.)	2018	2020
Size per bed (Kg. of compost it can store)	500	1000
Cost (Total)	9000	2000
Avg. Life of Bed (In years)	2	3
Vermi-Compost Bed 2	2	-
Year of Purchase (Avg.)	2018	-
Size per bed (Kg. of compost it can store-Avg.)	500	-
Cost (Total)	5500	-
Avg. Life of Bed (In years)	2	-

4.3.10 Water Tankers

In the GMI model year of 2020-2021, no water tanker service was called for in any of the seasons. However, a year earlier, in 2019-2020, one farmer ordered tankers due to a water shortage in the Kharif crop. The farmer had Custard fruit under cultivation. The tankers were ordered twice from private water suppliers, who charged Rs. 3500 for each trip.

4.3.11 Agricultural Assets Owned

Agricultural equipment and technology are usually significant costs for the farmer. The farmer usually weighs the costs while deciding to hire or own them and also evaluates their accessibility and efficiency, before deciding to purchase them. The

purchase is also contingent upon the farmer's economic background or repaying capacity by other means. Table 33 reveals that, in this GMI group of 47, about 16 of the farmers own tractors, 16 own sowing machines, 4 own weeding machines, and one owns a threshing machine. Owning tractors, purchased in different years (the year 2011, on average) cost them Rs. 85,00,000 overall. The sowing machinery costs stood at Rs.5,54,500, weeding machinery costs at about Rs. 2,09,000 and threshing machine costs at Rs. 95,000. In the years 2019-2020 and 2020-2021, some farmers incurred costs for the maintenance of their machinery. This was highest for tractor maintenance at Rs. 50,000 in the first year and Rs. 30,000 in the second year.

Table 33 Details of finance and loans in pre- and post-intervention of GMI-III

Agri-Assets Owned		2019-2020- Pre GMI	2020-2021- GMI Year
Tractors	Number	16	1
	Year Bought (Avg.)	2011	2020
	Purchase Price (Sum)	8500000	280000
	Maintenance Cost in 2019-2020 (Sum)	50000	-
	Maintenance Cost in 2020-2021 (Sum)	30000	-
Sowing Machinery	Number	16	1
	Year Bought (Avg.)	2013	2020
	Purchase Price (Sum)	554500	20000
	Maintenance Cost in 2019-2020 (Sum)	43000	-
	Maintenance Cost in 2020-2021 (Sum)	13000	-
Weeding	Number	4	-
	Year Bought (Avg.)	8060	-
	Purchase Price (Sum)	209000	-
	Maintenance Cost in 2019-2020 (Sum)	5000	-
	Maintenance Cost in 2020-2021 (Sum)	-	-
Threshing	Number	1	-
	Year Bought (Avg.)	2011	-
	Purchase Price (Sum)	95000	-
	Maintenance Cost in 2019-2020 (Sum)	3000	-
	Maintenance Cost in 2020-2021 (Sum)	-	-
Other Machinery	Number	1	-
	Year Bought (Avg.)	2015	-
	Purchase Price (Sum)	72000	-
	Maintenance Cost in 2019-2020 (Sum)	1000	-
	Maintenance Cost in 2020-2021 (Sum)	-	-

4.3.12 Finance and Loans

Table 34 reveals that to cover agricultural expenditure for the season utilize the money saved, and in case of deficiency in funds, farmers borrow from various sources such as banks or registered lenders, private lenders or friends, or family. The choices from whom to borrow finance depends on multiple factors including credit history, repayment capacity, creditworthiness for the future, interest rates, accessibility, etc. The details of loans taken by farmers in pre- and post-intervention of GMI-III are shown in figure 28. In this GMI group, it can be seen that in the

baseline year of 2019-2020, in the Kharif season, 17 of the total 47 farmers, had availed credit from banks to the tune of Rs.6,97,500 at an average interest rate of 5.71% for 6-12 months. The details of the principal loan amount taken by farmers in pre- and post-intervention of GMI-III are shown in Figure 29. The farmers mentioned investing this amount into purchasing agricultural inputs and services. Two farmers borrowed money from private lenders - an amount of Rs. 38,500 for 3-6 months at an average interest rate of about 4%. In the Rabi season of the same year, 7 farmers took loans from banks and 2 from private lenders. Loans from banks were taken for a duration of 6-12 months, while from private lenders, loans for taken for a duration of 3-6 months. The interest rates, on average, were almost the same at approx. 4%. The details of interest rates on loans taken by farmers in pre- and post-intervention of GMI-III are shown in figure 30. In 2020-2021, there was a drastic decrease in the number of farmers taking loans. In both the seasons combined, there were 5 loans taken to the tune of Rs, 1,87,500 and Rs, 65,000. One farmer borrowed money from a friend/family at an interest rate of 2%. The details of the duration of loans taken by farmers in pre- and post-intervention of GMI-I are shown in figure 31.

Table 34 Details of finance and loans in pre and post-intervention of GMI-III

Finance & Loans		Variables	2019-2020– Pre GMI				2020-2021- GMI Year			
			No. of Farmers Taken loan	Principle Amt (Rs.)	Interest rates (%)	Duration of Loan (Months)	No. of Farmers Taken loan	Principle Amt (Rs.)	Interest rates (%)	Duration of Loan (Months)
Kharif	Bank	Maximum	-	100000	12	12	-	50000	15	24
		Minimum	-	10000	4	6	-	37500	4	6
		Average	-	41029.41	5.71	9.88	-	46875	7.75	13.5
		Total	17	697500	-	-	4	187500	-	-
	Private Lenders	Maximum	-	30000	6	6	-	-	-	-
		Minimum	-	8500	2	3	-	-	-	-
		Average	-	19250	4	4.5	-	-	-	-
		Total	2	38500	-	-	-	-	-	-
	Friends & Family	Maximum	-	-	-	-	-	-	-	-
		Minimum	-	-	-	-	-	-	-	-
		Average	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-
Rabi	Bank	Maximum	-	100000	5	12	-	50000	4	12
		Minimum	-	10000	4	6	-	50000	4	12
		Average	-	42500	4.29	9.43	-	50000	4	12
		Total	7	297500	-	-	1	50000	-	-
	Private Lenders	Maximum	-	10000	6	6	-	-	-	-
		Minimum	-	8500	2	3	-	-	-	-
		Average	-	9250	4	4.5	-	-	-	-
		Total	2	18500	-	-	-	-	-	-
	Friends & Family	Maximum	-	-	-	-	-	15000	2	3
		Minimum	-	-	-	-	-	15000	2	3
		Average	-	-	-	-	-	15000	2	3
		Total	-	-	-	-	1	15000	-	-

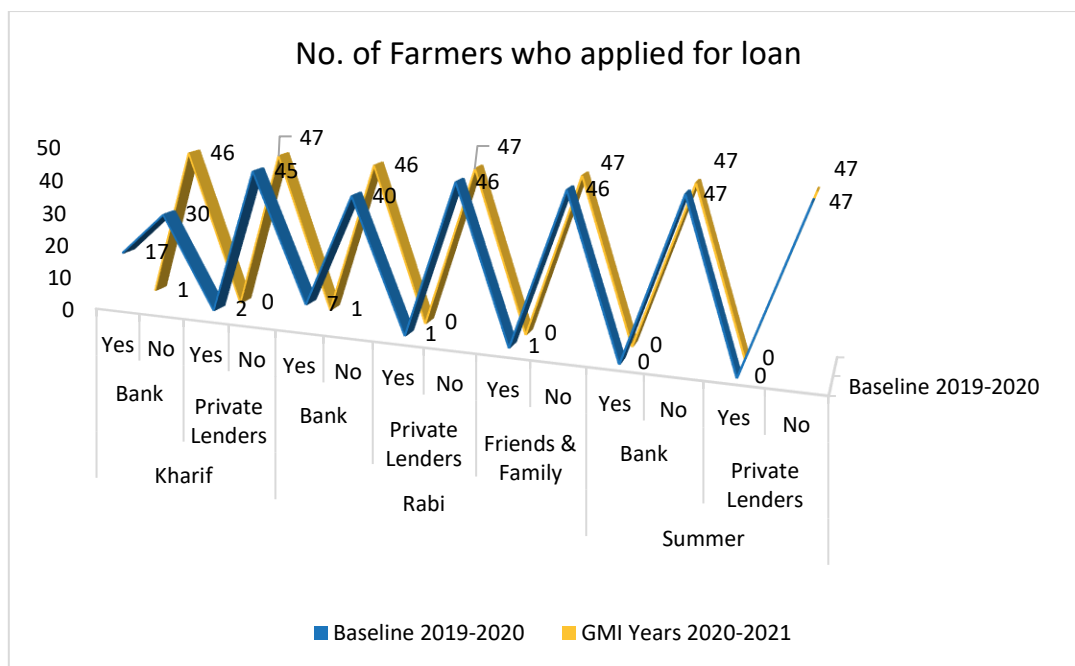


Figure 28 Comparison of pre- and post-intervention loan taken by farmers of GMI-III

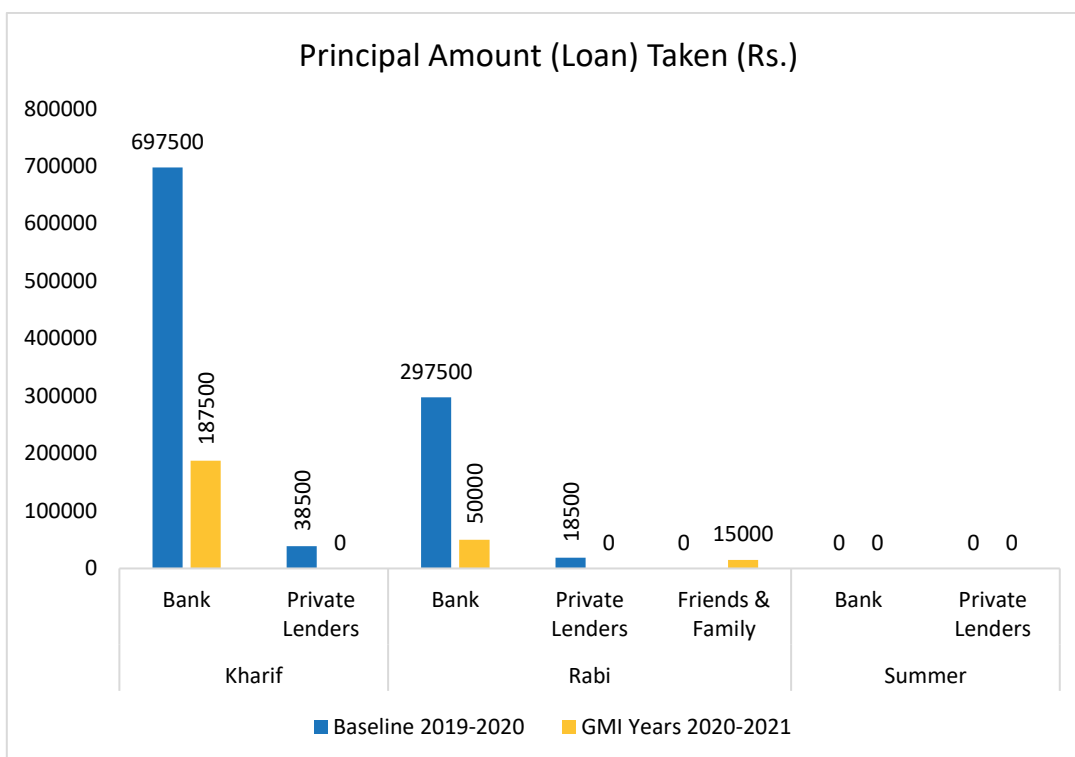


Figure 29 Comparison of pre- and post-intervention principal loan amount taken by farmers of GMI-III

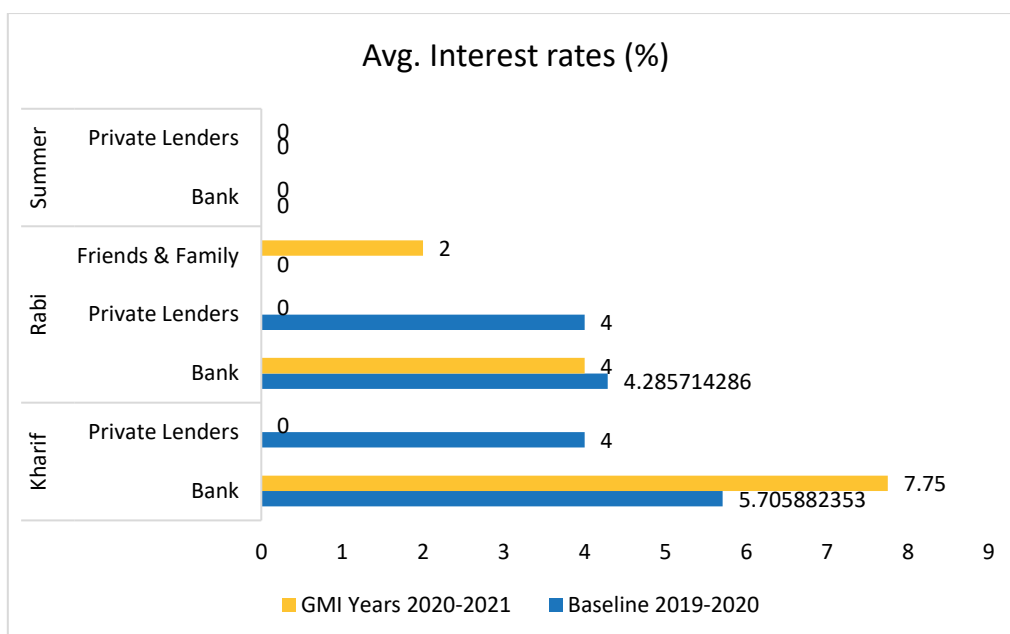


Figure 30 Comparison of pre- and post-intervention interest rate on loan taken by farmers of GMI-III

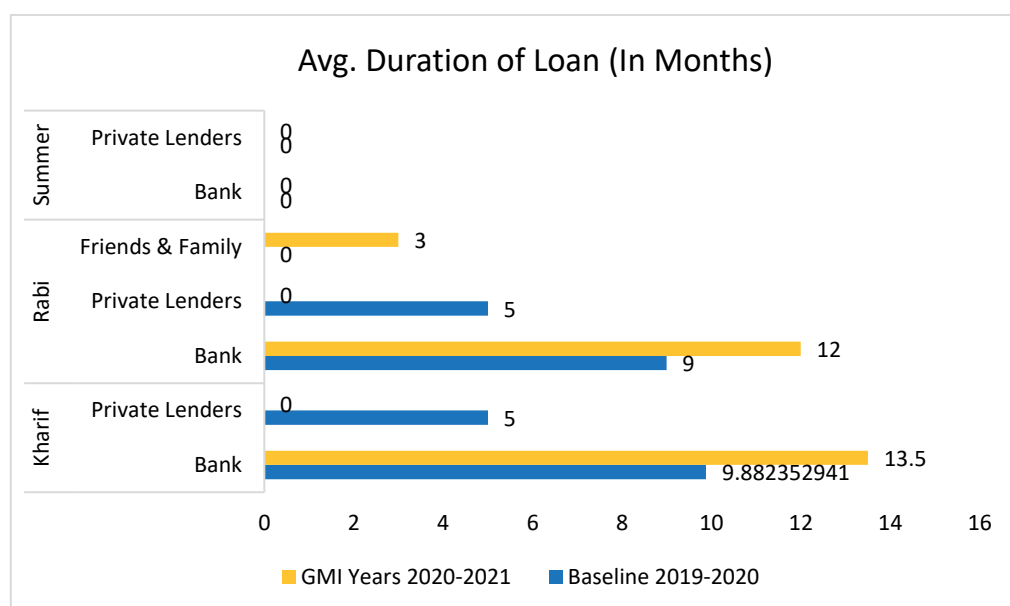


Figure 31 Details of pre- and post-intervention duration of loan taken by farmers of GMI-III

4.3.13 Change in Crop Productivity

Table 35 reveals that the crop productivity of Green Gram, Chickpea, Onion, and Pea almost doubled when compared with pre intervention. The shifting of the cropping pattern from cereals to vegetables is a positive sign of the availability of an assured source of irrigation. The crop productivity in pre- and post-intervention in GMI-III is shown in figure 32.

Table 35 Change in crop productivity of GMI-III

GMI Details	Crop Details	Crop Productivity (Quintal/Acre)		Rise in crop productivity (%)
		Pre-intervention	Post-intervention	
Bhangadewadi (47 Farmers)	Green Gram	2.11	3.69	174.88
	Sorghum	-	6.4	-
	Wheat	7.1	-	-
	Chickpea	3.2	6.86	214.38
	Onion	58.05	110.06	189.60
	Pearl millet	5.5	-	-
	Pea	2.5	9.14	365.60
	Cauliflower	-	51.68	-
	Cabbage	-	40.57	-
	Tomato	-	133.33	-
	Brinjal	-	27.65	-
	Groundnut	-	15	-

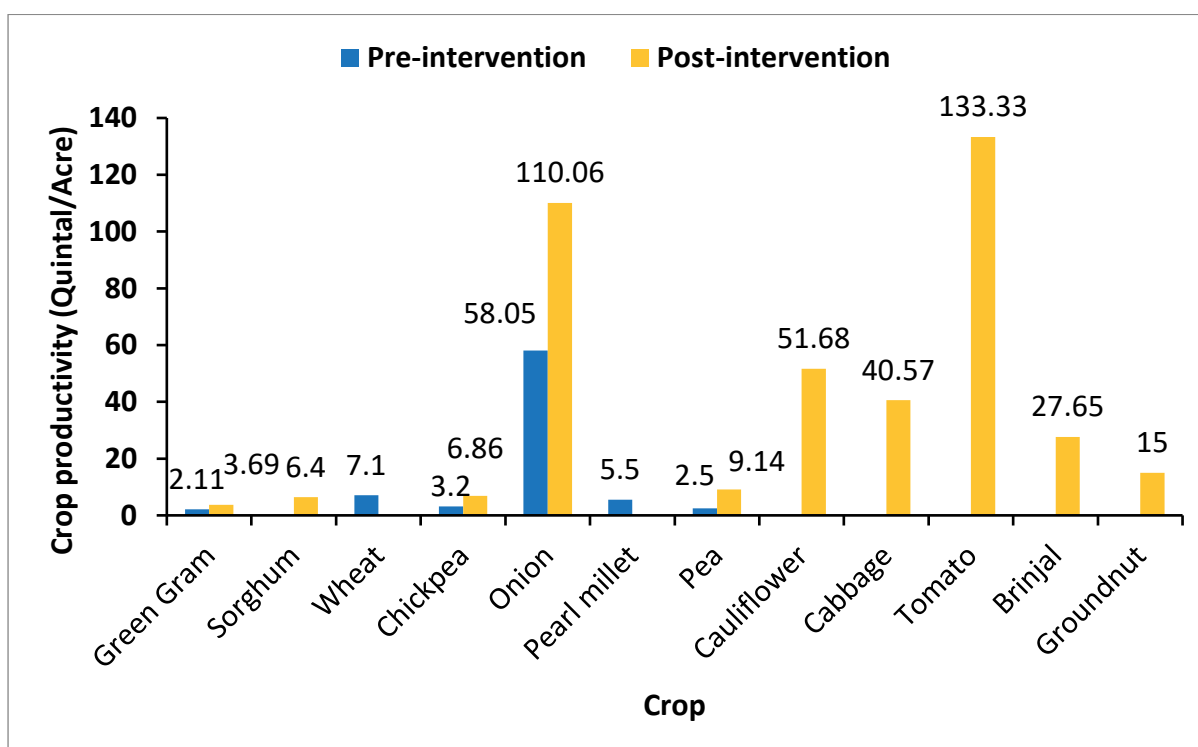


Figure 32 Comparison of change in pre and post-intervention crop productivity in GMI-III

4.3.14 Change in Water Productivity (Water Use Efficiency)

Table 36 reveals that the water productivity of Green Gram, Chickpea, Onion, and Pea is increased by 2.25 times when compared to pre intervention. The water productivity of vegetable crops is quite encouraging. However, there is considerable scope to increase this. The water productivity of crops in pre- and post-intervention in GMI-III is shown in figure 33.

Table 36 Change in water productivity of GMI-III

GMI Details	Crop Details	Water Productivity (kg/ha-mm)		Rise in water productivity (%)
		Pre-intervention	Post-intervention	
Bhangadewadi (47 Farmers)	Green Gram	1.68	2.64	157.14
	Sorghum	-	3.77	-
	Wheat	3.23	-	-
	Chickpea	3.2	5.72	178.75
	Onion	26.39	50.27	190.49
	Pearl millet	4.19	-	-
	Pea	1.56	5.71	366.03
	Cauliflower	-	31.28	-
	Cabbage	-	21.22	-
	Tomato	-	53.33	-
	Brinjal	-	10.63	-
	Groundnut	-	6.82	-

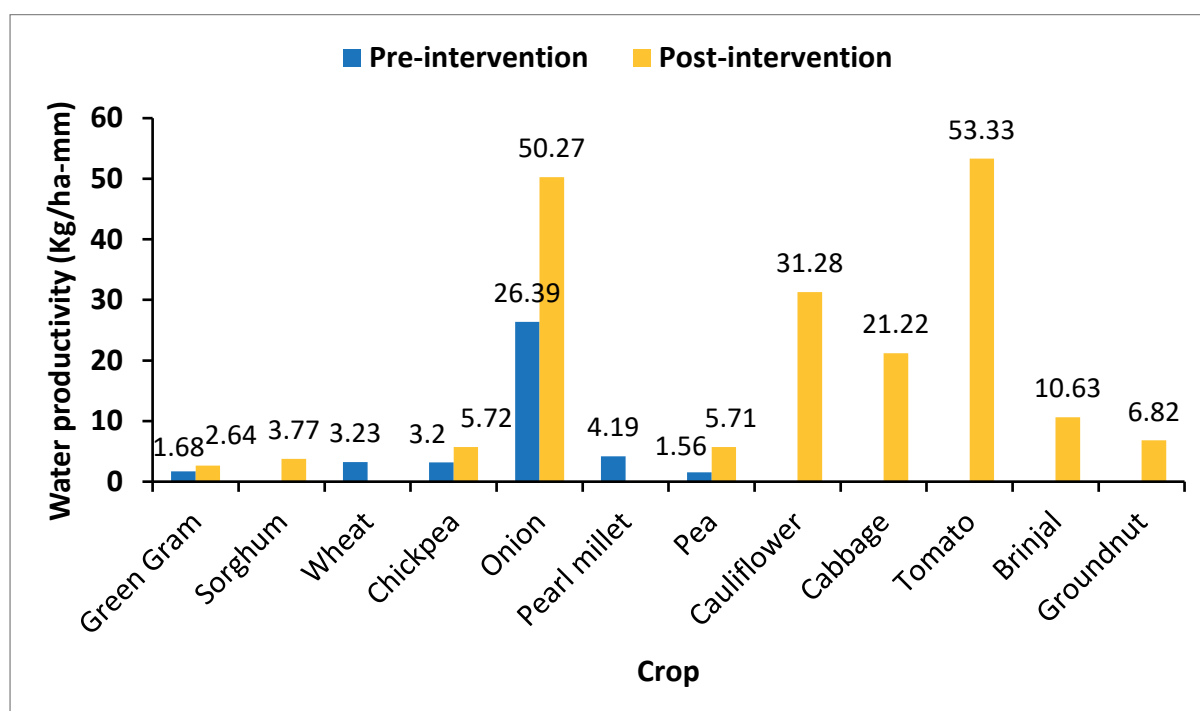


Figure 33 Comparison of change in pre and post-intervention water productivity in GMI-III

5. Discussion

This study assesses the possibility and effectiveness of WOTR's GMI approach for enhancing the agriculture productivity of a group of farmers, especially marginal and smallholder farmers, with their farms adjacent to each other. The GMI approach focus was on pooling the water resources in the area, sharing it through a micro-irrigation system, and supporting the farmers with an improved package of agriculture practices through weather-based location and crop-specific advisories.

The advisories were disseminated through the FarmPrecise mobile app developed by WOTR. The app provides information on up-to-date farming techniques and methods used, real-time weather data, 5-day weather forecast, early storm warning, fertiliser requirement for crops, their planning and application, information on irrigation needs and their application, nutrient management, integrated pest and disease management, and market prices of different crops in nearby markets. The GMI approach, thus, gives a complete package of agricultural advice to farmers with equal sharing and efficient use of available water resources, sustainably. The unique feature of the GMI approach is that the small patches of land owned by individual households are managed as one extensive farmland using common water sources and a micro-irrigation system. Also, there are common assets, e.g., water source (Dug well, farm pond, bore well, etc.), water pumping and distribution system, water filters, etc., which the group manages collectively, and individuals manage farm level assets, e.g., individual farmers maintaining drip laterals, emitters, venturi, sprinklers, etc. The interesting part about the GMI approach and the studied three GMI models is that a social institution has been formed (GMI farmers) with the help of government and non-governmental support, both in terms of finance and in building and implementing operating rules for the smooth execution of the model. The group (model) functions as one unit under a set of 8-10 rules which include the time each farm would receive irrigation through the installed drip systems. The pumping system, automation, water release valve mechanism, etc., helped provide equal water distribution. The rules were well documented and put up at the pump site/operating centre.

Rules (by groups) for the management of the GMI

- ✓ Water budgeting and crop planning before every season
- ✓ In crop planning, the selection of crops should be the same for all or with the same harvesting duration based on the water budget decisions
- ✓ Compulsory use of micro-irrigation
- ✓ Follow climate-resilient agricultural practices
- ✓ Compulsory contribution of group funds based on GMI land area for maintenance and repair expenditures
- ✓ Water-intensive crops not allowed when water availability is limited
- ✓ Rule breaking or late submission of maintenance funds to attract a fine which will be used for funding maintenance work
- ✓ A bank account should be maintained to deposit maintenance funds. This allows for tracking of all deposits and expenditures

For the smooth operation and management of GMI, some non-formalised rules were also followed in the groups. e. g. selecting different crops is permissible for the same seasons, provided they are not water-intensive, are of nearly the same crop period, and have almost similar water requirements (like Maize or Soybean, Cabbage, or Cauliflower, Onion, or Tomato).

The effectiveness of the GMI approach is evidenced by an increased area under crops and assured irrigation, a rise in cropping intensity, changing cropping patterns with diversified and high economic valued crops (e.g., Cotton, Onion, Vegetables, etc.), higher crop productivity, and improved water productivity. Adopting the GMI approach, therefore, supports various national and state level government programs, e.g., doubling farming income, wider adoption of micro-irrigation, organic farming, food, and nutritional security, etc.

In Tigalkheda, in the Bhokardan block of Jalna district, a GMI-I model established under a GIZ-funded project, is technically supported by the WOTR, including individual farmers' contributions according to land holding under GMI. The comparison in pre- and post-intervention revealed that post-intervention, there was about 44% rise in cropped area, 60% rise in cropping intensity, and conversion of a total of 64.9 acres (Kharif and Rabi) from partial to assured (full) irrigation. There was no significant change observed in the cropping pattern, but a large seasonal (Rabi) fallow land has come under irrigation. and an average of 50% rise in crop and water productivity for cereals and 18% for the cotton crop.

Similarly, in Ranmala hamlet of Bhangadewadi village, in the Parner block of Ahmednagar district, a GMI-II model again established under a GIZ-funded project, is technically supported by WOTR including individual farmers' contributions according to land holding involved in GMI. The comparison done on data collected for the pre- and post-project period revealed that in post-project years there was about 61% rise in cropped area, 117% rise in cropping intensity and conversion of 06 acres (area under GMI) of the area from rainfed and partial irrigation to assured (full) irrigation. No significant change was observed in cropping pattern but a gradual shift from cereals to vegetables (e.g., Drumstick, Onion, etc.) was seen. The observed average crop and water productivity for Drumstick were 75 qt/acre and 19.41 kg/ha-mm, respectively.

In Bhangadewadi village, in the Parner block of Ahmednagar district, a GMI-III model was established with GIZ, NABARD, Government of Maharashtra, and District Planning Board fund (Ahmednagar), with technical support from WOTR that included managing individual farmers' financial contribution as per the land holding allocated to GMI. The comparison of the data for the years revealed that post-intervention, there was about 15% rise in the cropped area and a 25% rise in cropping intensity, and a total of 65 acres (area under GMI) of the area was converted from rainfed and partial irrigation to assured (full) irrigation. A much-diversified change was observed in the cropping pattern with shifts seen from cereals to vegetable crops, and crop and water productivity for cereals were almost doubled.

The data for the three GMI models reveals that overall, there is a trend of decreased investments by farmers due to collaboration for the development and maintenance of water resources (e.g., dug wells, farm ponds, etc.) and installation and maintenance of water pumping and distribution system. Furthermore, as a group, GMI farmers can easily access subsidies for micro-irrigation. In addition to this, there has been a reduction in the agricultural input costs with the adoption of a package of CRA practices such as seed treatment, crop geometry, intercropping, trap crop,

application of Farmyard Manure (FYM), vermicompost, compost, Amrutpani, Jeevamrut, Vermiwash, pheromone trap, light trap, and bio-pesticides like Dashparni ark, and Neemark, etc. Also, costs related to transportation in the group were reduced with more coordination for sales of their harvest, procurement of seeds and agricultural inputs, etc.

As discussed above, for all the three GMI models, several factors contributed to the high production and productivity in the GMI group. The primary factors were the availability of efficient irrigation systems and a readily available source of water, and good coordination between farmers in terms of crop planning, water budgeting, resource management, implementation of irrigation scheduling, etc. Ultimately this coordinated mechanism of water sharing resulted in strengthened inter-personal relationships, judicious use of a precious resource that ensured sustainability of water for all even in the most severe drought conditions, and resilience to climate risks through the adoption of a package of practices. A secondary factor was the implementation of water conservation activities by the Government and WOTR in the area that enhanced available water resources.

There are also some challenges to the sustainability and upscaling of such GMI models. Farmers have always tied water ownership to land ownership, which becomes a barrier to sharing water. This perception of water users needs to change from competition to cooperation. This can be addressed by a regular collection of maintenance and development funds (monthly/seasonal contribution) for future repair and development needs. Utilisation of this fund when needed will be helpful for private resource owners (e.g., dug well and bore well owners) within the group to ensure a continued water supply to other members. The fund will reduce the individual investment of resource owners for future repairs and development of the resource. It would assure low-cost individual investment, equal and regulated access to water, and greater water availability throughout the year. Sufficient rainfall is required for the GMI approach to be successful, and farmers' adherence to the management rules of GMI is the only way to their sustainability. Also, further success of the GMI approach is contingent on post-harvest management systems and market linkages. The scaling up of GMI models requires careful study of the area's hydrogeological, biophysical and socio-economic conditions.

6. Conclusion

In India, more than 60% of irrigated agriculture and 85% of drinking water supplies depend on groundwater. Dependence on groundwater-based irrigation is expected to only increase due to fewer and sporadic precipitation events. As one of the worst climate affected countries, India's water scarcity issue is only escalating with time due to multiple factors including a rising population, increasing food demand, and natural and human-induced imbalance in the distribution of resources. To combat this situation, there is a need to adopt approaches/technologies that use and share available water resources efficiently and equally, and to apply climate-resilient farming practices to reduce climate-induced risks. In this context, our study findings reveal that WOTR's GMI approach has a significant impact on addressing

unsustainable use of available resources and addressing barriers to adopting micro-irrigation and climate-resilient farming practices by small and marginal farmers in a semi-arid area. Also, this approach enables an attitude of cooperation rather than competition, strengthens inter-personal relationships for effective coordination, lower individual investment, and provides equal access to water. It also provides easy access to subsidies and water-efficient technologies like micro-irrigation systems for those who otherwise cannot afford them. It enables farmers' risk-taking abilities, leading to crop diversification and uptake of new climate-resilient and water-efficient technologies, increases the bargaining power of a group, saves additional labour and transportation costs, and ultimately rewards them with higher profits.

At the field level, the effectiveness of the GMI approach is provided through empirical evidence of an increased cropped area, an assurance of irrigation water, a rise in cropping intensity with diversified crops of high economic value, and an increase in crop and water productivity. However, better adoption and implementation of the GMI approach and package of climate-resilient practices requires awareness at each stage of production. Moreover, market linkages and capacity building will further enable better adoption and upscaling.

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Watershed Organisation Trust, (WOTR)

2nd Floor, 'The Forum', Padmavati Corner

Pune Satara Road

Pune – 411009

Phone: +91 20 24226211; Fax: +91 20 24213530

Email: info@wotr.org ; Web: www.wotr.org