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A Study on Impact of Pradhan Mantri Krishi Sinchai Yojana (PMKSY) on Agricultural Productivity in Jhalawar District of Rajasthan

Ayush Gupta[1], Ashish Asopa[2], Gomi[3] Santosh Sharma[4] & K. R. Choudhary[5*]

[1]Research Scholar (Economics), Department of Social Sciences, University of Kota, Kota, Rajasthan, India.
[2]Assistant Professor, Department of Commerce & Management, University of Kota, Kota, Rajasthan, India.
[3]Research Scholar, Department of Geography, Career Point University, Kota, Rajasthan, India.
[4]Research Scholar (Economics), Department of Social Sciences, University of Kota, Kota, Rajasthan, India.
[5]Assistant Professor (Economics), Department of Social Sciences, University of Kota, Kota, Rajasthan, India

[*]**Corresponding author:** krjchoudhary@gmail.com

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Abstract: *The study examines the impact of the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) on irrigation development and agricultural performance in Jhalawar district of Rajasthan. Secondary data covering the period from 2014–15 to 2023–24 were analyzed to assess changes in irrigated area and crop yields. The findings show that the district achieved more than 31,000 hectares under micro irrigation, ranking eleventh in the state and surpassing 22 districts in coverage. Crop-wise analysis reveals major gains in mustard, gram, garlic, and wheat, which registered significant improvements in both irrigated area and yield. Paddy and rice expanded in area but recorded only moderate yield gains, while coriander and fenugreek experienced a decline in irrigated coverage. Garlic and onion displayed sharp fluctuations yet confirmed a shift toward high-value horticultural crops. The results indicate that PMKSY has strengthened water-use efficiency and promoted crop diversification in Jhalawar. The study also identifies challenges such as high installation costs, limited training, variable crop responses, and the need for region-specific strategies. The scheme has acted as a catalyst for irrigation-led growth in Jhalawar but requires complementary measures for sustaining balanced and inclusive agricultural development.*

Introduction

Early civilizations created irrigation systems and adopted water conservation practices to support agrarian life and safeguard social well-being. Agricultural production requires water as a primary resource to sustain crop yields and food availability. The reduction in water supply has deepened the rural crisis in several regions. Farming in India still depends largely on an unpredictable monsoon. Irrigation infrastructure is therefore vital to secure productivity and maintain sustainability. Since independence the Indian state has introduced a wide range of programmes and policies to strengthen irrigation and conserve water resources. In the present era irrigation and water management form the core of agricultural development planning. Government agencies are implementing several flagship schemes to enhance irrigation coverage across the country. Yet a considerable proportion of cultivable land continues to remain outside the reach of assured irrigation despite advances in technology and crop improvement **(Government of India 2021)**. To address this vulnerability the Government of India introduced the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) in July 2015. The scheme was launched with the vision of *Har Khet Ko Paani* which means irrigation for every field. It also adopted the guiding principle of *More Crop per Drop* which emphasizes water-use efficiency and the expansion of irrigation coverage **(NITI Aayog 2016)**. PMKSY was designed as an umbrella programme that brought together earlier initiatives such as the Accelerated Irrigation Benefits Programme, the Integrated Watershed Management Programme, and the On-Farm Water Management component of the National Mission on Sustainable Agriculture **(Planning Commission 2015)**. The scheme functions through four complementary parts. These are the Accelerated Irrigation Benefit Programme, Har Khet Ko Pani, Per Drop More Crop, and Watershed Development. Together these interventions aim to expand the irrigated area and reduce the dependence on monsoon rainfall. They also encourage micro-irrigation technologies and seek to improve agricultural productivity **(Ministry of Agriculture & Farmers Welfare 2020)**.

In Jhalawar district of Rajasthan the Pradhan Mantri Krishi Sinchai Yojana holds particular significance because of the region's distinct agro-climatic conditions. Unlike the arid western part of the state Jhalawar records comparatively high rainfall of about 900 to 1,000 millimetres each year **(Krishi Vigyan Kendra Jhalawar, n.d.)**. Even so variability in rainfall and uneven distribution of water across blocks continue to influence cropping intensity and household incomes. The district is widely known as the "Orange City" of Rajasthan where soybean, wheat, maize, and citrus crops dominate the agricultural economy. At the same time issues such as declining groundwater levels in certain areas rising costs of irrigation and continued dependence on monsoon rainfall in rainfed zones point to the urgent need for effective irrigation interventions.Under PMKSY, Jhalawar has witnessed investments in micro-irrigation through drip and sprinkler systems, construction of farm ponds and check-dams, and promotion of water-use efficiency among small and marginal farmers **(Government of Rajasthan, 2022)**. The success of these initiatives in the district depends not only on financial allocations but also on effective implementation, farmer participation, and coordination with other rural development programmes **(Choudhary & Mathur, 2021)**. Because irrigation is directly linked to resilience, farm productivity, and rural incomes, PMKSY in Jhalawar has become an essential focus for researchers and policymakers alike. Studying its progress at the district level offers valuable insights into the returns on public investment, the spread of micro-irrigation, and its impacts. The present paper examines the implementation of PMKSY with special reference to Jhalawar district, highlighting its achievements, challenges, and implications for fostering sustainable agricultural growth in water-dependent regions of Rajasthan.

Review of Literature

A study revealed that sprinkler irrigation has emerged as a promising technology in water scarce regions. It delivers water directly to the root zone and ensures efficient utilization of available resources. It also reduces wastage and enhances crop yields in different farming systems. In Rajasthan the compound annual growth rate of sprinkler irrigated area was recorded at 27.9 percent during 2005–06 to 2021–22 which indicates its increasing adoption as a micro irrigation practice. The study further showed that sprinkler irrigation improved crop productivity and also reduced energy consumption while minimizing the use of chemical inputs leading to an overall increase in farm incomes. Economic feasibility analysis demonstrated that the 2-inch sprinkler system was the most viable option as it provided the shortest payback period and the highest benefit cost ratio which made it particularly suitable for farmers in Bikaner district **(Kumari et al., 2023)**. In Uttarakhand the beneficiaries of the Pradhan Mantri Krishi Sinchai Yojana were predominantly middle-aged farmers with moderate levels of education, medium farm sizes, and average farming experience. The study emphasized that enhanced training opportunities, stronger extension linkages, and greater social participation are essential for promoting the wider adoption of micro-irrigation systems **(Adhikari et al., 2021)**. The adoption of drip irrigation under the Pradhan Mantri Krishi Sinchai Yojana in Tamil Nadu faced several constraints. Farmers experienced technical difficulties such as clogging of drippers and problems in maintaining water pressure. These challenges were compounded by infrastructural limitations including irregular electricity supply and inadequate after-sales service. The high cost of equipment and maintenance added to the financial burden of cultivators, while insufficient training, limited awareness, and weak extension support reduced the effective utilization of the system **(Rajaguru et al., 2023)**. A study was conducted in Satna district of Madhya Pradesh PMKSY interventions significantly improved the economics of wheat cultivation. Between 2014–15 and 2018–19, wheat production increased by 35.96 percent for non-beneficiaries and 52.33 percent for beneficiaries. Returns from by-products also rose by 33.01 percent and 33.86 percent respectively, indicating that PMKSY played a positive role in enhancing both productivity and profitability of wheat farmers **(Suryvanshi& Gupta, 2021)**. In the Amber block of Jaipur most of the Pradhan Mantri Krishi Sinchai Yojana beneficiary farmers were from the middle-aged group with small to medium family sizes and medium landholdings. Nearly ninety percent of the respondents were literate and the majority exhibited medium levels of information, economic motivation and risk orientation. Approximately half of the respondents possessed medium knowledge regarding the scheme while only 17.5 percent demonstrated high knowledge which highlights the need for enhanced awareness and strengthened extension support **(Sharma & Mazhar, 2023)**

Research Methodology

This study is based on secondary data related to the PMKSY in Jhalawar district of Rajasthan collected from Government of India's official website, https://www.pmksy.gov.in. The objectives of the Study are:

- To review the implementation of PMKSY in Jhalawar district and Rajasthan using official records, government reports, and published data sources.
- To analyze trends in irrigated area and micro-irrigation coverage in Jhalawar District since the launch of PMKSY.
- To study changes in crop diversification under the influence of improved irrigation facilities in the district.
- To study the impact of PMKSY on agricultural productivity in Jhalawar district.
- To identify gaps and challenges from the data trend& to suggest district-specific policy measures for strengthening irrigation efficiency and ensuring sustainable agricultural development in Jhalawar.

H_0a: The implementation of the Pradhan Mantri Krishi Sinchai Yojana has not significantly increased the irrigated area of major crops in Jhalawar district.

H_1a: The implementation of the Pradhan Mantri Krishi Sinchai Yojana has significantly increased the irrigated area of major crops in Jhalawar district.

H_0b: PMKSY has not significantly influenced agricultural productivity (crop yields) in Jhalawar district.

H_1b: PMKSY has significantly improved agricultural productivity (crop yields) in Jhalawar district.

The study employs descriptive statistical tools such as percentages, charts and growth rates, as well as econometric tools such as correlation analysis and Granger causality tests.

Result & Discussion

The 1.1 table demonstrates state-wise analysis of irrigated area under PMKSY. It underscores Rajasthan's prominent role in the national micro-irrigation landscape. Rajasthan has brought 8.23 lakh hectares under micro irrigation and ranks among the leading states. It follows Karnataka with 20.05 lakh hectares, Tamil Nadu with 11.35 lakh hectares, Gujarat with 11.16 lakh hectares, and Maharashtra with 10.26 lakh hectares. Rajasthan contributes more than 9 percent of the national total of 89.69 lakh hectares. This makes it the most significant adopter in northern India and a key driver of the scheme beyond the southern and western states. Rajasthan also outpaces its neighbouring states. Haryana has 1.78 lakh hectares, Uttar Pradesh has 3.93 lakh hectares, and Bihar has 25,660 hectares. This reflects more effective implementation strategies and higher farmer uptake in Rajasthan. The large-scale adoption in Rajasthan can be linked to the state's semi-arid climate, recurrent droughts, and dependence on groundwater, which make micro-irrigation a necessity rather than an option. Southern states dominate in absolute terms due to their early adoption and strong institutional capacity. Rajasthan's performance is noteworthy as it shows that micro irrigation can be scaled effectively in arid and resource-constrained environments. This not only enhances water use efficiency but also facilitates diversification into oilseeds, pulses, and horticultural crops. Such diversification contributes significantly to agricultural sustainability and strengthens income resilience for farmers.

Table 1:- State-wise Progress of Micro-Irrigation in India (2015–2023)

S. No.	State	Area Covered (In Hectares)
1.	Jammu And Kashmir	1,104.10
2.	Himachal Pradesh	10,822.40
3.	Punjab	16,162.22
4.	Uttarakhand	33,232.83
5.	Haryana	1,78,593.48
6.	Rajasthan	8,22,949.18
7.	Uttar Pradesh	3,93,193.08
8.	Bihar	25,660.06
9.	Sikkim	16,161.58
10.	Arunachal Pradesh	13,169.74
11.	Nagaland	25,185.00
12.	Manipur	15,262.00
13.	Mizoram	5,029.67
14.	Tripura	4,511.00
15.	Meghalaya	795.90
16.	Assam	42,073.00
17.	West Bengal	1,01,417.25
18.	Jharkhand	40,632.57
19.	Odisha	1,26,064.42
20.	Chhattisgarh	1,48,901.90
21.	Madhya Pradesh	3,90,058.13
22.	Gujarat	11,16,918.35
23.	Maharashtra	10,26,143.05
24.	Andhra Pradesh	9,31,011.08
25.	Karnataka	20,05,295.19
26.	Goa	959.74
27.	Kerala	6,335.53
28.	Tamil Nadu	11,35,052.14
29.	Telangana	3,36,537.88

Source: pmksy.gov.in.

Table 2: District-wise Progress of Micro-Irrigation in Rajasthan (2015–2023)

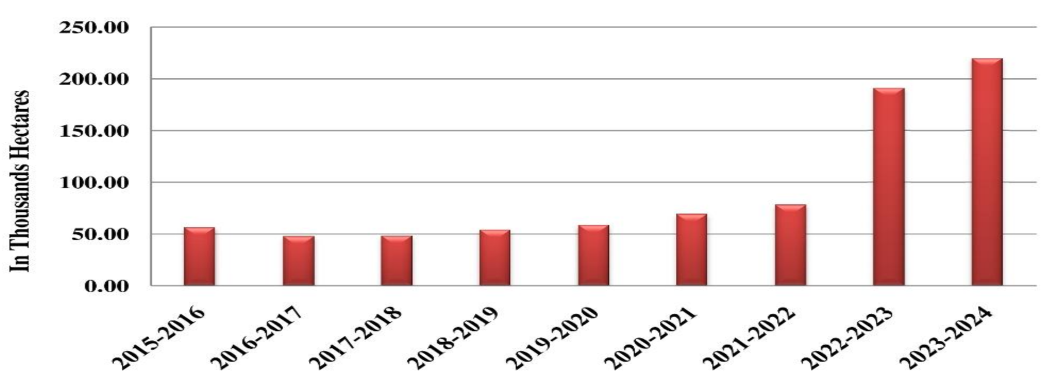
S. No.	District	Area Covered (in Hectare)
1.	Ajmer	13,637.59
2.	Alwar	34,134.35
3.	Banswara	7,123.55
4.	Baran	13,866.82
5.	Barmer	59,382.98
6.	Bharatpur	2,074.92
7.	Bhilwara	49,539.93
8.	Bikaner	38,986.82
9.	Bundi	15,785.76
10.	Chittorgarh	30,453.98
11.	Churu	30,486.83
12.	Dausa	10,056.40
13.	Dholpur	1,474.66
14.	Dungarpur	3,091.86
15.	Ganganagar	33,077.04
16.	Hanumangarh	54,852.36
17.	Jaipur	60,710.36
18.	Jaisalmer	11,600.26
19.	Jalore	93,343.55

20.	Jhalawar	31,065.28
21.	Jhunjhunu	25,934.44
22.	Jodhpur	39,170.63
23.	Karauli	3,533.02
24.	Kota	8,967.34
25.	Nagaur	14,839.40
26.	Pali	9,878.23
27.	Rajsamand	4,619.87
28.	Sawai Madhopur	21,021.37
29.	Sikar	46,449.69
30.	Sirohi	14,043.17
31.	Tonk	17,494.21
32.	Udaipur	3,487.80
33.	Pratapgarh	18,764.71
	State Wise Total :	**8,22,949.18**

Source: -pmksy.gov.in.

The district-wise distribution of micro-irrigation coverage in Rajasthan shows marked differences in adoption across the state. Jalore leads with 93,343.55 hectares under micro-irrigation, followed by Jaipur, Barmer, Hanumangarh and Bhilwara. These districts together contribute a large share of the state's total and illustrate relatively advanced adoption of irrigation technologies. Districts such as Sikar with 46,449.69 hectares, Jodhpur with 39,170.63 hectares, Bikaner with 38,986.82 hectares, Alwar with 34,134.35 hectares, and Ganganagar with 33,077.04 hectares occupy a middle position. Their progress reflects the influence of groundwater availability, canal networks, and stronger institutional support. At the other end, several districts have comparatively low coverage. Dholpur (1,474.66 ha), Dungarpur (3,091.86 ha), Udaipur (3,487.80 ha) and Karauli (3,533.02 ha) fall into this category, suggesting constraints related to fragmented holdings, terrain difficulties, limited awareness or weak infrastructure. Even Bharatpur, despite its fertile lands, has only 2,074.92 hectares under micro-irrigation, pointing to underutilization of the scheme. Overall Rajasthan has achieved 8.23 lakh hectares of micro-irrigation between 2015 and 2023. The pattern shows that western and central districts such as Jalore, Barmer, Hanumangarh and Jaipur have become centres of large-scale adoption, while many southern and eastern districts remain lagging. In the eastern region Jhalawar records 31,065.28 hectares and shows notable success at the district level.It has higher coverage than 22 out of 33 districts of Rajasthan. It ranks eleventh in the state in terms of area covered under the scheme. The performance of Jhalawar indicates the potential of the program to strengthen irrigation in regions with favourable agriculture climatic conditions. This uneven progress between districts shows the need for region specific strategies. These strategies must combine extension services, financial incentives, and technology demonstrations to expand the benefits of Pradhan Mantri Krishi Sinchai Yojana more evenly across the state.

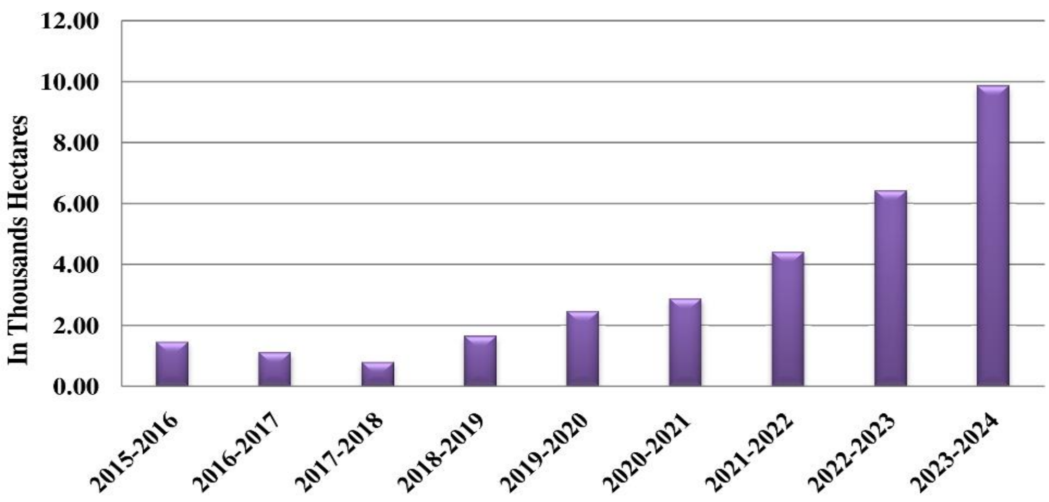
Fig. 1.1: Coverage of Micro-Irrigation Area in Rajasthan under PMKSY



Source: pmksy.gov.in.

Fig 1.1 Shows the temporal analysis of micro-irrigation coverage in Rajasthan under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) during 2015–16 to 2023–24. It demonstrates a substantial and consistent expansion. The coverage area increased from 56,345.98 hectares in 2015–16 to 219,763.74 hectares in 2023–24, registering an estimated compound annual growth rate of 18.55 percent. The period from 2015–16 to 2019–20 was characterized by moderate fluctuations. Initial time period data represented a phase of gradual adoption and program stabilization. From 2020–21 onwards the trend shows a clear upward movement and a sharp increase was observed in 2022–23 and 2023–24 when the coverage almost tripled compared to the earlier years. Such growth may be attributed to enhanced institutional support, improved policy interventions, and increasing awareness among farmers regarding the efficiency benefits of micro-irrigation. The findings indicate that Rajasthan has shifted from a gradual to a rapid phase of adoption, highlighting the role of PMKSY in enhancing water-use efficiency.

Fig 1.2: Coverage of Micro-Irrigation Area in Jhalawar District under PMKSY



Source: pmksy.gov.in.

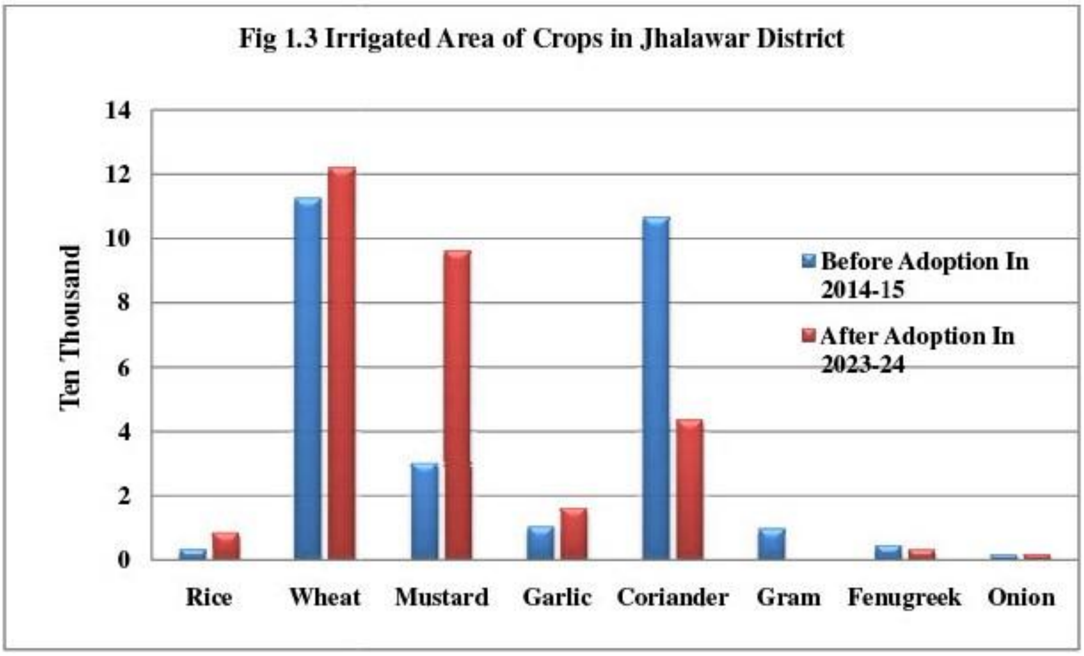
Fig. 1.2 shows the physical progress of micro-irrigation coverage in Jhalawar district under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) exhibits a significant upward trajectory during the period 2015–16 to 2023–24. The coverage area expanded from 1,456.26 hectares in 2015–16 to 9,868.90 hectares in 2023–24, corresponding to an impressive compound annual growth rate (CAGR) of approximately 27.02 percent. The adoption pattern indicates an initial phase of fluctuations and stagnation between 2016–17 and 2017–18, followed by gradual growth up to 2020–21. Thereafter, the district experienced accelerated expansion, with a pronounced surge during 2021–22 to 2023–24, wherein coverage more than doubled within three years. This steep rise may be attributed to strengthened program implementation, higher levels of farmer participation, and the introduction of targeted policy support in the district. Overall, the evidence suggests that Jhalawar has moved from incremental adoption to rapid scaling of micro-irrigation, underscoring the effectiveness of PMKSY in promoting water-use efficiency and sustainable agricultural practices at the district level.

Table 3: Change in irrigated area of selected cropsin Jhalawar district by adoption of PMKSY (In Hectare)

Crop	Before Adoption In 2014-15	After Adoption In 2023-24	Difference	% Change in Irrigated Area
Rice	3209	8484	5275	164.4
Wheat	112534	122054	9520	8.5
Mustard	30126	96185	66059	219.2
Garlic	10242	16174	5932	57.9

Coriander	106642	43594	-63048	-59.1
Gram	9671	46743*	37072	383.3
Fenugreek	4530	3166	-1364	-30.1
Onion	1544	1699	155	10.0

Source: Agriculture Statistics at A Glance Annual Reports, Commissionerate of Agriculture (CSO) Jaipur, Rajasthan.

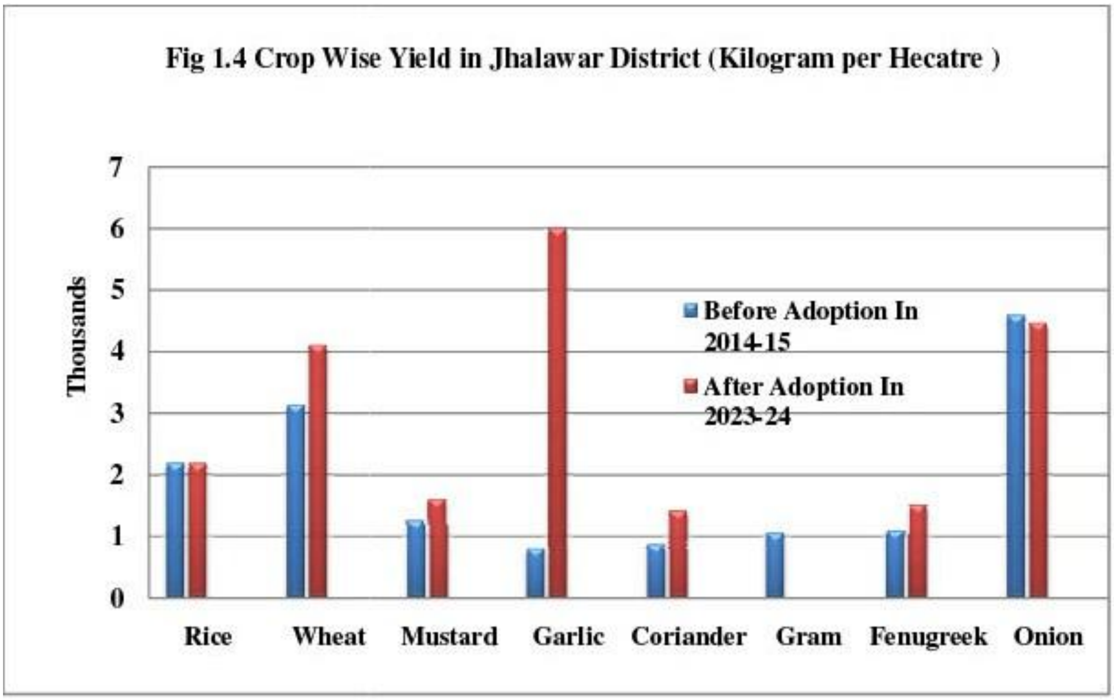


Source: Agriculture Statistics at A Glance Annual Reports, Commissioner ate of Agriculture (CSO) Jaipur, Rajasthan.

The change in irrigated area in Jhalawar district after the adoption of PMKSY shows distinct variations across crops. Rice expanded from 3209 hectares in 2014–15 to 8484 hectares in 2023–24 which represents a growth of +164.4%. Wheat recorded only a marginal improvement of +8.5% which indicates limited impact of the scheme on this crop. Mustard showed the highest gain with an increase from 30126 hectares to 96185 hectares equivalent to +219.2%. Garlic also improved significantly with a rise of +57.9% while onion expanded by +10.0%. Gram displayed the most striking change as the irrigated area rose from 9671 hectares to 46743 hectares which corresponds to +383.3%. In contrast coriander and fenugreek recorded sharp declines with irrigated area falling by –59.1% and –30.1% respectively. The overall pattern indicates that high value crops such as mustard garlic and gram have benefitted most from the adoption of PMKSY while coriander and fenugreek have experienced contraction in irrigated area.

Table 4: Change in Selected Crop Wise Yieldby adoption of PMKSY in Jhalawar District (KG per Hectare)

Crop	Before Adoption In 2014-15	After Adoption In 2023-24	Difference	% Change in Irrigated Area
Rice	2186	2185	-1	-0.04
Wheat	3135	4104	969	30.90
Mustard	1252	1602	350	27.95
Garlic	800	6000	5200	650.0
Coriander	862	1411	549	63.68
Gram	1049	1729*	680	64.82
Fenugreek	1089	1513	424	38.93
Onion	4586	4462	-124	-2.70



Source: Agriculture Statistics at A Glance Annual Reports, Commissionerate of Agriculture (CSO) Jaipur, Rajasthan

The yield data of major crops in Jhalawar district between 2014–15 and 2023–24 shows improvements after the adoption of PMKSY. Rice yield fell slightly from 2,186 kg/ha to 2,185 kg/ha (−0.04%), which indicates that this water-intensive crop did not gain from the program. Wheat yield rose from 3,135 kg/ha to 4,104 kg/ha (30.9%), which demonstrates the strong role of assured irrigation in improving cereal productivity. Farmers achieved higher yields in oilseed and pulse crops as well: mustard increased by 27.9% (1,252 to 1,602 kg/ha), gram by 64.8% (1,049 to 1,729 kg/ha), and fenugreek by 38.9% (1,089 to 1,513 kg/ha). These gains show that irrigation support under PMKSY strengthened the performance of crops that usually struggle under rainfed conditions. Farmers shifted strongly toward high-value crops, as garlic yield surged from 800 kg/ha to 6,000 kg/ha (650%) and coriander yield climbed by 63.7% (862 to 1,411 kg/ha). Onion yield dropped from 4,586 kg/ha to 4,462 kg/ha (−2.7%), which reflects possible challenges such as pests, soil exhaustion, or market pressures. Overall, PMKSY in Jhalawar district improved productivity in wheat, pulses, oilseeds, and spices, and it encouraged farmers to diversify into profitable crops that respond well to efficient irrigation.

Table 5: Annual Crop Wise Yield in Jhalawar District (Kilogram per Hectare)

Crop	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2021-22**	**2022-23**	**2023-24**
Paddy	3279	3033	2728	4327	3320	2217	3473	3209	3277
Rice	2186	2022	1819	2885	2214	1478	2315	2139	2185
Sorghum	1012	1331	604	582	832	710	863	891	890
Millet	1080	769	1000	909	889	1333	1000	1286	1056
Maize	2031	1804	1869	3064	2858	676	1927	2379	2398
Wheat	3135	3472	3829	4044	4033	4176	4390	4061	4104
Barley	2801	2995	3298	3322	3598	3525	3546	2915	3665
Rabi pulses (except Gram)	1000	711	1025	1307	1307	1419	1455	1467	1387
Lentil	1000	701	1010	1310	1156	1429	1452	1461	1385
Soyabean	999	529	1040	1349	1235	277	674	885	1096
Mustard	1252	1277	1494	257	1645	1628	1785	1730	1602

Coriander	862	911	874	1231	1056	1308	1328	1221	1411
Fenugreek	1089	990	1315	1341	1133	1477	1416	1396	1513
Garlic	800	6000	6000	3000	2500	2500	4714	6000	6000
Onion	4586	7320	603	6172	2834	2612	4455	3932	4462
Gram	1049	1049	1291	1534	1343	1566	1729	-	-

Source: Agriculture Statistics at A Glance Annual Reports, Commissionerate of Agriculture (CSO) Jaipur, Rajasthan

Table 1.5 shows that wheat and barley demonstrate consistent growth with yields exceeding 4000 and 3600 kilograms per hectare in recent years. Paddy, rice, and maize show fluctuations with phases of decline followed by partial recovery. Sorghum and millet remain low yielding crops with only limited improvement. Pulses including lentil and other rabi pulses display gradual increase whereas mustard and soybean indicate unstable trends. Spices such as coriander and fenugreek record steady progress while garlic and onion exhibit sharp fluctuations. Gram shows continuous improvement with yield reaching 1729 kilograms per hectare. Overall cereals act as the most stable contributors whereas spices strengthen their role and oilseeds and horticultural crops reflect variable performance.

Table 6: Annual Crop Wise Irrigated Area in Jhalawar District (in Hectare)

Crop	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2022-23	2023-24
Paddy	3209	3239	4376	4418	4692	5006	5964	6807	8484
Rice	3209	3239	4376	4418	4692	5006	5964	6807	8484
Wheat	112534	102108	109041	102202	105638	156254	148555	131075	122054
Barley	267	202	319	205	132	162	157	250	227
Rabi pulses (except Gram)	10694	14675	10536	8858	5939	5939	14	8188	11015
Lentil	10416	14406	10393	8568	5905	5490	5657	8111	10676
Soyabean	0	0	0	0	0	0	0	0	0
Mustard	30126	39508	34962	39607	68795	34296	38286	65119	96185
Coriander	106642	98356	91631	53806	43828	35700	64664	54187	43594
Fenugreek	4530	7654	5223	2837	2088	2798	4120	2817	3166
Garlic	10242	13727	23240	27763	19411	18322	20493	15676	16175
Onion	1544	2680	2359	2447	3321	3607	2883	1617	1699
Gram	9671	8532	16070	55362	55995	51909	45008	46743	-

Source: Agriculture Statistics at A Glance Annual Reports, Commissionerate of Agriculture (CSO) Jaipur, Rajasthan

The analysis of irrigated area across major crops in the district during 2014–15 to 2023–24 reflects both structural shifts in cropping patterns and the influence of interventions under the Pradhan Mantri Krishi Sinchai Yojana (PMKSY). Wheat maintained the largest irrigated share, expanding until 2019–20 (156,254 ha) before a moderate decline, suggesting that irrigation support stabilized but did not lead to further expansion in later years. Paddy (rice) recorded a consistent rise from 3,209 hectare in 2014–15 to 8,484 hectares in 2023–24, a trend that coincides with improved micro-irrigation coverage and command area development under PMKSY, enabling higher water availability for water-intensive crops. Mustard showed the most striking expansion, more than tripling its irrigated area from 30,126 hectare in 2014–15 to 96,185 hectares in 2023–24, which may be directly linked to enhanced access to irrigation infrastructure and farmer incentives for oilseed cultivation under the scheme. In contrast, coriander, despite being a traditional irrigated spice crop, declined sharply from 1,06,642 hectare to - 43,594 hectare, indicating that irrigation support alone could not offset market or climatic constraints. Pulses (especially lentil) demonstrated cyclical trends but recovered in recent years, aligning with PMKSY's emphasis on "more crop per drop" through efficient irrigation for water-sensitive crops. Garlic and onion exhibited volatility, but their sustained irrigation indicates diversification into high-value horticultural crops supported by PMKSY's micro-irrigation interventions. The evidence shows that Pradhan Mantri Krishi Sinchai Yojana has played a catalytic role in expanding the irrigated area of cereals and oilseeds, particularly paddy and mustard. It has also enabled diversification into pulses and horticultural crops. However, the declining share ofcoriander underscores that irrigation infrastructure must be complemented by price support, extension services, and climate resilience measures to ensure balanced crop diversification.

Statistical Analysis

Granger Causality Test

This research investigates how irrigation impacts crop yields across various types of crops, with the goal of offering practical recommendations for irrigation policy under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). By employing Granger causality tests, we evaluate whether changes in irrigated land can successfully forecast yield results, which helps identify crops that respond best to water management strategies. Gaining insight into these connections assists in prioritizing irrigation resources, improving water efficiency, and boosting overall agricultural production, thus supporting the objectives of PMKSY for sustainable and effective water management in farming.

For the purpose of this study, crops were classified into three groups according to their irrigation requirements, reflecting their level of water dependency and sensitivity to irrigation practices. High irrigation crops, including paddy, rice, onion, and garlic, demand frequent and substantial water supply. Medium irrigation crops, such as maize, wheat, barley, rabi pulses (excluding gram), and soybean, require a moderate amount of irrigation, with yields influenced by both rainfall and supplemental water. Low irrigation crops, including sorghum, millet, lentil, gram, mustard, coriander, and fenugreek, are comparatively drought-tolerant and can sustain yields with limited irrigation. This classification provides a structured basis for examining the impact of irrigation on crop yields and aligns with the objectives of PMKSY in promoting efficient and equitable water use.

- Crops with high irrigation needs demand regular water supply and are extremely responsive to irrigation practices.
- Crops with medium irrigation requirements seek moderate water; their yields are influenced by irrigation as well as weather conditions.
- Crops with low irrigation demands are generally more drought-resistant and can achieve yields with limited additional water.

Table 7: Granger Causality Test & Results

Irrigation Group	Crops Included
High	Paddy, Rice, Onion, Garlic
Medium	Maize, Wheat, Barley, Rabi Pulses (except Gram), Soyabean
Low	Sorghum, Millet, Lentil, Gram, Mustard, Coriander, Fenugreek

Source: Author Analysis

- **Granger Causality for Low Irrigation Group**

The Granger causality test for low-irrigation crops reveals the presence of a bi-directional relationship between irrigated area (irrlow) and yield (yield low). The chi-square results ($\chi^2 = 17.452$ for irrigation influencing yield, $\chi^2 = 54.878$ for yield influencing irrigation, $p < 0.001$ for both) confirm that changes in irrigation significantly forecast yield outcomes, while yield performance also influences subsequent irrigation decisions. This finding corresponds with field-level practices, as even drought-tolerant crops such as sorghum, millet, pulses, and fenugreek show productivity gains when provided with additional water, and farmers often adjust irrigation according to expected yield conditions.The existence of this two-way causality highlights a feedback mechanism in which water input and crop output continuously shape each other. From a policy perspective, this suggests that PMKSY should integrate both supply-oriented and demand-oriented approaches to irrigation planning for low-irrigation crops. Such measures would improve water-use efficiency and enhance overall agricultural productivity in regions dependent on resource-conserving crops.

Table 8: Granger Causality Test & Low Irrigation Crops

Equation (Dependent Variable)	Excluded Variable(s)	Chi²	df	Prob > Chi²	Interpretation
yield low	irr_low	17.452	2	0	Irrigation Granger-causes yield; changes in irrigated area predict yield.
irr_low	yield_low	54.878	2	0	Yield Granger-causes irrigation; farmers adjust water allocation based on expected productivity.

Source: Author Analysis

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
yield_low	irr_low	17.452	2	0.000
yield_low	ALL	17.452	2	0.000
irr_low	yield_low	54.878	2	0.000
irr_low	ALL	54.878	2	0.000

Sample: 3 - 9		Number of obs	= 7
Log likelihood =	-117.9776	AIC	= 36.56503
FPE =	5.38e+13	HQIC	= 35.60998
Det(Sigma_ml) =	1.49e+12	SBIC	= 36.48776

Equation	Parms	RMSE	R-sq	chi2	P>chi2
yield_low	5	561.066	0.8844	53.55114	0.0000
irr_low	5	13912.5	0.8968	60.83577	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
yield_low						
yield_low						
L1.	.2544086	.2291194	1.11	0.267	-.1946573	.7034744
L2.	-.1308119	.2154881	-0.61	0.544	-.5531608	.291537
irr_low						
L1.	-.0068796	.0054278	-1.27	0.205	-.0175179	.0037586
L2.	-.0231273	.0064343	-3.59	0.000	-.0357383	-.0105163
_cons	9997.342	2078.6	4.81	0.000	5923.361	14071.32
irr_low						
yield_low						
L1.	-6.25468	5.681353	-1.10	0.271	-17.38993	4.880568
L2.	34.98908	5.343344	6.55	0.000	24.51632	45.46185
irr_low						
L1.	.1517852	.1345898	1.13	0.259	-.112006	.4155764
L2.	.4327052	.1595476	2.71	0.007	.1199976	.7454128
_cons	-141791.3	51541.94	-2.75	0.006	-242811.6	-40770.93

- **Medium Irrigation Group**

For medium irrigation crops such as maize, wheat, barley, Rabi pulses (excluding gram), and soybean, the findings from Granger causality analysis reveal a one-way relationship where yield influences irrigation. The non-significant χ^2 for irrigation affecting yield ($p = 0.339$) indicates that in the short term variations in irrigated acreage do not significantly affect productivity for these crops that require moderate water. This could be attributed to the impact of rainfall and other management practices (like fertilization and soil quality) which also play a crucial role in influencing yields, thereby lessening the immediate effects of irrigation.On the other hand, the confirmed causality from yield to irrigation ($\chi^2 = 10.178$, $p = 0.006$) suggests that farmers adjust their future water allocations based on actual or anticipated yield results. This behavior indicates a demand-driven approach to irrigation with water resources being directed toward crops and fields projected to yield better results. For initiatives like PMKSY and comparable programs this highlights the necessity of connecting water supply with crop performance monitoring and farmer decision-making, as trends in productivity direct irrigation application for medium irrigation crops.

Table 9: Granger Causality Test & Medium Irrigation Crops

Dependent Variable	Excluded Variable(s)	Chi²	df	Prob > Chi²	Interpretation
yield_medium	irr_medium	2.1641	2	0.339	Irrigation does not significantly predict yield; short-term yield response to irrigation is limited.
irr_medium	yield_medium	10.178	2	0.006	Yield significantly predicts future irrigation allocation; farmers adjust water based on crop performance.

Source: Author Analysis

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  Granger causality Wald tests

  +------------------------------------------------------------------+
  |          Equation           Excluded |   chi2     df Prob > chi2 |
  |--------------------------------------+---------------------------|
  |      yield_medium         irr_medium |  2.1641     2    0.339    |
  |      yield_medium                ALL |  2.1641     2    0.339    |
  |--------------------------------------+---------------------------|
  |        irr_medium       yield_medium |  10.178     2    0.006    |
  |        irr_medium                ALL |  10.178     2    0.006    |
  +------------------------------------------------------------------+

Vector autoregression

Sample:  3 - 9                              Number of obs     =          7
Log likelihood = -123.4991                  AIC               =   38.14259
FPE            =  2.60e+14                  HQIC              =   37.18753
Det(Sigma_ml)  =  7.23e+12                  SBIC              =   38.06532

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
yield_medium         5     1547.36   0.3461   3.704696   0.4474
irr_medium           5     19413.7   0.6645   13.86132   0.0078
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             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
yield_medium |
yield_medium |
         L1. |   .4465632   .3600578     1.24   0.215     -.259137    1.152264
         L2. |  -.6415556   .3485192    -1.84   0.066    -1.324641    .0415295
             |
  irr_medium |
         L1. |    .041641   .0283118     1.47   0.141    -.0138491    .0971311
         L2. |  -.0278701   .0267191    -1.04   0.297    -.0802386    .0244985
             |
       _cons |   12169.74   4637.577     2.62   0.009     3080.253    21259.22
-------------+----------------------------------------------------------------
irr_medium   |
yield_medium |
         L1. |  -.6092465   4.517427    -0.13   0.893     -9.46324    8.244747
         L2. |   11.17782   4.372659     2.56   0.011     2.607565    19.74808
             |
  irr_medium |
         L1. |   .0378095   .3552109     0.11   0.915     -.658391    .7340101
         L2. |   .2459166   .3352289     0.73   0.463      -.41112    .9029532
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- **High Irrigation Crops**

For crops that require high irrigation such as paddy, rice, onion, and garlic, the Granger causality analysis indicates a one-way causal relationship where irrigation affects yield. The significantly high χ^2 statistic ($\chi^2 = 20.655$, $p < 0.001$) for the relationship between irrigation and yield confirms that expanding the irrigated area positively influences productivity for these water-dependent crops. This finding is consistent with agricultural principles, as high-irrigation crops need considerable water to reach optimal growth and are responsive to variations in water supply.

On the other hand, the χ^2 statistic for the influence of yield on irrigation ($\chi^2 = 5.2252$, $p = 0.073$) does not reach significance at the 5% level, indicating that farmers' decisions regarding water allocation are less influenced by actual or anticipated yields for these crops. This could illustrate that irrigation practices are guided by fixed schedules or predetermined water distributions for crops with high demands, where policies or infrastructure guarantee that adequate water is provided regardless of short-term yield variations.PolicyConsiderations:The findings for PMKSY and similar irrigation initiatives emphasize the importance of ensuring adequate water supply for high-irrigation crops to enhance productivity, while yield-based adjustments are more relevant for crops requiring medium or low levels of irrigation. Prioritizing water-intensive crops can deliver significant short-term productivity gains and support the efficient allocation of irrigation resources.

Table 10: Granger Causality Test & High Irrigation Crops

Dependent Variable	Excluded Variable(s)	Chi²	df	Prob > Chi²	Interpretation
yield_high	high_irrigation	20.655	2	0	Irrigation significantly predicts yield; increases in irrigated area lead to higher crop productivity.
high_irrigation	yield_high	5.2252	2	0.073	Yield does not significantly predict irrigation allocation at 5% level; farmers' irrigation decisions are less yield-driven.

Source: Author Analysis

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Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
yield_high	high_irrigation	20.655	2	0.000
yield_high	ALL	20.655	2	0.000
high_irrigation	yield_high	5.2252	2	0.073
high_irrigation	ALL	5.2252	2	0.073

Sample: 3 - 9		Number of obs =	7
Log likelihood =	-125.8135	AIC =	38.80385
FPE =	5.04e+14	HQIC =	37.84879
Det(Sigma_ml) =	1.40e+13	SBIC =	38.72658

Equation	Parms	RMSE	R-sq	chi2	P>chi2
yield_high	5	2547.97	0.7585	21.99136	0.0002
high_irrigation	5	23511.2	0.6307	11.957	0.0177

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
yield_high						
yield_high						
L1.	1.316995	.549478	2.40	0.017	.2400376	2.393952
L2.	1.07094	.3450699	3.10	0.002	.3946158	1.747265
high_irrigation						
L1.	.2755984	.0855363	3.22	0.001	.1079503	.4432464
L2.	-.1156016	.0665123	-1.74	0.082	-.2459633	.0147601
_cons	-40213.38	15238.11	-2.64	0.008	-70079.53	-10347.24
high_irrigation						
yield_high						
L1.	-11.25212	5.070252	-2.22	0.026	-21.18963	-1.31461
L2.	-5.1824	3.184097	-1.63	0.104	-11.42312	1.058316
high_irrigation						
L1.	-.9734059	.7892774	-1.23	0.217	-2.520361	.5735494
L2.	1.018368	.6137354	1.66	0.097	-.1845316	2.221267
_cons	355829	140608.1	2.53	0.011	80242.17	631415.9

- **Conclusion of Granger Causality Test**

The analysis of Granger causality across different irrigation categories shows that the impact of irrigation on crop yield varies significantly:

- Crops requiring high irrigation, such as paddy, rice, onion, and garlic, demonstrate a strong causal relationship where irrigation directly enhances productivity.
- Crops with medium irrigation needs, including maize, wheat, barley, rabi pulses, and soybean, show a causative effect from yield to irrigation, suggesting that farmers adjust water usage based on anticipated yields.
- Crops with low irrigation demand, such as sorghum, millet, pulses, gram, mustard, coriander, and fenugreek, reveal a two-way causal relationship, indicating reciprocal influence between irrigation and yield.

In conclusion, these findings highlight the need for tailored irrigation strategies under PMKSY. Policies should prioritize water-intensive crops while also considering the behavioral responses of farmers managing medium- and low-irrigation crops. Such an approach would optimize water distribution, enhance overall productivity, and improve water-use efficiency.

Correlation Analysis

The correlation analysis provides further insights into the relationship between irrigation practices and crop yields across the three irrigation categories. A strong positive correlation exists between high- and medium-irrigation crops (r = 0.975), indicating that water allocation trends for these categories move closely together over time. In contrast, a moderate negative correlation with low-irrigation crops (r = –0.549) suggests possible competition or trade-offs in water use. Yield correlations show that low-irrigation crops have a strong positive association with high- and medium-irrigation areas (r = 0.900 and r = 0.840, respectively), implying that greater water allocation for high-demand crops may also produce indirect benefits for low-demand crops. Conversely, the yields of medium-irrigation crops exhibit weak correlations with irrigation, which is consistent with the Granger causality results indicating that irrigation does not significantly predict yield in this category. Overall, these correlations highlight the interconnected nature of irrigation management and suggest that coordinated water allocation strategies can improve productivity across crop groups while advancing PMKSY objectives of efficient and need-based water use.

Table 11: Correlation Analysis & Different Type of Irrigation Crops

Variable	high_irrigation	irr_low	irr_medium	yield_high	yield_medium	yield_low
high_irrigation	1	-0.5487	0.9754	-0.2472	-0.0454	0.8998
irr_low	-0.5487	1	-0.5103	0.4145	-0.207	-0.2861
irr_medium	0.9754	-0.5103	1	-0.2777	-0.252	0.8403
yield_high	-0.2472	0.4145	-0.2777	1	0.1844	-0.1494
yield_medium	-0.0454	-0.207	-0.252	0.1844	1	0.1084
yield_low	0.8998	-0.2861	0.8403	-0.1494	0.1084	1

Source: Author Analysis

	high_i~n	irr_low	irr_me~m	yield_~h	yield_~m	yield_~w
high_irrig~n	1.0000					
irr_low	-0.5487	1.0000				
irr_medium	0.9754	-0.5103	1.0000			
yield_high	-0.2472	0.4145	-0.2777	1.0000		
yield_medium	-0.0454	-0.2070	-0.2520	0.1844	1.0000	
yield_low	0.8998	-0.2861	0.8403	-0.1494	0.1084	1.0000

Conclusion

Crop-wise analysis of Jhalawar district shows major gains in mustard, gram, garlic, and wheat. These crops record strong improvements in both irrigated area and yield.Paddy and rice also expanded in irrigated area but showed only moderate yield gains, while coriander and fenugreek experienced decline in coverage despite overall scheme progress. Garlic and onion exhibited sharp fluctuations yet confirmed a shift toward high-value horticultural crops.High irrigation crops display a strong one-way causality from irrigation to yield, supported by significant correlation, confirming that these water-intensive crops respond directly to expansion in irrigated area. Medium irrigation crops reveal a one-way causality from yield to irrigation, with weak correlations, indicating that farmer decisions on water allocation are shaped more by anticipated yield outcomes and less by irrigation expansion. Low irrigation crops demonstrate bi-directional causality between irrigation and yield, along with strong positive correlations with high- and medium-irrigation groups, showing reciprocal influence and indirect benefits from overall irrigation development.

Study in Jhalawar district demonstrates that PMKSY has strengthened water-use efficiency. It has supported diversificationtoward oilseeds, pulses, and horticultural crops, though challenges remain in sustaining spice cultivation and stabilizing crop performance across seasons. The study indicates that the provision of micro irrigation subsidy encouraged farmers to adopt high value crops and enhanced their capacity to raise agricultural income.At the same time, uneven performance across spices and oilseeds reflects the need for complementary measures such as better market access, price support, farmer training, and climate-resilient technologies. The experience of Jhalawar demonstrates that the scheme has acted as a catalyst for irrigation-led growth, but long-term success will depend on region-specific strategies and sustained institutional support.

Suggestions

The study indicates that effective implementation of the Pradhan Mantri Krishi Sinchai Yojana depends on addressing key operational challenges. Frequent damage to main lines and laterals reduces system efficiency and points to the necessity of strict quality control and durable materials suited to local conditions. Government should ensure that farmers receive reliable materials and equipment by enforcing strict quality standards, introducing mandatory certification, and conducting regular inspections of company supplies. Another challenge is the inadequate number of demonstrations and training sessions, which limits farmer awareness and technical skills. Strengthening capacity-building initiatives and organizing more field demonstrations would enable farmers to adopt and operate micro-irrigation systems with greater effectiveness. The high installation cost remains a major obstacle for small and marginal farmers, highlighting the need for enhanced subsidies, flexible credit arrangements, and cost-sharing mechanisms. Frequent damage to micro-irrigation systems under extreme climatic conditions such as frost, low winter temperatures, or high summer heat emphasizes the importance of developing climate-resilient designs and field-tested technologies suited to diverse agro-climatic zones. The long-term success of the Pradhan Mantri Krishi Sinchai Yojana in Rajasthan depends on making its guidelines more practical and accessible for resource-constrained farmers. By reducing procedural rigidity and incorporating farmer-oriented provisions, the program can secure broader participation and generate more sustainable outcomes. The evidence emphasizes the need for differentiated irrigation policies: assured and adequate water supply for high-irrigation crops, demand-based support and monitoring for medium-irrigation crops, and integrated strategies for low-irrigation crops that leverage indirect benefits while preventing trade-offs. Coordinated water allocation across groups can optimize productivity, improve water-use efficiency, and strengthen the role of PMKSY in promoting sustainable agricultural growth in Jhalawar.

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