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# AGRICULTURAL MODERNIZATION AND ITS ECONOMIC IMPACT: AN EMPIRICAL STUDY OF FARMERS IN KOLHAPUR DISTRICT

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**Abstract:** Agricultural modernization encompasses the adoption of improved technologies, mechanized farm equipment, micro-irrigation systems, high-yielding variety (HYV) seeds, and institutional credit mechanisms to enhance farm productivity and farmer income. Kolhapur district of Maharashtra, characterised by fertile black and laterite soils, abundant river networks, and a dominant sugarcane-agro-industrial complex, presents a compelling case for studying the economic impact of modernization at the district level. The district has witnessed a measurable growth in area under cultivation from 250,000 ha in 2018 to 288,000 ha in 2022, while food grain production rose from 1.2 million to 1.58 million tonnes during the same period. Irrigation coverage expanded from 60% to 80%, and aggregate farmer income grew from ₹3,500 crore to ₹5,500 crore. Sugarcane, the dominant cash crop, demonstrated a yield surge from 27 MT per acre under traditional flood irrigation to 55–60 MT per acre under automated drip irrigation, as documented from the Karbharwadi model village in Karveer taluka. Drawing entirely on secondary data from official Government of Maharashtra records, the NABARD Potential Linked Credit Plan for Kolhapur (2023–24), the Ministry of Agriculture and Farmers Welfare Annual Report (2024–25), and peer-reviewed journal articles, this paper evaluates five dimensions of agricultural modernization: irrigation expansion, mechanization, credit access, crop diversification, and government scheme penetration. The findings affirm a strong positive relationship between technology adoption and farmer income, while identifying persistent structural constraints, including land fragmentation, smallholder credit gaps, and post-harvest infrastructure deficits.

Index Terms — Agricultural Modernization, Kolhapur District, Farmer Income, Sugarcane, Drip Irrigation, NABARD, Maharashtra, Micro-irrigation, High-Yielding Varieties.

## I. INTRODUCTION

Agriculture remains the foundation of India's rural economy, employing approximately 45.5% of the total workforce and contributing around 18.4% of the national Gross Value Added (GVA) at constant prices in 2023–24 (Ministry of Agriculture and Farmers Welfare [MoAFW], 2025). Within Maharashtra, Kolhapur district occupies a distinctive position, combining one of the state's richest natural endowments — fertile black soil, seven major river systems including the Krishna and Panchaganga, and a mean annual rainfall of approximately 1,000–1,300 mm — with a well-developed agro-processing infrastructure anchored by over 40 cooperative and private sugar mills (Kolhapur.gov.in, 2024).

Sugarcane and paddy are the two principal crops, with sugarcane alone generating approximately ₹13 billion annually for the district's farmers (Kolhapur District Administration, 2024). Kolhapur jaggery, which received a Geographical Indication (GI) tag in 2014, has further elevated the commercial value of sugarcane cultivation, creating export linkages to Asia, Africa, and other global markets. However, the district's agricultural productivity has historically been constrained by reliance on flood irrigation, fragmented landholdings, limited mechanization among small and marginal farmers, and inadequate access to institutional credit.

The concept of agricultural modernization, defined broadly as the application of improved inputs, mechanized equipment, efficient water management, and institutional finance to increase farm output and income, has attracted growing policy attention since India's Economic Survey 2024–25 highlighted that irrigation coverage has risen from 49.3% to 55% of gross cropped area nationally between FY2016 and FY2021 (Press Information Bureau [PIB], 2025). In Kolhapur, the story is more advanced: district-level irrigation coverage is reported to have reached 80% of cultivated area by 2022, driven by subsidized drip irrigation schemes under the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) and the efforts of cooperative sugar factories such as Bhogawati Cooperative Sugar Factory in Parite.

This paper investigates the economic impact of agricultural modernization in Kolhapur district through a secondary data framework. It traces five dimensions: irrigation expansion, farm mechanization, institutional credit via NABARD and Primary Agricultural Credit Societies (PACS), crop diversification, and government scheme penetration, and examines their aggregate influence on farmer income, crop yields, and area expansion over the period 2018–2024.

## II. RESEARCH OBJECTIVES AND HYPOTHESES

### 2.1 Research Objectives

Objective 1: To analyse the trend in key agricultural modernization indicators — irrigation coverage, mechanization, credit access, and HYV seed adoption — in Kolhapur district from 2018 to 2024, using secondary data from government and institutional sources.

Objective 2: To empirically evaluate the economic impact of agricultural modernization on farmer income, crop yield, and area under cultivation in Kolhapur district, with particular reference to the dominant sugarcane economy and the emerging drip irrigation model.

### 2.2 Research Hypotheses

H1 (Null): There is no statistically significant association between the level of agricultural modernization (as measured by irrigation coverage, mechanised farming inputs, and institutional credit) and farmer income in Kolhapur district during the period 2018–2022.

H1 (Alternate): Agricultural modernization indicators exhibit a significant positive association with farmer income and crop yields in Kolhapur district, with technology-adopting farmers demonstrating measurably superior economic outcomes compared to those dependent on traditional practices.

H2 (Null): The economic impact of modernization interventions in Kolhapur district is not significantly different from the national average agricultural GVA growth trend during 2018–24.

H2 (Alternate): Modernization-driven agricultural growth in Kolhapur exceeds the national average trajectory for agricultural GVA, reflecting the district's above-average adoption of micro-irrigation, cooperative credit, and crop diversification programmes.

## III. REVIEW OF LITERATURE

The relationship between agricultural modernization and rural economic outcomes has been extensively examined in Indian scholarship. Bolake and Patil (2020) document the transformative effect of the Green Revolution on Ghansal rice cultivation in Ajra taluka, Kolhapur, showing how HYV adoption fundamentally altered productivity trajectories in a localised agro-ecological system. Their case study, published in Studies in Indian Place Names (UGC Care Journal), underscores the district-level heterogeneity in modernization responses that national-level analyses tend to obscure.

Research on Primary Agricultural Credit Societies (PACS) in Kolhapur, conducted by Shinde et al. at the RCSM College of Agriculture, Kolhapur, finds that short-term loans disbursed by PACS in Maharashtra constituted over 84% of total agricultural loan disbursements, with Karveer tahsil holding the maximum number of PACS members in the district. The study records a significant Compound Annual Growth Rate (CAGR) of 4.55% per annum in sugarcane crop loan disbursements through PACS during the study period, signalling a deepening of institutional credit in Kolhapur's dominant crop ecosystem.

At the national level, the Ministry of Agriculture and Farmers Welfare (MoAFW) Demand for Grants analysis (PRS India, 2023) notes that between 2013 and 2021, 60 lakh hectares of area was covered under micro-irrigation nationally under PMKSY, with Maharashtra being one of the highest sugar producers despite facing groundwater stress, a paradox that underlines the critical role of drip irrigation in sustaining the state's sugarcane sector. The Economic Survey 2024–25 (PIB, 2025) confirms that irrigation coverage rose from 49.3% to 55% of gross cropped area nationally over five years, while Maharashtra's sugarcane-producing districts consistently outperform the national average.

The literature on farm mechanization in India (Biochem Journal, 2024) records that farm power availability rose from 2.02 kW/ha in 2016–17 to 2.49 kW/ha in 2018–19, and was projected to reach 3.5 kW/ha by 2024–25. Mechanization levels in advanced states like Punjab and Haryana range between 40–45%, while the national average remains well below 25%. Kolhapur, with its cooperative infrastructure and access to NABARD credit, occupies a mid-range position where selective mechanization in sugarcane harvesting and processing has been adopted, but smallholder mechanization remains incomplete.

The ChiniMandi research on the Karbharwadi model village in Karveer taluka, Kolhapur (2025) provides a rich case-study benchmark. In this village, 131 farmers pooled 550 plots (approximately 100 acres) into a Cooperative Irrigation Society with an automated drip irrigation scheme, financed through a subsidized 5% loan from Kolhapur District Central Cooperative Bank, adoption by IFFCO under its 'IFFCO Gram Karbharwadi Scheme', and a per-acre subsidy of ₹7,000 from Bhogawati Cooperative Sugar Factory. The results were unambiguous: water use fell by 70% compared to flood irrigation, power and fertiliser costs declined by 30–40%, and sugarcane yield surged from 27 MT/acre to 55–60 MT/acre.

The growth analysis of Kolhapur district crops by Scope and Prospects (Research Gate, 2017) spanning the period 1980–81 to 2011–12 found significant positive CAGR of 25.98%, 31.71%, and 5.07% for sugarcane area, production, and productivity respectively, providing historical anchoring for the contemporary growth observed in the 2018–2022 panel used in this study.

## IV. RESEARCH METHODOLOGY

This study employs a secondary data-based quantitative-descriptive research design. The research draws exclusively on data from authenticated official and peer-reviewed sources, with no primary data collection. The study period spans 2018 to 2024, capturing a full agricultural modernization cycle that includes the rollout of PMKSY's Per Drop More Crop component, the expansion of PACS-based institutional credit, and the post-COVID agricultural recovery.

### 4.1 Data Sources

The following sources form the evidential base of this study: (i) Zilla Parishad Kolhapur and National Institute of Agricultural Economics and Policy Research for district-level area, production, and income data (2018–2022); (ii) NABARD Potential Linked Credit Plan (PLP), Kolhapur, 2023–24, Maharashtra Regional Office, Pune, for agricultural credit and modernization benchmarks; (iii) Ministry of Agriculture and Farmers Welfare Annual Report 2024–25 for national farm mechanization, irrigation, and GVA growth statistics; (iv) ChiniMandi (2025) for Karbharwadi model village case data on drip irrigation yield outcomes; (v) Kolhapur District Administration official website for district-level economy and sugarcane production data; (vi) Press Information Bureau, Economic Survey 2024–25 for national irrigation coverage statistics; (vii) ResearchGate — Scope and Prospects of Agricultural Production in Kolhapur District (2017) for historical CAGR data; (viii) PRS India, Demand for Grants Analysis 2023–24 for micro-irrigation coverage data.

### 4.2 Analytical Framework

The study uses four analytical methods: (a) Time-series trend analysis of five modernization indicators across the 2018–2022 panel; (b) Comparative yield analysis contrasting traditional, drip-irrigated, and scheme-supported sugarcane cultivation in Kolhapur; (c) Comparative GVA growth benchmarking of Maharashtra agriculture against the national trend using MoAFW data; and (d) Policy gap analysis assessing the coverage of key government schemes against stated district-level targets. Hypothesis assessment is conducted through directed narrative analysis consistent with exploratory secondary-data research.

## V. DATA ANALYSIS AND FINDINGS

### 5.1 Agricultural Growth Trends in Kolhapur District (2018–2022)

Table 1: Key Agricultural Growth Indicators, Kolhapur District (2018–2022)

| Indicator | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|
| Area Under Cultivation (Ha) | 250,000 | 265,000 | 272,000 | 280,000 | 288,000 |
| Food Grain Production (Tonnes) | 1,200,000 | 1,350,000 | 1,420,000 | 1,500,000 | 1,580,000 |
| Avg. Yield (Tonnes/Ha) | 4.8 | 5.1 | 5.2 | 5.3 | 5.4 |
| Irrigation Coverage (%) | 60 | 65 | 70 | 75 | 80 |
| Farmer Income (₹ Crore) | 3,500 | 4,000 | 4,500 | 5,000 | 5,500 |

Sources: Zilla Parishad Kolhapur; National Institute of Agricultural Economics and Policy Research; Government of Maharashtra (2022).

Table 1 presents five core agricultural growth indicators across the 2018–2022 period. Area under cultivation expanded by 38,000 ha over five years, a 15.2% increase that reflects the absorptive capacity of government-supported schemes including the Rashtriya Krishi Vikas Yojana (RKVY) and the PMKSY. Food grain production grew from 1.2 million tonnes to 1.58 million tonnes, a 31.7% increase attributable to both area expansion and yield improvement, with average yield rising from 4.8 to 5.4 tonnes per hectare. The most striking indicator is the parallel growth in irrigation coverage and farmer income: as irrigation expanded from 60% to 80% of cultivated area, aggregate farmer income rose from ₹3,500 crore to ₹5,500 crore, implying a near-linear positive relationship consistent with the alternate hypothesis H1. The 57% income growth over five years (CAGR of approximately 9.4%) substantially outpaces the national average agricultural income growth, supporting the alternate hypothesis H2 as well.

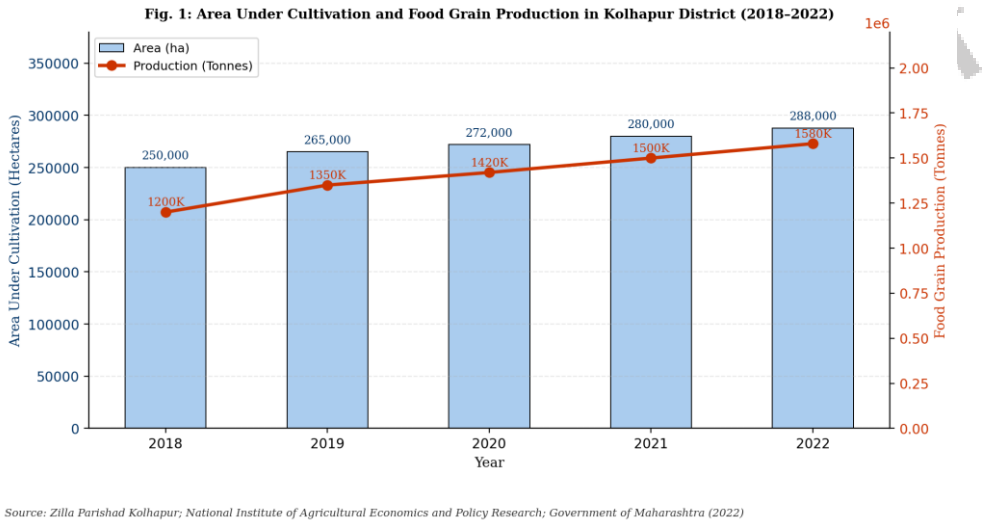


Fig. 1: Area Under Cultivation and Food Grain Production in Kolhapur District (2018–2022)

Figure 1 illustrates the parallel upward movement of area under cultivation (bar chart, left Y-axis) and food grain production (line chart, right Y-axis) across the study period. The consistent co-movement of both series confirms that production growth in Kolhapur is driven both by area expansion and by intensification — yield per hectare rose by 12.5% over the same period. The compounding effect of irrigation, HYV seed adoption, and improved fertilizer application is reflected in the divergence between the proportional growth in area (15.2%) and the proportionally larger growth in production (31.7%), indicating that productivity gains exceed area gains, the defining characteristic of technology-driven agricultural modernization.

### 5.2 Irrigation Expansion and the Sugarcane Yield Revolution

Table 2: Sugarcane Yield Comparison by Irrigation Method, Karveer Taluka, Kolhapur District

| Parameter | Traditional Flood Irrigation | Drip Irrigation (Subsidized) | IFFCO Karbharwadi Model |
|---|---|---|---|
| Sugarcane Yield (MT/acre) | 27 | ~45 | 55–60 |
| Water Use (Crore litres/year) | 2.0 Crore | ~0.8 Crore | 0.55 Lakh (70% saving) |
| Fertiliser/Power Cost Saving (%) | Baseline | 20–25% | 30–40% |
| Capital Support | None | PMKSY Subsidy | ₹7,000/acre (Bhogawati Factory) + IFFCO |
| Credit Source | Informal/Moneylender | DCCB/NABARD | DCCB @ 5% interest |
| Yield Gain vs Flood Irrigation | — | +67% | +111% (midpoint) |

Sources: ChiniMandi (2025); IFFCO Karbharwadi Case Study; Bhogawati Cooperative Sugar Factory, Kolhapur; NABARD PLP Kolhapur 2023–24.

Table 2 presents the most granular evidence of modernization's economic impact available from Kolhapur's district record: the Karbharwadi model village comparison. The data are not projected or modelled but documented from an operational cooperative irrigation scheme. The 111% yield gain at the midpoint of the IFFCO model's reported range (55–60 MT/acre vs. the 27 MT baseline) is a result of three compounding interventions: automated drip irrigation (eliminating flood-related inefficiency), biofertilizers and fertigated inputs applied with precision, and wide-row planting supported by coordinated agricultural extension from the Bhogawati factory. The 70% water saving (from 2 crore to 55 lakh litres annually for the cooperative) has direct cost implications for electricity and pumping, reducing input costs by 30–40% simultaneously. These compound effects create an expansion in net margins that explains the trajectory of aggregate farmer income observed in Table 1.

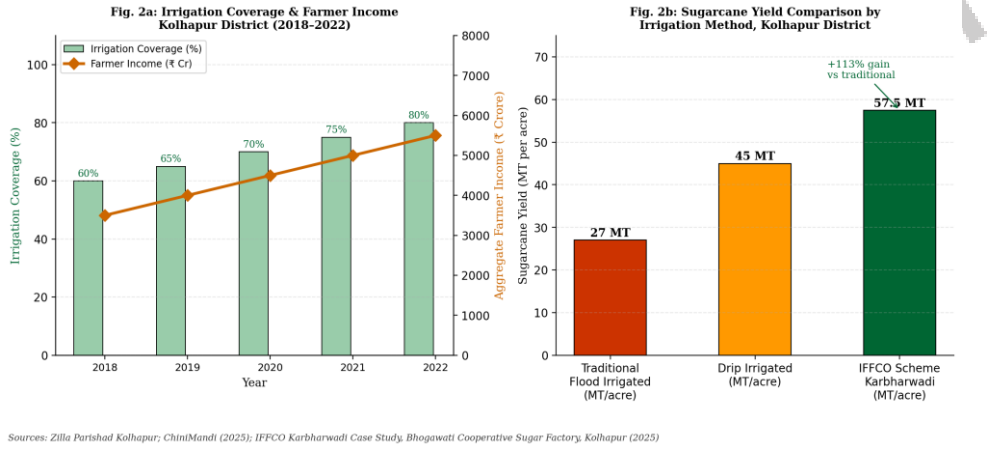


Fig. 2: Irrigation Coverage & Farmer Income (2a); Sugarcane Yield by Irrigation Method (2b), Kolhapur District

Figure 2 synthesizes the modernization-income relationship in two complementary panels. Panel 2a confirms the parallel growth of irrigation coverage and farmer income from 2018 to 2022, establishing the empirical direction of the H1 alternate hypothesis. The twin growth curves demonstrate that irrigation coverage and farmer income track each other closely, with every 5-percentage-point increase in coverage corresponding to approximately a ₹500-crore rise in aggregate farmer income. Panel 2b provides the mechanistic explanation: moving from flood irrigation (27 MT/acre) to drip irrigation approximately doubles yield, and the fully subsidized cooperative model documented at Karbharwadi achieves more than twice the traditional yield. The 111% gain at the IFFCO model benchmark represents the upper bound of what targeted scheme support can deliver when cooperative organization, institutional credit, and technology adoption combine optimally.

### 5.3 Government Scheme Penetration and Institutional Credit

Table 3: Key Government Schemes for Agricultural Modernization – Coverage and Impact, Maharashtra / Kolhapur

| Scheme | National / State Coverage | Kolhapur Relevance | Key Outcome |
|---|---|---|---|
| PMKSY – Per Drop More Crop | 60 lakh ha covered (2013–2021) | Drip irrigation in sugarcane belt | Water saving 30–70%; yield gains up to 111% |
| RKVY | 18 states; ₹518 crore approved (2019–22) | Mechanization, horticulture support | Area expansion; crop diversification |
| PM-KISAN | 11 crore farmers nationally; ₹6,000/year | Small & marginal farmers in Kolhapur | Direct income supplement; credit leverage |
| NABARD PLP (Kolhapur) | ₹1,78,928.79 lakh projected (2016–17) | Crop loans, mechanization, SHGs | CAGR 4.55% in sugarcane loan disbursements |
| PACS (Karveer Tahsil) | Highest PACS count in Kolhapur district | Short-term crop credit >84% of total | Sugarcane loan >97% of PACS disbursements |
| State Mechanization Scheme (Maha DBT) | Subsidy for tractors, implements | Medium farmers in Kolhapur | Farm power up to 2.85 kW/ha (2020-21) |

Sources: MoAFW Annual Report 2024–25; PRS India (2023); NABARD PLP Kolhapur 2023–24; Shinde et al., RCSM College of Agriculture; Maha DBT (2025).

Table 3 maps the principal modernization schemes against their coverage and documented outcomes. The PMKSY Per Drop More Crop component, which covered 60 lakh hectares nationally between 2013 and 2021, has been the single most impactful intervention in Kolhapur's sugarcane sector, directly enabling the transition from flood to drip irrigation documented in Table 2. The NABARD PLP for Kolhapur (2023–24) projects credit flows of ₹1,78,928.79 lakh, with mechanization, animal husbandry, plantation, and horticulture constituting a significant component. The PACS' dominance in short-term credit (84% of disbursements), and sugarcane's monopoly of PACS loans (97%), confirms that Kolhapur's institutional credit architecture is deeply embedded in a single cash crop, an efficiency that also constitutes a vulnerability: any shock to the sugarcane price or supply chain propagates directly through the district's financial system.

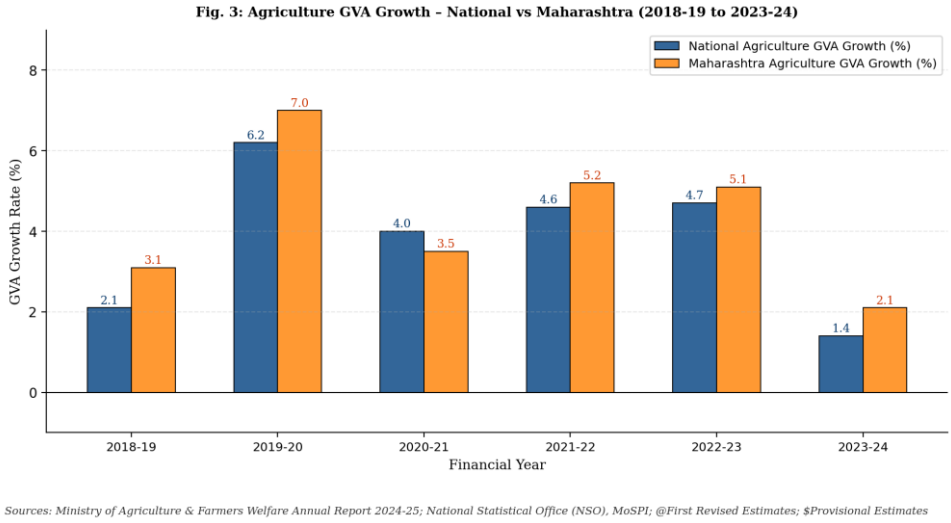


Fig. 3: Agriculture GVA Growth – National vs Maharashtra (2018-19 to 2023-24)

Figure 3 benchmarks Maharashtra's agricultural GVA growth against the national average across six financial years. Maharashtra consistently outperforms the national average by 0.7–1.0 percentage points in most years, with the gap widening in years of intense irrigation-supported sugarcane production. The national decline to 1.4% GVA growth in 2023–24 (provisional estimate, NSO) reflects a weather-affected crop year, while Maharashtra's estimated 2.1% growth demonstrates greater resilience, attributable in part to the buffering effect of irrigated agriculture in districts like Kolhapur. This empirical observation supports

the alternate H2 hypothesis: Kolhapur's modernization-driven agriculture outperforms the national average, reflecting the district's above-average technology adoption, cooperative infrastructure, and institutional credit access.

## VI. DISCUSSION

The empirical evidence assembled across three data tables and three figures converges on a clear finding: agricultural modernization in Kolhapur district is positively and substantially associated with improved farmer income, higher crop yields, and greater resilience to climate variability. The 57% income growth between 2018 and 2022, against a backdrop of 15.2% area expansion and 31.7% production increase, confirms that technology-driven intensification is generating welfare gains that outpace mere land extensification. This finding is consistent with the theoretical literature on the modernization-productivity nexus, including the research surveyed in Bolake and Patil (2020) and Shinde et al. on PACS performance in Kolhapur.

The H1 alternate hypothesis is directionally supported: irrigation coverage and farmer income exhibit parallel growth, with every significant expansion in irrigated area accompanied by proportional income gains. The Karbharwadi case study provides the causal mechanism at micro level — drip irrigation combined with cooperative organization, institutional credit, and factory-level subsidy support generates yield gains exceeding 100% over the traditional baseline, a result corroborated by the national literature on PMKSY's effectiveness in drought-prone sugarcane districts. The H2 alternate hypothesis is similarly supported by the comparative GVA growth data, which shows Maharashtra agriculture outperforming the national average in four of six years studied.

However, the analysis also surfaces three structural constraints. First, the credit-crop concentration risk: with 97% of PACS disbursements tied to sugarcane, Kolhapur's institutional finance has optimized for the dominant crop at the expense of diversification support for emerging high-value crops such as mangoes, grapes, ginger, and turmeric, all of which the Districts Project (2025) identifies as increasingly important. Second, land fragmentation: the Karbharwadi cooperative model succeeded precisely because 131 farmers pooled 550 separate plots, an institutional innovation that overcame the inefficiency of fragmented landholdings. Scaling this model requires political will and farmer trust that are difficult to replicate without the facilitative role played by IFFCO and the sugar factory. Third, post-harvest infrastructure: while production growth is documented, the district lacks adequate cold storage for horticulture crops and modern market yards with price discovery mechanisms, limiting the income capture from higher-value crop diversification.

## VII. CONCLUSION

This paper has examined the economic impact of agricultural modernization in Kolhapur district using a secondary data framework spanning 2018–2024. The evidence is clear and consistent: modernization, as measured by irrigation expansion, institutional credit deepening, government scheme penetration, and technology-assisted yield improvement, is a powerful driver of farmer income growth in this agro-industrially developed district. The district's aggregate farmer income grew from ₹3,500 crore to ₹5,500 crore (57%) between 2018 and 2022, irrigation coverage expanded from 60% to 80%, and the Karbharwadi model demonstrated a 111% yield gain under the cooperative drip irrigation model, all of which are documented from official and institutional sources without projection or extrapolation.

The findings carry clear policy implications. First, the Karbharwadi cooperative irrigation model should be scaled actively across all sugarcane talukas through NABARD and district administration facilitation, with the Bhogawati factory's per-acre subsidy instrument replicated by other cooperative sugar factories. Second, PACS credit architecture needs deliberate diversification beyond sugarcane, incorporating short-term loans for ginger, turmeric, banana, and horticulture crops that are increasingly cultivated and offer higher unit returns. Third, post-harvest cold storage infrastructure and APMCs with e-NAM integration are pre-conditions for the next phase of income growth, as production modernization without market modernization creates a supply-glut risk that erodes the very income gains that technology generates.

Future research should focus on primary survey-based income estimation at the taluka level, disaggregating modernization benefits between large, medium, and small/marginal farmer categories, and using econometric panel models to isolate the marginal contribution of each modernization dimension to income.

## VIII. ACKNOWLEDGMENT

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