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Coping with Climate Change by Using Climate Resilient Technology in Rainfed Areas

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Abstract:
There are critical challenges of climate change on agriculture, particularly in developing countries like India, where a significant portion of the population depends on agriculture for livelihoods and food security. With over 80% of agricultural land rainfed and more than 60% of available groundwater dedicated to agriculture, there is a pressing need for water-saving practices to counter overexploitation of the groundwater. Focusing on Maharashtra, the study explores the implementation of the World Bank-aided Project on Climate Resilient Agriculture (PoCRA). PoCRA aims to enhance climate resilience and farm production in drought-prone villages across 16 districts, primarily in Marathwada and Vidarbha regions. The multifaceted approach of PoCRA introduces transformational changes in agriculture through climate-smart technologies and practices at the farm and micro-watershed levels, focusing on small landholders for drought-proofing and management. Critical interventions include soil and water management, micro-irrigation practices like drip and sprinkler irrigation, cropping pattern diversification, soil health improvement, Broad Bed Furrow (BBF), Zero tillage, climate resilient variety seed production and capacity building for farmers. The study focuses on the importance of the various climate-resilient agricultural technology components in mitigating the impact of reduced rainfall days and increasing drought situations in project areas. PoCRA's unique strategy aims to improve soil health, enhance water security and increase farm productivity and crop diversification through the micro-irrigation component. The study highlights the widespread adoption of climate-resilient technologies as cost-effective and location-specific, especially in drought-prone regions like Marathwada and Vidarbha. The study emphasizes the necessity of such practices to sustain the sector in the face of climate change.

Keywords: *Project Area, Climate Resilient Agriculture, Project on Climate Resilient Agriculture – PoCRA*, *Micro-Irrigation*

INTRODUCTION

The climate, both globally and in the Indian region, has been changing since the last century because of natural and man-made activities, as per the IPCC Fifth Assessment Report (Stocker et al., 2013). Climate change significantly impacts agriculture, affecting aspects such as crop production, livestock farming and water scarcity, leading to poor agricultural growth. Extreme weather conditions are direct hazards to crops. Climate change is predicted to reduce yields by 4.5 to 9 per cent, depending on the magnitude and distribution of warming (Guiteras, 2009). This has further caused increased concern over changes in climate and its direct and indirect impact on agriculture. Higher temperatures increase evaporation rates due to more energy in the system, accelerating the transition of water from liquid to vapour. This affects crop water requirements by necessitating more frequent irrigation to compensate for the faster water loss. Elevated temperatures often coincide with higher crop water needs as plants experience more excellent transpiration rates to cool themselves. This relationship is essential for effective water management in agriculture, especially in regions susceptible to drought. Most crops require specific climatic conditions, which involve the correct water amounts provided through irrigation. Notably, smaller farmers may need help investing in wells due to cost considerations compared to their larger counterparts (Foster et al., 2008).

About 49% of the country's labour force depends on agriculture for their livelihoods. Despite the decline in its contribution to the gross domestic product (GDP) due to the growth of other sectors, agriculture remains the backbone of India's economy. India's agriculture heavily depends on the Southwest monsoon, with more than 80% of the annual rainfall occurring between June and September Noaa (2024). The National Rainfed Area Authority of India reports that 60% of the country's cultivated area depends on natural rainfall, known as rainfed agriculture NMSA (2014). This temporal concentration poses a risk to Indian agriculture due to uncertainties in both timing and distribution, significantly impacting crop growth and yield and posing a considerable threat to the nation's overall agricultural productivity. This makes it imperative to address climate variations' potential risks and challenges to safeguard its agricultural sector, a crucial component of the country's economy. With only 4% of the total global land, India accommodates 24% of the world's population and has more than 30% of the global irrigated land. (FAO 2013). Over the years, the irrigated area in the country has risen from 58.8% in 1961 to 60.4% in 2016 (World Bank data 2017). However, despite this, per capita water availability has drastically declined from 5200m^3 in 1950 to 1820m^3 in 2001, reaching 1700m^3 in 2009, with projections suggesting a further reduction to below 1000m^3 by 2050 (Samra et al., 2009). The need for systematic planning for groundwater extraction in India adds to the concerns. (Aggarwal et al., 2009). India faces over-exploitation of groundwater, with an estimated 15% of the country's food production relying on unsustainable groundwater mining. The increasing reliance on groundwater for irrigation necessitates a comprehensive and sustainable approach to water management to address the challenges posed by diminishing per capita water availability.

In India, the two main categories of operators managing small-sized land holdings are (i) small farmers, overseeing land holdings ranging from 2.5 to 5 acres, and (ii) marginal farmers, handling fewer than 2.5 acres. India's average size of land holdings has steadily decreased from 2.28 ha. In 1970–71 to 1.08 ha. In 2015–16 PIB (2020), reaching economically unsustainable levels. This trend forces farmers to abandon land and seek better opportunities elsewhere. Consequently, substantial portions of productive land remain uncultivated or underutilized due to a lack of physical and human capital (NITI Aayog, 2016). This scarcity of resources makes it challenging for farmers to adopt new technologies, adversely impacting both farm productivity and farmers' incomes. Unfortunately, the smaller land size for these farmers makes it difficult to generate sufficient employment and income solely from crop cultivation. Despite this, small and marginal farmers have higher efficiency per hectare basis and cropping intensity compared to their larger counterparts (Chand et al., 2011). The increase in deforestation and expansion of crop cover across the Indian region has led to notable shifts in surface temperatures on both daily and extreme scales with changes in rainfall patterns and intensity (Halder et al., 2016). The rising temperatures in surface water are intensifying evapotranspiration, increasing the water demand for crops. With limitations on the water supply side, the focus must shift to reducing the water footprint through enhanced water use efficiency. Maharashtra, with the highest number of dug wells in India at 2,749,088 as per the 6th Census Minor Irrigation Scheme Report (2017-18), faces challenges due to igneous basaltic rock hindering groundwater recharge. The southwestern part of Maharashtra, including the regions of Marathwada and Vidarbha, falls under the rain shadow area of the southwest monsoon. This geographical area often struggles with water scarcity due to lower rainfall compared to the state's western half. This has led to the overexploitation and depletion of groundwater resources. To tackle the current climate change and drought challenges, there's a critical need to promote micro-irrigation practices and enhance water efficiency among farmers.

STUDY AREA

The state of Maharashtra is situated in the western and central part of India, with a geographical area of 307,713 sq. km, bounded by latitude 15°40' and 22°00' N and longitude 72°30' and 80°30' E. There are nearly 44664 villages in Maharashtra (Common Village Master of Maharashtra). The state is classified into nine different agro-climatic zones, i.e. South Kokan Coastal Zone, North Kokan Coastal Zone, Western Ghat Zone, Sub Mountain Zone, Plain Zone, Scarcity Zone, Central Maharashtra Plateau Zone, Central Vidarbha Zone, Eastern Vidarbha Zone. The state experiences a tropical monsoon climate and receives rainfall from the Southwest monsoonal winds (June – September). Most blocks in Maharashtra have experienced a rise in southwest monsoon rainfall over the last decade. However, this increase is mainly due to short-lived heavy rainfall events. Indian agriculture faces challenges due to variations in southwest monsoon rainfall distribution patterns (Mandal et al., 2013). These variations increase the country's drought-like conditions, resulting in the late sowing of rainy-season crops. An early withdrawal of rains results in reduced yields due to severe moisture stress on crops (Dixit et al., 2005). Semi-arid regions in districts such as Jalgaon, Nashik, Chhatrapati Sambhajinagar, Beed, and Dharashiv have dry climates. This region experiences average daily temperatures between 18°C and 22°C in winter and above 22°C in other months, with low annual rainfall ranging from 600–900 mm, primarily during the southwest monsoon season. Relative humidity remains below 50% throughout the year, dropping below 30% for two to three months in summer. Precipitation is limited to the monsoon season, with annual rainfall exceeding 700 mm. The average relative humidity is above 60%, dropping to less than 30% for one or two months in summer. In several districts, such as Akola, Aurangabad, Hingoli, Jalgaon, Latur, Osmanabad, and Parbhani, groundwater levels are relatively deep, exceeding 10 meters. The average groundwater depth in these districts falls below 15 meters. The private investment in bore wells has led to over-exploitation of groundwater resources, further complicating the agricultural landscape. About 80% of Maharashtra's agricultural land operates outside the formal irrigation systems provided by the State, as revealed by the Economic Survey of Maharashtra 2013-14. Although the state has recently embarked on large-scale investments in water harvesting structures, the area under irrigation remains low. Addressing the existing yield gaps and enhancing crop productivity in Maharashtra's semi-arid regions needs a primary focus on augmenting water availability for agriculture, particularly during periods of soil moisture deficit.

Climate Resilient Agriculture (CRA)

As defined by the Food and Agriculture Organization (FAO), CRA is an agricultural model that not only boosts sustainable productivity but also enhances resilience through adaptive strategies while concurrently mitigating greenhouse gas emissions (FAO). Climate-resilient agriculture (CRA) represents a holistic approach to farming, which is crucial for adapting to the challenges of climate change.

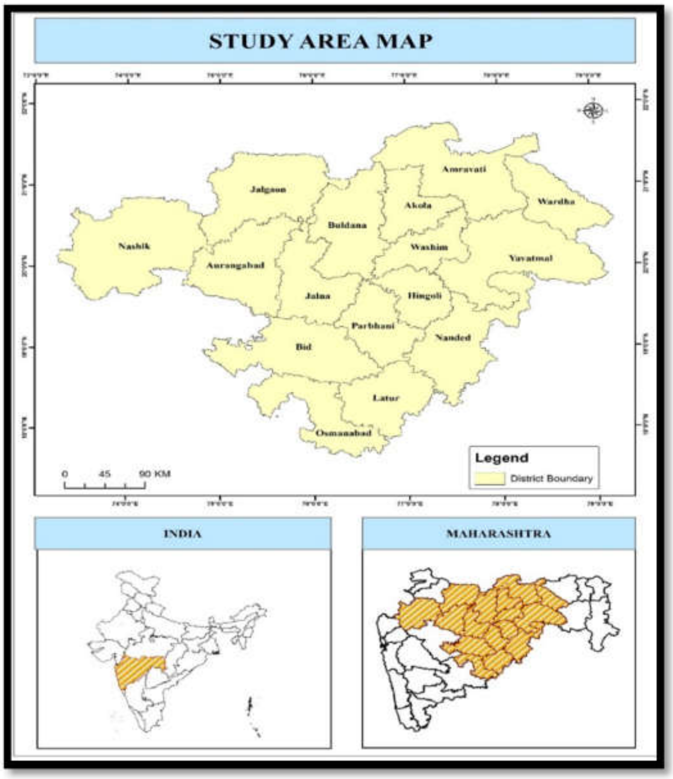


Figure 1: PoCRA Study Area

Project on Climate Resilient Agriculture – PoCRA

To tackle the challenges arising from altered monsoon patterns and groundwater depletion, the GoM has initiated the World Bank-aided Project on Climate Resilient Agriculture (PoCRA) to develop a drought-proofing and climate-resilient strategy for the agriculture sector as a long-term and sustainable measure to address the likely impacts due to climate variabilities and climate change. The project aimed to enhance the climate resilience and profitability of small landholders in selected districts of Maharashtra, using a multi-sector approach that focuses specifically on building climate resilience in agriculture through scaling up tested technologies and practices. PoCRA aimed to provide back-ended subsidies to farmers in 5220 villages across 700 project clusters in 16 districts of Maharashtra. The villages in these 16 districts were selected based on Vulnerability Assessment Indicators like ***Climate Exposure indicators*** (such as rainfall, cold days, dry spells, frost days, temperature), ***Sensitivity Indicators*** (net sown area, degraded area, wasteland area, drought proneness, percentage of small and marginal farmers, groundwater prospects), and ***Adaptive Capacity*** (farmer suicide rates, percentage of Scheduled Castes, Scheduled Tribes, agricultural labour, female literacy gap), etc. Interventions for building resilience were taken at **the farm level**, where water security, soil health, crop diversification, climate-resilient practices, and allied activities were focused through drip irrigation, sprinkler irrigation, protective cultivation like shade net and polyhouse, agro-forestry, horticulture, sericulture, broad bed furrow method etc. **Community** support for agribusiness activities such as storage, processing units, and custom hiring centers for mechanization was provided through components like agri-business value chain, warehouse, and processing and value chain development. **Village-level** interventions like natural resource management are essential aspects.

Under the project, water security was provided through supply-side interventions such as wells, well recharge, area treatment activities (continuous counter trench, loose boulder structure, farm pond, etc.), drainage line treatment (Mati-Nala Band, Earthen-Nala Band, Gabion, Cement-Nala Band, recharge shaft, etc.), and demand-side water-saving interventions like drip and sprinkler irrigation, etc. Micro irrigation has emerged as a critical aspect of India's demand-side management strategy, focusing significant policy attention (Malik et al., 2016, Government of India Budget 2017). Micro irrigation is a modern agricultural practice offering a solution to the challenges of water scarcity and resource efficiency. The Drip and Sprinkler irrigation systems are the two micro irrigation systems practised in India. The overall water use efficiency varies across different irrigation methods. Surface irrigation is around 40%, 50%, and 60%, sprinkler irrigation is 80% and 85%, and drip irrigation reaches 90% and 95% efficiency. The Water Use Efficiency achieved through project interventions covers an extensive area of 507719 hectares under micro-irrigation. This has provided substantial benefits to 230485 farmers (beneficiaries) through Drip irrigation, alongside positive impacts seen on 218713 farmers (beneficiaries) supported by Sprinkler irrigation.

Micro-Irrigation

The **Drip Irrigation** system stands out as a cutting-edge irrigation method, offering remarkable efficiency by delivering water directly to the base of plants at a rate nearly matching their consumptive needs. This precision application method minimizes traditional water losses such as percolation, runoff, and soil evaporation. Its success has been particularly notable in diverse crops such as mangoes, grapes, papayas, and orchards; moreover, by localizing water application and reducing leaching, fertilizer use efficiency increases. Drip irrigation also suppresses weed growth, adapts to uneven terrains without requiring levelling, allows for inter-cultivation alongside watering, and remarkably saves energy, labour and workforce. The holistic benefits of this method are evident in its ability to enhance plant growth and boost the overall quality and quantity of crop yield, making it a transformative approach in modern agricultural practices. (Guidelines for Planning and Design of Micro Irrigation System - Irrigation and Water Resources Department Uttar Pradesh)

Sprinkler Irrigation emerges as a dynamic method, where pressurized water jets are discharged into the air, mimicking artificial rainfall upon reaching the earth's surface. Utilizing a network of High-Density Polyethylene (HDPE) pipes and a series of nozzles, this system offers versatility for a range of crops such as Wheat, Cotton, Groundnut, Tobacco, Potato, Onion, Ginger, Peas, and more. This method mitigates waterlogging issues and eliminates runoff, making it ideal for challenging terrains where surface irrigation may not be viable. Moreover, it aids in maintaining optimal soil moisture levels, enhancing both the quantity and quality of agricultural yields. Another advantage lies in the ease of applying water-soluble insecticides, herbicides, and pesticides during irrigation, leading to efficient pest and disease management and significant cost savings for farmers. (Guidelines for Planning and Design of Micro Irrigation System - Irrigation and Water Resources Department Uttar Pradesh)

METHODOLOGY

The project evaluation involves a comprehensive approach utilizing various surveys and monitoring mechanisms. It includes baseline, mid-term, and end-term surveys conducted through a household survey tool to gather quantitative data. Additionally, qualitative insights on the micro irrigation system are obtained through Focus Group Discussions (FGDs) with beneficiaries and the Village Climate Resilience Management Committee (VCRMC). Concurrent monitoring rounds are carried out every six months to assess the process and progress of micro-irrigation implementation. The data collection methodology involves a representative random sampling from 5220 project villages, with 898 villages sampled for the project area and 690 villages for the comparative area. The evaluation employs a statistical method using a Quasi-experimental Design with a Double Difference approach, ensuring a robust a-priori matching of project and comparison clusters for reliable attribution of project outcomes. Quasi-experimental designs help select a comparison group resembling the project group in pre-intervention characteristics. In the Marathwada region, the project-to-comparison ratio is 1:1, while in the Rest of the Project Area (RoPA), it is 2:1. Furthermore, the qualitative and quantitative data are assessed separately through a dedicated micro irrigation component questionnaire as part of the evaluation process. The evaluation of micro irrigation focuses on a specific result framework indicator - improving water use efficiency through adopting new or improved irrigation services. The end-term target was set at 624,000 hectares, and as of the data available until March 15, 2024, the achievement stands at 507,719 hectares. This indicator is a crucial measure of the impact and effectiveness of the micro-irrigation interventions within the project. Data regarding the number of villages, farmers, and the disbursement amount for micro-irrigation beneficiaries is obtained through the Project's Direct Beneficiary Transfer system.

An empanelled third-party monitoring and evaluation agency thoroughly analyzes the data on the micro irrigation system. This includes conducting Household Surveys (HH surveys), qualitative interviews, essential expert field visits, and drawing relevant secondary data sources. The assessment focused on various aspects, determining the extent of area covered under micro irrigation, quantifying the water and energy conservation achieved in comparison to traditional methods, evaluating the impact of micro irrigation on the cultivation of high-value crops with reduced water usage, analyzing the increase in crop yields, and understanding how these factors contribute to the overall augmentation of farm income. Furthermore, the agency identifies villages with high and low adoption rates of micro-irrigation, comparing their impact on water use efficiency. These villages are geographically plotted on a map to assess their distribution visually. The analysis also shows the reasons for low adoption rates and suggests forward-looking strategies to enhance the adoption and effectiveness of micro-irrigation practices in the region.

DISCUSSION

Drip

Farmers' response towards the micro irrigation component in the project area has been exceptionally high, emerging as one of the most demand-driven elements within the project. As of 15th March 2024 (DBT- PoCRA), 2420.72 crore has been disbursed for this component, indicating considerable demand and uptake among farmers.

Table no. 1 provides data on the implementation of drip irrigation across various districts in the project area. It includes the number of farmers adopting drip irrigation and the corresponding disbursement amount (INR Cr). The districts vary widely in farmer participation, with Wardha having the lowest number of 238 farmers (beneficiaries), covering a total irrigated area of 267.51 hectares, while Chh. Sambhajinagar has the highest participation with 63266 farmers (beneficiaries), covering 79,571.46 hectares. The total indicates significant adoption and investment in drip irrigation, totalling 230,485 farmers (beneficiaries) and a disbursement amount of INR 1,993.18 Cr. The total area under drip irrigation across the 16 districts within the project area covers 286,407.75 hectares. (Table 1)

Table 1: Drip Irrigation beneficiaries in project area.

Drip Irrigation					
Sr. No.	**District**	**No of Villages**	**No. of farmers**	**This Amt (In Crore)**	**Total Area District wise (in Ha)**
1	Akola	487	1185	10.89	1375.29
2	Amravati	516	1865	7.95	2173.38
3	Beed	391	12964	103.99	16419.12
4	Buldhana	428	14083	121.70	16921.95
5	Chh. Sambhajinagar	405	63266	557.95	79571.46

6	Dharashiv	283	10418	74.75	12432
7	Hingoli	236	9153	70.12	10796.97
8	Jalgaon	454	59055	549.90	76612.2
9	Jalna	363	34380	306.10	41940.24
10	Latur	280	6062	48.25	7249.41
11	Nanded	384	7578	61.70	8830.05
12	Nashik	142	2379	15.31	2721.72
13	Parbhani	275	5181	40.87	6019.53
14	Wardha	125	238	1.75	267.51
15	Washim	149	1555	11.68	1768.23
16	Yavatmal	302	1123	10.26	1308.69
	Grand Total	**5220**	**230485**	**1993.18**	**286407.75**

The data collected for five case studies shows a mixture of irrigation sources, with bore wells and open wells being the primary sources. The area under micro-irrigation (Drip) ranges from 0.40 hectares to 2.83 hectares (1 to 7 acres), with corresponding pump capacities varying from 3 to 7.5 HP. The total number of irrigations throughout the crop cycle differs significantly, from 4 to 45, showing different irrigation practices and needs for each plot among various districts. The hours of per-day irrigation range from 2 to 8 hours, showing the duration of water application for each plot and crop. The total annual incomes exhibit substantial variation, from 30,000 to 300,000, reflecting each plot's different yields and profitability. (Table 2)

Table 2: Drip Irrigation case study in the project area.

Drip Irrigation					
District	Akola	Amravati	Buldana	Jalgaon	Wardha
Taluka	Akot	Chandur Bazar	Khamgaon	Jalgaon	Arvi
Village	Belura	Sarfabad	Atali	Beli	Gaurkheda
Name of Farmer	Prabhudas Sabale	Rushikesh Nawalkar	Devidas P. Dandale	Liladhar Narkhede	Meera Dole
Irrigated Crop Name	Oranges	Oranges	Onion	Sugarcane	Pigeon Pea
Irrigation before PoCRA intervention	Flood	Flood	Flood	Flood	Flood
Source of irrigation	Bore well	Bore well	Open well	Open well	Open well
Micro-Irrigation type	Drip	Drip	Drip	Drip	Drip
Area under Micro-Irrigation (Acre)	1	4	1	7	5
Type of Pump	Electric	Electric	Electric	Electric	Electric
Pump Capacity (HP)	7.5	5	3	5	5
Total Number of Irrigation (Sowing to harvest)	10	4	20	45	5
Date of first irrigation	X	X	1/10/2022	6/9/2020	9/5/2020
Number of hours of Per-day Irrigation (in hours)	2	8	6	3	5
Total Annual Income	34,000	300,000	100,000	30,000	220,000

According to the Aquifer Maps and Groundwater Management Plan for Aurangabad (Chh. Sambhajinagar) District 2019, as reported by the CGWB, the average rainfall from 1998 to 2017 was recorded at 734.1 millimeters. There has been a decreasing trend in long-term rainfall, dropping at a rate of 4.47 millimeters per year. Additionally, the groundwater levels have been decreasing at a rate of 0.2 meters per year across most of the district's blocks. This decrease has reduced surface water availability and groundwater storage availability, ultimately leading to water scarcity. Consequently, this has resulted in a noticeable shift from traditional irrigation practice (Flood) towards the adoption of micro-irrigation practice (Drip) in Chhatrapati Sambhajinagar, particularly in the project areas.

Sprinkler

Table no. 3 presents data on farmers' adoption of sprinkler irrigation across various districts. It includes the number of farmers utilizing sprinkler irrigation, the number of applications, and the disbursement amount (INR Cr) for each district. The districts range from Nashik with four farmers (beneficiaries) and Jalgaon with 991 farmers (beneficiaries) with the lowest adoption to Dharashiv with the highest number of 30396 farmers (beneficiaries). The total indicates substantial adoption and investment in sprinkler irrigation, with 218,713 farmers (beneficiaries) and a disbursement amount of INR 427.56 Cr. The total area under sprinkler irrigation across the 16 districts within the project area amounts to 221312 hectares. (Table No 3)

Table 3: Sprinkler Irrigation beneficiaries in project area.

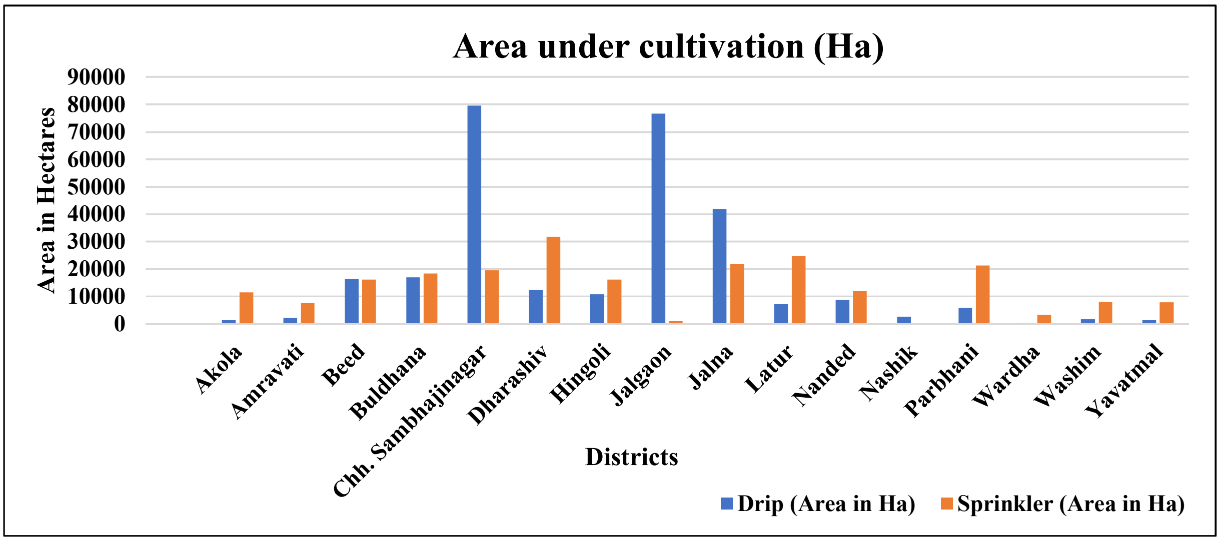
Sprinkler Irrigation					
Sr. No.	**District**	**No of Villages**	**No. of farmers**	**This Amt (In Crore)**	**Total Area District wise (in Ha)**
1	Akola	487	11290	27.63	11562
2	Amravati	516	7632	16.77	7698
3	Beed	391	16151	30.26	16202
4	Buldhana	428	18287	34.99	18419
5	Chh. Sambhajinagar	405	19521	35.96	19582
6	Dharashiv	283	30396	67.15	31858
7	Hingoli	236	16091	29.30	16168
8	Jalgaon	454	991	1.92	998
9	Jalna	363	21666	40.04	21732
10	Latur	280	24429	47.86	24679
11	Nanded	384	11866	21.92	11936
12	Nashik	142	4	0.01	4
13	Parbhani	275	21260	39.13	21302
14	Wardha	125	3298	5.95	3312
15	Washim	149	7956	14.52	7974
16	Yavatmal	302	7875	14.15	7886
	Grand Total	**5220**	**218713**	**427.56**	**221312**

The data collected for five case studies show a mixture of open wells, bore wells, and a canal as irrigation sources, with sprinkler-type micro-irrigation uniformly employed across all plots. The area under micro-irrigation (Sprinkler) varies from 0.80 hectares to 2.02 hectares (2 to 5 acres), with corresponding pump capacities ranging from 3 to 5 HP. The total number of irrigations required from sowing to harvest also shows variability across plots, ranging from 1 to 6 irrigations. The data shows the number of hours per day for irrigation, varying from 2 to 6 hours. This reflects the duration of water application for each plot, possibly influenced by factors such as soil type and crop water requirements. Total annual incomes range from 34,000 to 200,000, indicating the varying profitability of each plot.

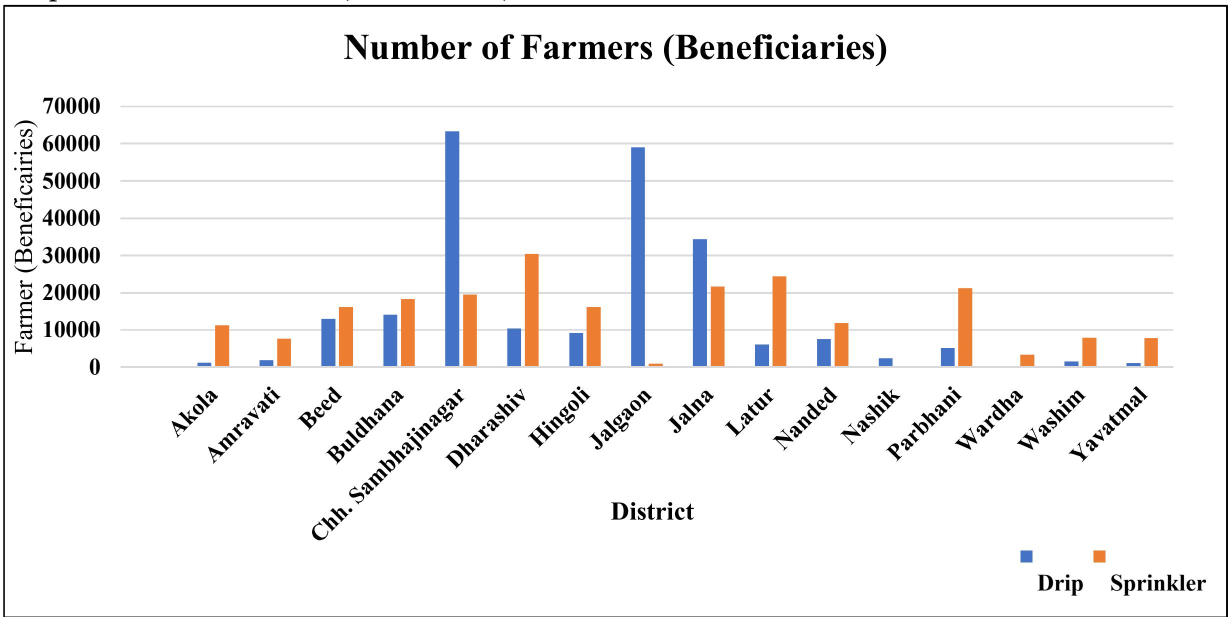
Table 4: Sprinkler Irrigation sample study in project area.

Sprinkler					
District	Akola	Amravati	Jalgaon	Buldana	Wardha
Taluk	Barshitalki	Chandur Bazar	Muktainagar	Jalgaon Jamod	Samudrapur
Village	Tiwasa Bk.	Asegaon	Rigaon	Hashampur	Waigaon
Name of Respondent	Dhondu Kamble	Janardhan Bobde	Ganjidhar Baghe	Nasiroddin Vajiroddi	Shravan Laxman Pawar
Irrigated Crop Name	Wheat	Soybean	Cotton	Cotton	Chickpea
Source of irrigation	Open Well	Bore Well	Open well	Open well	Canal
Irrigation before PoCRA intervention	Flood	Flood	Flood	Flood	Flood
Micro-Irrigation type	Sprinkler	Sprinkler	Sprinkler	Sprinkler	Sprinkler
Area under Micro-Irrigation (Acre)	2	2.2	5	5	4
Type of Pump	Electric	Electric	Electric	Electric	Electric
Pump Capacity (HP)	5	5	3	3	3
Total Number of Irrigation (Sowing to harvest)	5	1	2	6	3
Date of first irrigation	12/3/2020	6/23/2020	5/30/2020	10/7/2020	11/7/2020
Number of hours of Per-day Irrigation (in hours)	5	6	6	6	2
Total Annual Income	200,000	100,000	110,000	34,000	50,000

According to the Aquifer Maps and Groundwater Management Plan for Osmanabad (Dharashiv) District 2019, as reported by the CGWB, the average rainfall from 1998 to 2017 was recorded at 807.2 millimeters. There has been a decreasing trend in long-term rain, dropping to 7.1 millimeters per year. Additionally, the groundwater levels have been decreasing at a rate of 0.2 meters per year across most of the district's blocks. This decrease has reduced surface water availability and groundwater storage availability, ultimately leading to water scarcity. Consequently, there has been a remarkable shift towards adopting micro-irrigation techniques (Sprinkler) in Dharashiv, particularly in the project areas.



Graph 1: Number of Farmer (Beneficiaries)



Graph 2: Area under cultivation (In Hectares)

Graph no. 1 shows the leading districts in farmer adoption of irrigation methods, Chh. Sambhajinagar stands out among the farmers (beneficiaries) who utilize drip irrigation the most, while Dharashiv takes the lead in adopting sprinkler irrigation. In contrast, Wardha has few farmers adopting drip irrigation, and Nashik and Jalgaon have the lowest adoption rates for sprinkler irrigation.

Graph no. 2 shows the districts with the most significant cultivation areas (in hectares) for irrigation methods Chh. Sambhajinagar shows the maximum drip irrigation cultivation area, while Dharashiv leads the sprinkler irrigation cultivation area. Conversely, Wardha, Nashik, and Jalgaon exhibit the minimum drip and sprinkler irrigation cultivation areas. An interesting observation is that Jalgaon ranks second in drip irrigation adoption but displays the lowest adoption rate for sprinkler irrigation. India holds the top position globally for banana production (World Population Review Report 2024), with Jalgaon ranking first in Maharashtra for banana production. The banana crops under drip irrigation used 273 m3 less water (471 m3) compared to surface irrigation (744 m3), showing 25% to 50% water savings (Ahmed et al., 2011). Drip irrigation leads to a 29% increase in banana crop productivity due to the absence of moisture stress (Narayanamoorthy 2009). It may be one reason for the second-highest drip irrigation adoption in the Jalgaon district. There is a clear relationship between the adoption of micro-irrigation techniques by farmers (beneficiaries) and the cultivated area (in hectares) within each district.

CONCLUSION

The adoption and sustainability of micro irrigation systems in agriculture, particularly in Maharashtra, reflects a positive shift towards efficient water use and enhanced farm productivity. The government's commitment to providing subsidies for micro-irrigation systems like drip and sprinkler technologies once every seven years reflects a strategic approach to supporting farmers in their investment decisions, as outlined in the Operational Guidelines of PMKSY. According to the land utilization statistics for 2021-22, the net sown area accounted for 165.90 lakh hectares, constituting approximately 53.9 per cent of the state's total geographical area, which stands at 307.58 lakh hectares. Despite significant efforts through various micro-irrigation schemes, the irrigated area still needs to be improved. As of 2021-22, in Maharashtra, the area covered under micro-irrigation stands at about 8.86 lakh hectares, representing about 5.34% of the total net sown area (Economic Survey of Maharashtra 2022-23). Hence, there is a vast scope for increasing the irrigation area with the help of various micro-irrigation schemes. Additionally, PoCRA has extended its support for micro-irrigation across 5,220 villages in 16 districts within the project area, benefiting about 449,198 farmers and covering an area of approximately 507,719.75 hectares under micro-irrigation. Through such initiatives, the agricultural sector can continue to evolve towards climate-resilient agriculture more efficiently, with environmentally friendly and economically viable practices, benefiting both farmers and the larger ecosystem and addressing the issue of climate change. Policy focus should mainly target the promotion of micro-irrigation in areas where water scarcity is a significant concern, thereby addressing crucial agricultural sustainability challenges and ensuring improved water management practices nationwide.

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The authors of this manuscript do not oppose the interest.

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