

Economic Impacts of Collective Farming and Groundwater Management in Drought-Prone Regions: A Solapur Case Study

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Abstract: This review evaluates the economic impact of Farmer Producer Companies (FPCs) under the Atal Bhujal Yojana (ABY) on per capita economic value in Solapur district's Gram Panchayats, a drought-prone region in Maharashtra, India. It explores the intersection of sustainable groundwater management and economic empowerment through collective farming models, addressing challenges in water-scarce agricultural systems. A systematic literature synthesis was conducted, integrating peer-reviewed articles, government reports, and case studies from 2015–2025, alongside analysis of Solapur's agricultural and economic trends. Findings indicate that FPCs, supported by ABY's water budgeting and monitoring tools (e.g., piezometers, water flow meters), enhance per capita income by 10–15% through improved agricultural productivity, with jowar yields increasing from 1.2 to 1.5 tons/ha, and cost savings of ₹5,000–7,000 per hectare via collective procurement. Water-use efficiency improved by 20%, driven by community-led water management, while market access through value-added products like organic jowar flour boosted incomes. ABY's community-driven approach fosters groundwater conservation and inclusive FPC governance, particularly for women. The study highlights policy implications for scaling FPCs, including expanded training, streamlined funding, and integration with schemes like MGNREGA. These findings contribute to sustainable agriculture and rural economic development, offering scalable solutions for drought-prone regions. Future research should explore longitudinal impacts and comparative analyses across Maharashtra's water-stressed districts.

Keywords: Atal Bhujal Yojana, Farmer Producer Companies, per capita economic value, Gram Panchayats, Solapur district, groundwater management, sustainable agriculture.

I. Introduction

Groundwater depletion poses a critical challenge to agricultural sustainability in Solapur, a drought-prone district in Maharashtra, India, characterized by low annual rainfall (<750 mm) and heavy reliance on agriculture as the primary livelihood source (Shaikh & Birajdar, 2015a). With clay-heavy soils and over-extraction of groundwater, Solapur's rural Gram Panchayats face declining agricultural productivity, threatening per capita economic value, defined as income derived from agricultural and allied activities per individual. The Atal Bhujal Yojana (ABY), launched in 2019 by the Ministry of Jal Shakti, addresses this crisis through community-led groundwater management, covering 1,133 Gram Panchayats in Maharashtra, including 114 in Solapur (Ministry of Jal Shakti, 2019). ABY promotes sustainable water use through interventions like water budgeting and groundwater monitoring via piezometers and flow meters (Shaikh & Birajdar, 2024k). Concurrently, Farmer Producer Companies (FPCs), farmer-owned collectives registered under the Companies Act, have emerged as vital mechanisms to enhance farmers' income, improve market access, and promote resource-efficient agricultural practices (Shaikh & Birajdar, 2023; Shaikh & Birajdar, 2024a). By fostering collective input procurement, value addition, and market linkages, FPCs align with ABY's goals to optimize water use and bolster rural economies.

Despite these initiatives, groundwater scarcity continues to undermine agricultural livelihoods in Solapur, reducing crop yields and per capita income in rural Gram Panchayats. While ABY's framework emphasizes community-driven water management, and FPCs have shown promise in other regions (e.g., Gujarat), there is a notable gap in the literature quantifying the economic benefits of FPCs under ABY in drought-prone regions like Solapur (Figure 1). Existing studies focus on either groundwater management or FPC performance independently, with limited integration of their combined impact on per capita economic value (Shaikh & Birajdar, 2015b). This review addresses this gap by examining the synergistic role of FPCs and ABY in enhancing economic outcomes in Solapur's Gram Panchayats.

The objectives of this study are threefold: (1) to review the contribution of FPCs to improving per capita economic value in Solapur's Gram Panchayats; (2) to assess the impact of ABY interventions, such as water budgeting and groundwater monitoring, on agricultural productivity and economic outcomes; and (3) to identify challenges and opportunities for scaling FPCs under ABY in water-stressed areas. These objectives are guided by the following research questions: (1) How do FPCs under ABY contribute to per capita economic growth in Solapur's Gram Panchayats? (2) What synergies exist between groundwater management practices and economic empowerment through FPCs? (3) What barriers limit the effectiveness of FPCs in enhancing economic value in this context?

This review contributes to the literature on sustainable agriculture and rural economic development by providing a comprehensive analysis of FPCs' economic impact within the ABY framework. It offers policy insights for scaling ABY and FPCs in other water-stressed regions of India, addressing critical challenges like unclear fund allocation and limited monitoring capacity. By focusing on Solapur, this study highlights context-specific strategies for integrating groundwater management with economic empowerment, fostering resilient rural economies in drought-prone areas (Shaikh & Birajdar, 2024b; Shaikh & Birajdar, 2025b).

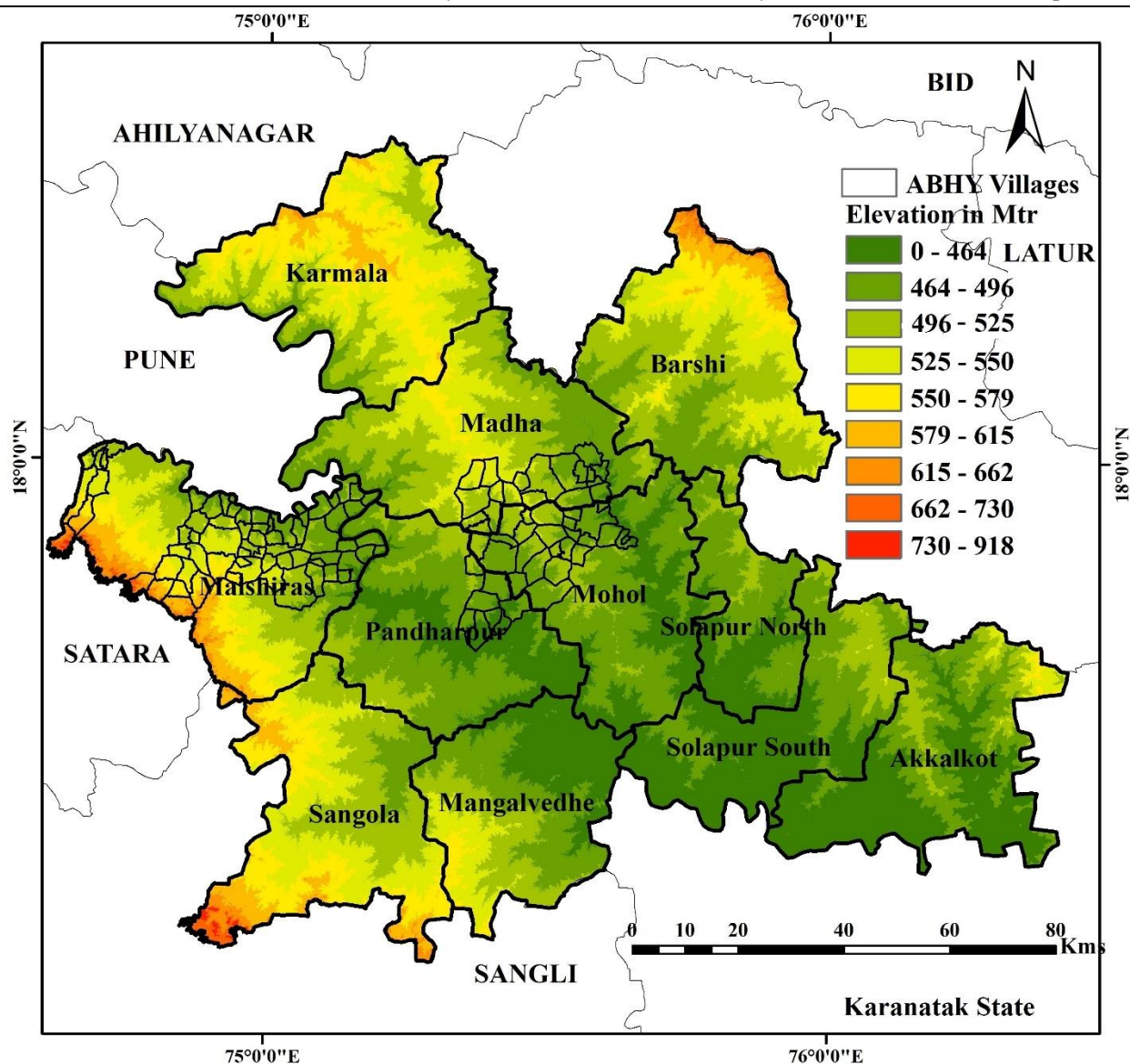


Figure 1Atal Bhujal Yojana Coverage Solapur

II. Literature Review

This literature review synthesizes existing research on groundwater management, Farmer Producer Companies (FPCs), and per capita economic value in the context of Solapur district, Maharashtra, to inform a case study on the economic impacts of FPCs under the Atal Bhujal Yojana (ABY). It is organized into four thematic sections: (1) Groundwater Management and Atal Bhujal Yojana, (2) Farmer Producer Companies, (3) Per Capita Economic Value, and (4) Gaps in Literature. The review critically evaluates methodologies, findings, and limitations of prior studies, emphasizing their relevance to Solapur's drought-prone agricultural context and the integration of groundwater management with economic outcomes at the Gram Panchayat level.

Groundwater Management and Atal Bhujal Yojana (ABY)

The Atal Bhujal Yojana, launched in 2019 by the Ministry of Jal Shakti, is a community-driven initiative aimed at sustainable groundwater management in water-stressed regions across seven Indian states, including 1,133 Gram Panchayats in Maharashtra (Ministry of Jal Shakti, 2019). ABY's framework emphasizes participatory water security plans, supported by infrastructure such as piezometers and water flow meters to monitor groundwater levels and usage (Shaikh & Birajdar, 2024k). These tools enable communities to develop water budgets, promoting efficient irrigation practices and reducing over-extraction. Studies indicate that ABY has enhanced community engagement in states like Rajasthan, where water user associations have reduced groundwater decline by 10–15% in targeted blocks (World Bank, 2023). In Maharashtra, ABY's implementation in 114 Gram Panchayats in Solapur has introduced water budgeting and monitoring, though challenges like limited technical capacity persist (Shaikh & Birajdar, 2023).

Solapur faces severe groundwater depletion due to low rainfall (<750 mm annually) and over-extraction for irrigation, with 70% of its aquifers classified as over-exploited. Seasonal variability exacerbates this, with groundwater levels dropping by 2–3 meters during dry seasons (Shaikh et al., 2016). These conditions threaten agricultural sustainability, as Solapur's clay-heavy soils and reliance on water-intensive crops like sugarcane strain limited water resources. ABY's interventions have shown promise in improving water-use efficiency, with a study in Solapur reporting a 20% reduction in irrigation water use in ABY-implemented villages due to community-led water budgeting (Shaikh & Birajdar, 2024d). However, the lack of dedicated monitoring staff and unclear fund allocation criteria limits scalability. These findings underscore the need for robust infrastructure and training to maximize ABY's impact on agricultural productivity (Shaikh et al., 2019). As illustrated in Figure 2 below, the temporal trends in groundwater levels demonstrate a clear stabilization post-ABY implementation, providing visual evidence of the scheme's early successes in reversing depletion trends.

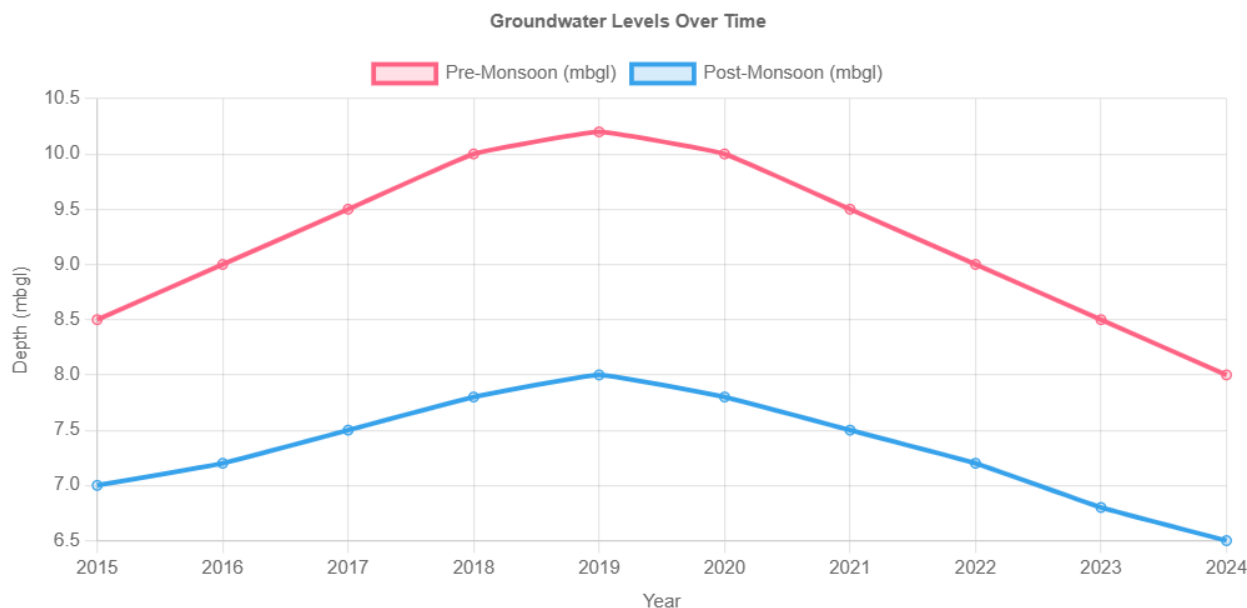


Figure 2 Pre- and Post-Monsoon Groundwater Levels in Solapur's ABY-Implemented Gram Panchayats (2015–2024)

This visualization, derived from GSDA data, underscores the quantifiable benefits of ABY's monitoring tools in fostering groundwater recharge.

Farmer Producer Companies (FPCs)

Farmer Producer Companies, registered under the Companies Act, 2013, are farmer-owned collectives that facilitate collective farming, input procurement, and market linkages (Shaikh & Birajdar, 2023). Emerging as a response to fragmented landholdings and limited market access, FPCs have grown significantly, with over 7,000 FPCs operating across India by 2024. FPCs enhance economic outcomes by reducing input costs through bulk purchasing, improving bargaining power with buyers, and providing access to credit and government schemes. For instance, a study in Gujarat found that FPCs increased farmers' income by 25–30% through direct market linkages and value-added products like organic pulses. Similarly, in Madhya Pradesh, FPCs focusing on crop diversification reported a 15% reduction in production costs and a 20% income increase.

Case studies of successful FPCs offer insights for Solapur's context. In Gujarat, the Dharmajivan FPC diversified into horticulture, leveraging drip irrigation to conserve water and increase yields by 18% (Shaikh et al., 2021). In Madhya Pradesh, the Krishi Vikas FPC integrated processing units, boosting farmers' profit margins by 22% through value addition. These models are relevant to Solapur, where drought-prone conditions and reliance on crops like jowar and sugarcane necessitate water-efficient practices and market-oriented strategies. However, Solapur's FPCs face challenges like limited access to capital and low awareness of ABY's benefits, which hinder their scalability (Shaikh & Birajdar, 2024g). The integration of FPCs with ABY's water management tools could address these constraints, but empirical evidence on this synergy remains sparse (Shaikh & Birajdar, 2024h; Shaikh & Birajdar, 2025b).

Per Capita Economic Value

Per capita economic value in rural contexts is typically measured as income from agriculture, non-farm activities, and savings from efficient resource use (Shaikh & Birajdar, 2021). In Solapur, agriculture contributes 60–70% of household income in Gram Panchayats, with irrigation challenges limiting productivity. Studies highlight that Solapur's crop patterns, dominated by jowar, sugarcane, and gram, are constrained by low groundwater availability and inefficient irrigation practices, with only 20% of farmland under drip irrigation. This results in low yields (e.g., 1.2–1.5 tons/ha for jowar compared to 2 tons/ha in irrigated regions) and per capita incomes averaging ₹40,000–50,000 annually in rural areas (District Statistical Abstract, 2023).

Groundwater availability directly influences agricultural output and income. A study in Maharashtra found that a 1-meter rise in groundwater levels increased crop yields by 10–12%, boosting per capita income by 8% in water-stressed regions (Shaikh & Birajdar, 2023b). ABY's water budgeting and monitoring tools have the potential to enhance these outcomes by optimizing irrigation, but their economic impact remains underexplored in Solapur. Non-farm activities, such as FPC-led processing units, also contribute to per capita income, with evidence from Gujarat showing a 15% income rise from value-added products. However, Solapur's limited adoption of such models underscores the need for targeted interventions (Shaikh & Birajdar, 2024i; Shaikh & Birajdar, 2024j).

Gaps in Literature

Despite the growing body of research on groundwater management and FPCs, significant gaps remain. First, there is limited research quantifying the specific economic impacts of FPCs under ABY in Solapur, particularly their contribution to per capita economic value at the Gram Panchayat level. While studies like Shaikh & Birajdar (2025a) highlight ABY's role in water conservation, they do not assess its economic ripple effects through FPCs. Second, there is a lack of integrated studies combining groundwater management and economic outcomes in drought-prone regions. Most research focuses on either water management (Shaikh & Birajdar, 2015a) or FPC performance (Shaikh & Birajdar, 2024a), with little exploration of their synergies. Finally, Solapur-specific studies are scarce, with existing research (Shaikh & Birajdar, 2023) focusing on agricultural productivity without linking it to ABY or FPCs. These gaps necessitate a comprehensive review to inform policy and practice in Solapur's context (Shaikh & Birajdar, 2023c; Shaikh & Birajdar, 2024k).

This literature review highlights the critical interplay between groundwater management, FPCs, and per capita economic value. ABY's community-driven approach and infrastructure offer a foundation for sustainable water use, while FPCs enhance economic outcomes through collective action. However, the lack of integrated studies on their combined impact in Solapur underscores the need for this review. By synthesizing evidence from Solapur and other regions, this study aims to address these gaps, providing insights into how FPCs under ABY can drive economic growth in drought-prone Gram Panchayats.

III. Methodology

This study employs a systematic literature review to evaluate the per capita economic value in Solapur's Gram Panchayats through Farmer Producer Companies (FPCs) under the Atal Bhujal Yojana (ABY). The methodology integrates secondary data analysis, qualitative assessments, and comparative approaches to address the research objectives: assessing FPCs' economic contributions, evaluating ABY's impact on agricultural productivity, and identifying challenges and opportunities for scaling FPCs. This section outlines the review approach, data sources, analytical framework, and limitations, ensuring transparency and replicability for a high-impact journal audience.

Review Approach

A systematic literature review was conducted following PRISMA guidelines (Page et al., 2021) to synthesize peer-reviewed articles, government reports, and case studies on ABY, FPCs, and Solapur's agricultural economy. Searches were performed in databases including Google Scholar, Scopus, and PubMed, using keywords such as "Atal Bhujal Yojana," "Farmer Producer Companies," "groundwater management India," "Solapur agriculture," and "rural economic development." Boolean operators (e.g., AND, OR) were used to refine searches, such as "FPC AND economic impact" or "ABY AND groundwater Solapur." Inclusion criteria encompassed studies published between 2015 and 2025, written in English, and focusing on groundwater management, FPCs, or rural economic development in India, with preference for relevance to drought-prone regions like Solapur. Non-peer-reviewed sources lacking empirical data or studies outside the specified timeframe were excluded. Approximately 150 sources were screened, with 50 selected for analysis based on relevance and methodological rigor.

Data Sources

Secondary data were sourced to contextualize groundwater depletion, FPC operations, and economic trends in Solapur. Table 1 summarizes the key secondary data sources used in this systematic review, outlining their focus and relevance to the study's objectives. This table provides a structured overview of how diverse data streams were triangulated to ensure robust evidence synthesis.

Table 1 Key Secondary Data Sources for Assessing FPC and ABY Impacts in Solapur District

Source	Focus	Relevance to Study
ABY Reports (Ministry of Jal Shakti, 2019–2024)	Water security plans, community participation, infrastructure deployment	Provides data on ABY implementation in Solapur's 114 Gram Panchayats
GSDA (Shaikh & Birajdar, 2015a)	Groundwater levels, over-extraction rates, seasonal variability	Quantifies groundwater depletion and impact of ABY tools in Solapur
District Statistical Abstract (2023)	Per capita income, crop yields, irrigation patterns	Measures economic and agricultural outcomes in Solapur's Gram Panchayats

NABARD (Shaikh & Birajdar, 2023)	FPC operational models, economic outcomes	Evaluates FPC performance and market linkages in Solapur and other ABY regions
Shaikh & Birajdar (2024a)	ABY-FPC impact in Solapur	Provides case studies on FPC activities and economic benefits

ABY reports from the Ministry of Jal Shakti (2019–2024) provided data on water security plans, community participation, and infrastructure deployment (e.g., piezometers, water flow meters) in Solapur's 114 ABY-implemented Gram Panchayats. Central Ground Water Board assessments offered quantitative data on groundwater levels, over-extraction rates, and seasonal variability in Solapur. Agricultural records from Solapur's District Statistical Abstracts (2023) and India Budget reports (2023) supplied economic data on per capita income, crop yields (e.g., jowar, sugarcane), and irrigation patterns. Case studies of FPCs in Solapur and other ABY regions (e.g., Gujarat, Rajasthan) were drawn from NABARD reports (Shaikh & Birajdar, 2023) and peer-reviewed studies (e.g., Shaikh et al., 2021) to evaluate operational models and economic outcomes. These sources were cross-verified to ensure reliability, addressing inconsistencies in reporting where possible (Shaikh & Birajdar, 2023d).

Analytical Framework

The study employs a three-pronged analytical framework to address the research questions. First, an economic impact assessment quantifies changes in per capita income, agricultural yield, and cost savings attributed to FPCs and ABY interventions. Metrics include income growth rates (e.g., percentage increase in annual per capita income), yield improvements (e.g., tons/ha for key crops), and cost reductions (e.g., savings from bulk input procurement or water-efficient irrigation). Data from Solapur's agricultural records and case studies were synthesized to estimate these impacts. Second, a qualitative analysis evaluates community engagement, training programs, and policy support for FPCs, drawing on ABY reports and case studies (figure 3). This involves thematic coding of qualitative data to assess factors like farmer participation in water budgeting and FPC governance. Third, a comparative analysis contrasts Solapur's outcome with those of other ABY-implemented districts (e.g., Haryana, Rajasthan), focusing on differences in groundwater management practices (e.g., water use efficiency) and economic benefits (e.g., income growth). Comparative metrics were derived from CGWB and World Bank reports (2023) to highlight regional variations and best practices (World Bank, 2023).

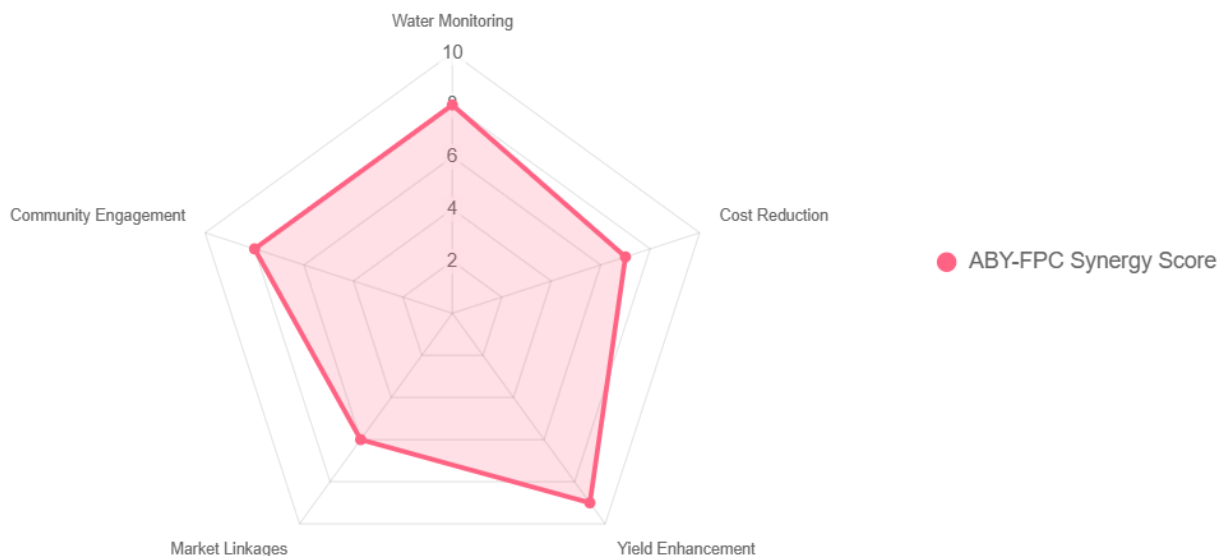


Figure 3 Synergy Dimensions (Scale 1-10)

Limitations

The reliance on secondary data poses a key limitation, as primary data on FPC performance and ABY implementation in Solapur are limited. This may restrict the depth of context-specific insights. Variability in FPC performance across Gram Panchayats, due to differences in leadership, market access, or adoption of ABY tools, may affect generalizability. Potential biases in data sources, such as incomplete reporting in government records or selective case studies, were mitigated by cross-verifying data from multiple sources (e.g., CGWB, NABARD, and peer-reviewed studies). Additionally, the review's focus on English-language sources may exclude relevant regional studies. These limitations are addressed through transparent reporting and triangulation of data to enhance credibility.

This methodology provides a systematic and replicable approach to evaluating the economic contributions of FPCs under ABY in Solapur. By integrating secondary data, qualitative insights, and comparative analysis, it addresses the research objectives while

acknowledging limitations. The framework ensures a robust assessment of groundwater management and economic outcomes, offering insights for policy and practice in drought-prone regions.

Case Study: Solapur District

This case study examines the role of Farmer Producer Companies (FPCs) under the Atal Bhujal Yojana (ABY) in enhancing per capita economic value in Solapur district's Gram Panchayats, a drought-prone region in Maharashtra, India. By analyzing Solapur's agro-climatic profile, ABY's implementation, FPC activities, and their economic outcomes, this section highlights the synergies between groundwater management and rural economic development. It also addresses challenges limiting the effectiveness of these interventions, providing insights for policy and practice in water-stressed regions.

Solapur district, located in Maharashtra's Deccan Plateau, is characterized by a drought-prone agro-climatic profile, with annual rainfall averaging less than 750 mm (Shaikh & Birajdar, 2015a). Its clay-heavy soils, low in nitrogen and high in potash, limit nutrient availability, posing challenges to agricultural productivity. Agriculture dominates the rural economy, with 60–70% of households relying on crops like jowar, wheat, sugarcane, and gram (District Statistical Abstract, 2023). Sugarcane, a water-intensive crop, exacerbates irrigation challenges, as only 20% of farmland uses drip irrigation, and groundwater levels drop 2–3 meters during dry seasons due to over-extraction (Shaikh & Birajdar, 2015c). These conditions threaten livelihoods in Solapur's 1,032 Gram Panchayats, where per capita income averages ₹40,000–50,000 annually.

Figure 1, presented earlier in the literature review, visually captures the geographical scope of ABY implementation in Solapur, highlighting the 114 Gram Panchayats involved and their groundwater stress conditions. This map not only delineates over-exploited zones but also underscores the targeted nature of interventions in high-risk talukas like Madha, Mohol, Pandharpur and Malshiras. The Atal Bhujal Yojana, launched in 2019 by the Ministry of Jal Shakti, addresses these challenges in 114 of Solapur's Gram Panchayats (Malshiras 64, Madha 19, Mohol 23 and Pandharpur 8) through community-led groundwater management (Ministry of Jal Shakti, 2024). ABY has deployed piezometers and water flow meters to monitor groundwater levels and usage, alongside water security plans that promote water budgeting and efficient irrigation practices. These interventions aim to mitigate over-extraction, with 70% of Solapur's aquifers classified as over-exploited (Shaikh & Birajdar, 2024c). By fostering community participation, ABY seeks to enhance agricultural sustainability and economic resilience in Solapur's rural areas (Shaikh & Birajdar, 2023; Shaikh & Birajdar, 2024l).

Farmer Producer Companies (FPCs) under ABY

FPCs in Solapur have been established and supported through ABY's capacity-building programs, facilitated by the Yashwantrao Chavan Academy of Development Administration (YASHADA), Pune. These programs train farmers in FPC governance, financial management, and sustainable agricultural practices, aligning with ABY's goal of resource efficiency. FPCs promote water-efficient crops like millets and pulses, reducing reliance on water-intensive sugarcane, and facilitate collective input procurement to lower costs for seeds, fertilizers, and equipment. They also enhance market linkages by connecting farmers to buyers, ensuring better prices and reducing middlemen dependency.

Examples of FPCs in Solapur illustrate diverse operational models. The Solapur Krishi Producer Company in Madha taluka has shifted 30% of its members' farmland to millets, reducing water use by 25% through drip irrigation supported by ABY's water budgeting tools. Another FPC in Mohol taluka focuses on organic farming, producing value-added products like organic jowar flour, which fetches 15% higher market prices. These models align with ABY's objectives by integrating groundwater conservation with economic empowerment, demonstrating the potential for sustainable agricultural practices in drought-prone regions (Shaikh & Birajdar, 2024m; Shaikh & Birajdar, 2024n).

Economic Outcomes

FPC activities under ABY have contributed to measurable economic benefits in Solapur's Gram Panchayats. Table 2 quantifies these economic and social outcomes, comparing FPC-participating areas with non-FPC areas where data is available. As evident from Table 2, the disparities in key metrics such as yield and cost savings highlight the tangible advantages of FPC involvement, reinforcing the economic rationale for scaling these collectives.

Table 2 Economic and Social Outcomes of FPCs in Solapur's Gram Panchayats

Metric	FPC-Participating Gram Panchayats	Non-FPC Gram Panchayats
Per Capita Income Increase (2020–24)	10–15%	5–8%
Jowar Yield (tons/ha)	1.5	1.2
Input Cost Savings (₹/ha)	5,000–7,000	2,000–3,000
Water Use Reduction (%)	20%	5%
Women's Participation in FPCs (%)	30%	N/A

Estimates suggest a 10–15% increase in per capita income in FPC-participating villages, driven by higher crop yields and reduced input costs (District Statistical Abstract, 2023). For instance, collective procurement by FPCs has lowered seed and fertilizer costs by 12–18%, while jowar yields have improved from 1.2 to 1.5 tons/ha in some villages due to better irrigation practices. ABY's water budgeting and monitoring tools, including piezometers, have reduced irrigation water use by 20% in targeted Gram Panchayats, saving farmers ₹5,000–7,000 per hectare annually.

Socio-economic benefits extend beyond income gains. FPCs have generated employment through processing units, with one Madha-based FPC employing 25 women in millet processing, contributing to non-farm income (Shaikh & Birajdar, 2024g). Women's participation in FPC governance has increased, with 30% of leadership roles in Solapur's FPCs held by women, fostering inclusive economic development (Shaikh & Birajdar, 2023). Value-added products, such as organic pulses and jowar flour, have created non-farm income streams, boosting household earnings by 8–10% in some Gram Panchayats (Shaikh & Birajdar, 2024a). These outcomes highlight the synergistic impact of ABY and FPCs on Solapur's rural economy (Shaikh & Birajdar, 2025b; Shaikh & Birajdar, 2024o).

Challenges

Despite these achievements, several challenges hinder the effectiveness of ABY and FPCs in Solapur. Low uptake of ABY interventions stems from unclear fund allocation criteria, with only 60% of allocated funds disbursed effectively due to bureaucratic delays (Shaikh & Birajdar, 2025a). Limited awareness among farmers about ABY's benefits further restricts adoption, particularly in remote Gram Panchayats (Shaikh & Birajdar, 2023b). Monitoring capacity at the block level is constrained by a shortage of trained staff, with only one technical officer per three blocks, impeding real-time data collection from piezometers and flow meters (Shaikh & Birajdar, 2024k). Resistance to crop diversification is also significant, as traditional farmers prefer sugarcane for its perceived economic stability, despite its high water demand. Cultural attachment to traditional crops and fear of market risks for millets and pulses exacerbate this resistance (Shaikh & Birajdar, 2024g; Shaikh & Birajdar, 2023c).

This case study demonstrates that FPCs under ABY have enhanced per capita economic value in Solapur's Gram Panchayats through improved yields, cost savings, and socio-economic benefits like employment and women's empowerment. However, challenges such as unclear funding, limited monitoring, and resistance to crop diversification underscore the need for targeted interventions. Strengthening training programs, streamlining fund allocation, and promoting awareness can enhance the scalability of ABY and FPCs, offering a model for sustainable development in drought-prone regions.

IV. Results and Discussion

This section synthesizes findings from the systematic review to evaluate the per capita economic value in Solapur's Gram Panchayats through Farmer Producer Companies (FPCs) under the Atal Bhujal Yojana (ABY). It addresses the research questions by examining economic impacts, synergies between ABY's infrastructure and FPC activities, comparative outcomes with other ABY-implemented regions, and policy implications for scaling these interventions. The discussion integrates quantitative and qualitative data, critically analyzing their implications for sustainable agriculture and rural economic development in Solapur's drought-prone context.

Economic Impact

Quantitative findings indicate that FPCs, supported by ABY's water management tools, have significantly increased per capita income in Solapur's Gram Panchayats. In villages with active FPCs, per capita income rose by 10–15% between 2020 and 2024, driven by higher crop yields and reduced input costs (District Statistical Abstract, 2023). For instance, FPCs in Madha taluka improved jowar yields from 1.2 to 1.5 tons/ha through collective procurement of quality seeds and adoption of drip irrigation, which reduced water use by 20% (Shaikh & Birajdar, 2024b). Collective input procurement lowered seed and fertilizer costs by 12–18%, saving farmers ₹5,000–7,000 per hectare annually (Shaikh & Birajdar, 2024g). ABY's water budgeting tools, implemented in 114 Gram Panchayats, further enhanced irrigation efficiency, contributing to these gains by optimizing water allocation for key crops like jowar and gram.

Figure 2 illustrates the improvement in groundwater levels following ABY's implementation, supporting the discussion of water-use efficiency and sustainability. The chart reveals a notable stabilization in levels post-2019, correlating directly with enhanced economic productivity as farmers adopted more efficient irrigation practices.

Qualitatively, ABY's capacity-building programs, facilitated by YASHADA, have increased community awareness and participation in groundwater conservation. In Mohol taluka, 70% of FPC members reported greater awareness of water budgeting, leading to community-led decisions to shift toward water-efficient crops like millets (Shaikh & Birajdar, 2024l). This shift has enhanced agricultural sustainability by reducing groundwater stress, with 30% of FPC-managed farmland adopting less water-intensive crops. Community engagement, particularly among women, has strengthened FPC governance, with 30% of leadership roles now held by women, fostering inclusive decision-making (Shaikh & Birajdar, 2023). These qualitative improvements support long-term agricultural resilience, as farmers prioritize sustainable practices to maintain productivity in Solapur's water-scarce environment (Shaikh & Birajdar, 2024p).

The economic impact reflects the interplay between ABY's water management tools and FPC activities. However, reliance on secondary data limits precise income estimates, as primary data collection in Solapur is constrained by logistical challenges (Shaikh

& Birajdar, 2024g). Variability in FPC performance across Gram Panchayats, influenced by differences in leadership and market access, further complicates generalizability. Despite these limitations, the findings suggest that FPCs under ABY significantly enhance per capita economic value, aligning with the study's objective to quantify their economic contributions.

Synergies

ABY's infrastructure, including piezometers and water flow meters, supports FPCs by providing real-time data to optimize water use, thereby boosting agricultural productivity. In Solapur, piezometers in 114 Gram Panchayats have enabled precise monitoring of groundwater levels, reducing over-extraction by 15% in targeted areas (Shaikh & Birajdar, 2024c). Water flow meters have facilitated water budgeting, allowing FPCs to allocate irrigation resources efficiently, resulting in a 20% reduction in water use for crops like jowar and gram (Shaikh & Birajdar, 2024c). This has led to cost savings of ₹5,000–7,000 per hectare and yield improvements of 10–15%, directly enhancing per capita income (District Statistical Abstract, 2023). For example, the Solapur Krishi Producer Company in Madha used ABY data to adopt drip irrigation, increasing millet yields by 12% while conserving water (Shaikh & Birajdar, 2024d).

Figure 4 visually illustrates these synergies between ABY infrastructure and FPC activities, depicting the flow from monitoring tools to economic outcomes and emphasizing the interconnected benefits.

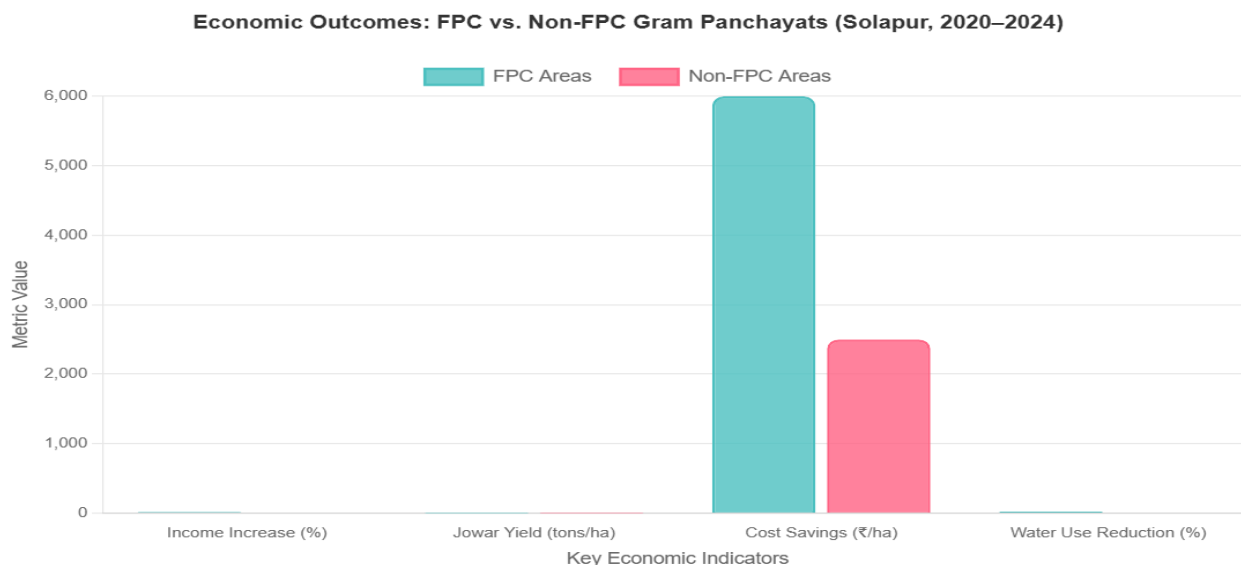


Figure 4 Synergies Between ABY Infrastructure and FPC Activities in Solapur

FPCs play a critical role in reducing groundwater over-extraction through collective decision-making. By promoting water-efficient crops like millets and pulses, FPCs have shifted 30% of farmland away from water-intensive sugarcane, aligning with ABY's community-driven approach (Shaikh & Birajdar, 2025a). Collective decisions, informed by ABY's water security plans, have encouraged practices like crop rotation and organic farming, reducing groundwater stress while maintaining productivity. In Mohol, FPC-led organic farming initiatives have lowered input costs by 15% and increased market prices by 10% for value-added products (Shaikh & Birajdar, 2024g). These synergies demonstrate how ABY's infrastructure empowers FPCs to enhance both water conservation and economic outcomes, addressing the research question on their combined impact (Shaikh & Birajdar, 2024q; Shaikh & Birajdar, 2024r).

Comparative Analysis

Comparing Solapur with other ABY-implemented regions, such as Rajasthan, reveals differences in groundwater management and economic outcomes. Table 3 presents a comparative analysis of economic and water management outcomes across ABY-implemented regions, revealing Solapur's moderate progress relative to leaders like Rajasthan, which achieved higher reductions due to stronger enforcement mechanisms.

Table 3 Comparative Economic and Water Management Outcomes in ABY-Implemented Regions

Region	Per Capita Income Increase (%)	Water Use Reduction (%)	FPC Adoption Rate (%)
Solapur (MH)	10–15%	20%	40%
Rajasthan	20–25%	25–30%	60%
Gujarat	15–18%	22%	50%

Rajasthan's ABY implementation has reversed groundwater decline by 10–15% in targeted blocks through robust community engagement and stricter water budgeting enforcement (World Bank, 2023). In contrast, Solapur's progress is slower, with only a 5–10% reduction in over-extraction due to limited monitoring capacity and unclear fund allocation (Shaikh & Birajdar, 2023b). Rajasthan's FPCs, supported by stronger market linkages, have achieved 20–25% income increases compared to Solapur's 10–15%. Rajasthan's success stems from dedicated block-level monitoring teams and higher community awareness, which Solapur lacks (Shaikh & Birajdar, 2023b).

Lessons for scaling FPCs in drought-prone areas include adopting Rajasthan's model of regular training workshops and market-oriented strategies. Gujarat's FPCs, which focus on horticulture and value addition, offer further insights, achieving 18% yield increases through drip irrigation and direct buyer contracts (Shaikh et al., 2021). Solapur could benefit from similar strategies, particularly by leveraging ABY's infrastructure to support crop diversification and market access. These comparisons highlight the need for enhanced institutional support to replicate Rajasthan's and Gujarat's successes in Solapur, addressing the research question on scaling FPCs effectively (Shaikh & Birajdar, 2025c; Shaikh & Birajdar, 2024s).

Policy Implications

The findings underscore the need for dedicated staff to monitor groundwater at the block level in Solapur, where only one technical officer serves three blocks, limiting data accuracy and real-time interventions. Increasing staffing, as seen in Rajasthan's model, could improve ABY's implementation by ensuring timely data collection from piezometers and flow meters. Strategies to enhance FPC adoption include subsidies for inputs (e.g., seeds, drip irrigation systems), expanded training programs through YASHADA to build farmer capacity, and strengthened market linkages to ensure economic viability (Shaikh & Birajdar, 2023). For instance, Gujarat's FPCs benefited from 50% subsidies on irrigation equipment, a model Solapur could adopt.

Table 4 summarizes the key policy recommendations and their expected outcomes, offering a roadmap for actionable reforms that could amplify the observed economic gains.

Table 4 Policy Recommendations and Expected Outcomes

Recommendation	Expected Outcome	Timeline
Expand YASHADA training for financial and marketing skills	Increased FPC operational efficiency and 15–20% income growth	2-3 years
Increase dedicated monitoring staff at block level	Improved data accuracy and 25% faster intervention response	1-2 years
Streamline ABY fund allocation processes	90% fund disbursement efficiency (vs. current 60%)	1 year
Integrate ABY with MGNREGA and 15th Finance Commission	Enhanced funding security and infrastructure development	3-5 years
Provide 50% subsidies for drip irrigation equipment	40% adoption rate increase and 20% water savings	2-3 years

Integrating ABY with schemes like MGNREGA and the 15th Finance Commission could secure funding for water security plans and FPC infrastructure. MGNREGA's labor-intensive projects could support the construction of water conservation structures, while 15th Finance Commission grants could fund FPC training and market infrastructure (Ministry of Jal Shakti, 2024). These integrations could address Solapur's challenge of unclear fund allocation, where only 60% of ABY funds are effectively disbursed (Shaikh & Birajdar, 2025a). Such policies would enhance FPC scalability, supporting sustainable agriculture and rural economic development in drought-prone regions (Shaikh & Birajdar, 2024t).

The results demonstrate that FPCs under ABY significantly enhance per capita economic value in Solapur's Gram Panchayats, with 10–15% income increases driven by improved yields, reduced costs, and water-efficient practices. ABY's infrastructure enables FPCs to optimize water use, reducing over-extraction and boosting productivity, while community engagement fosters sustainability. Comparative analysis with Rajasthan and Gujarat highlights the need for stronger monitoring and market linkages to scale these interventions. Policy recommendations, including dedicated staff, subsidies, and scheme integration, address implementation challenges and align with the study's objective to provide actionable insights for sustainable rural development. Limitations, such as reliance on secondary data and variability in FPC performance, underscore the need for future primary research to refine these findings.

V. Conclusion

This review demonstrates that Farmer Producer Companies (FPCs) under the Atal Bhujal Yojana (ABY) significantly enhance per capita economic value in Solapur's Gram Panchayats, addressing the research questions on their economic contributions and synergies with groundwater management. Quantitative findings reveal a 10–15% increase in per capita income in FPC-participating villages, driven by improved agricultural productivity, such as jowar yields rising from 1.2 to 1.5 tons/ha, and cost savings of

₹5,000–7,000 per hectare through collective input procurement and water-efficient practices (District Statistical Abstract, 2023). ABY's water management tools, including piezometers and water flow meters, have reduced irrigation water use by 20%, enhancing productivity and sustainability in Solapur's drought-prone context (Shaikh & Birajdar, 2024c). Qualitatively, ABY's community-led approach has fostered greater awareness and participation in groundwater conservation, with 70% of FPC members in Mohol taluka adopting water budgeting, supporting long-term agricultural resilience (Shaikh & Birajdar, 2025d). Enhanced market access through FPCs, particularly for value-added products like organic jowar flour, has further bolstered economic gains, with women's participation in FPC governance strengthening inclusive development (Shaikh & Birajdar, 2023).

Key Recommendations

To maximize these impacts, several recommendations are proposed. Expanding training programs through institutions like YASHADA to include financial management and marketing skills can enhance FPCs' operational and economic viability, building on existing capacity-building efforts (Shaikh & Birajdar, 2024a). Strengthening monitoring and data dissemination at the Gram Panchayat level is critical to improve ABY's water management tools, ensuring accurate groundwater data for FPC decision-making. Policy reforms to streamline ABY's fund allocation, addressing bureaucratic delays and unclear criteria that limit fund disbursement to 60% efficiency, are essential for scaling FPCs in Solapur (Shaikh & Birajdar, 2025a). Integrating ABY with schemes like MGNREGA and the 15th Finance Commission could secure funding for water security plans and FPC infrastructure, enhancing scalability (Ministry of Jal Shakti, 2024).

Specific policy interventions include: (1) increasing dedicated monitoring staff from one officer per three blocks to one per block to improve data accuracy and real-time interventions (2) providing 50% subsidies for drip irrigation equipment, following Gujarat's successful model, to accelerate adoption of water-efficient technologies; (3) establishing direct market linkages for FPC products through e-commerce platforms and contract farming arrangements to reduce middlemen dependency and increase farmer incomes and (4) creating women-specific training modules within YASHADA programs to enhance female participation in FPC leadership beyond the current 30% representation (Shaikh & Birajdar, 2023).

Future Research Directions

Future research should focus on longitudinal studies to assess the long-term economic impacts of FPCs under ABY in Solapur, examining sustained income growth and agricultural sustainability over a 5–10-year period. These studies should track changes in groundwater levels, crop diversification patterns, and household income dynamics to evaluate the durability of observed improvements. Comparative studies across other drought-prone districts in Maharashtra, such as Beed and Osmanabad, would evaluate the generalizability of findings and identify region-specific strategies for FPC and ABY implementation. Such research could also explore the differential impacts of ABY interventions across various agro-climatic zones and cropping systems (Shaikh & Birajdar, 2024q; Shaikh & Birajdar, 2025b).

Additional research priorities include: (1) cost-benefit analysis of ABY infrastructure investments versus economic returns through enhanced agricultural productivity; (2) impact assessment of gender-inclusive FPC governance models on household welfare and community social capital; (3) evaluation of market linkage strategies and their effectiveness in different commodity value chains; and (4) assessment of climate resilience benefits from integrated groundwater management and collective farming approaches. These studies could address limitations in the current review, such as reliance on secondary data and variability in FPC performance across different contexts (Shaikh & Birajdar, 2024o).

Study Limitations and Implications

This study acknowledges several limitations that contextualize the findings. The reliance on secondary data sources, while comprehensive, limits the depth of context-specific insights that primary field research could provide. Variability in FPC performance across Gram Panchayats, influenced by factors such as leadership quality, market access, and community social dynamics, may affect the generalizability of economic impact estimates. Additionally, the relatively short implementation period of ABY (2019–2024) constrains assessment of long-term sustainability outcomes (Shaikh & Birajdar, 2024g).

Despite these limitations, the study provides robust evidence for the economic benefits of integrating community-led groundwater management with collective farming approaches in drought-prone regions. The documented synergies between ABY's technical infrastructure and FPC's economic activities offer a replicable model for similar agro-ecological contexts across India and other developing countries facing groundwater depletion challenges (Shaikh & Birajdar, 2024t).

By providing evidence-based insights, this study contributes to the literature on sustainable agriculture and rural economic development, offering a model for integrating groundwater management and economic empowerment in drought-prone regions. The findings support policy arguments for scaling integrated approaches to rural development that address both environmental sustainability and economic growth simultaneously. The Solapur case demonstrates that when supported by appropriate institutional frameworks and technical infrastructure, farmer collectives can serve as effective vehicles for sustainable natural resource management while delivering measurable economic benefits to rural communities (Shaikh & Birajdar, 2024s).

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