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BRIDGING TECHNOLOGY AND TRADITION: THE ROLE OF FPOS IN ENHANCING AGRI-RESILIENCE IN MAHARASHTRA'S VIDARBHA

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Abstract

In India, the Vidarbha region of Maharashtra has long exemplified agrarian distress, marked by recurrent droughts, rainfall variability, and groundwater depletion. Structural barriers to resilience persist. India's collectivization policy, scaled through the 10,000 FPO strategy, aims to consolidate smallholders, enhance bargaining power, and create new avenues for risk-sharing. However, there is limited empirical evidence on whether FPOs actually strengthen resilience. This paper examines the role of Farmer Producer Organizations (FPOs) in enhancing agricultural resilience. The resilience metric employed is the Agricultural Resilience Index (ARI). Market resilience is assessed via crop output variability and mandi price fluctuations, while climate and resource resilience are evaluated using rainfall anomalies. Methodologically, we integrate quantitative panel econometrics with qualitative insights. Composite indices are used within the ARI framework. We apply models to test whether increased FPO penetration is associated with improved resilience. These statistical findings are complemented with case narratives from selected FPOs, illustrating how traditional practices are being embedded within new institutional and technological frameworks. Preliminary results show that districts with stronger FPO presence experience lower output volatility, higher policy adoption, and better price stabilization. Cotton-intensive districts show more significant improvements in market resilience. Our analysis demonstrates that resilience extends beyond technological adoption—it is also rooted in traditional collective practices. The study makes three major contributions. First, it provides one of the earliest district-level assessments of FPO impact in the region. Second, the index integrates climatic, market, financial, and institutional dimensions. Finally, it shows that FPOs can act as a bridge between local traditions and emerging digital and policy infrastructures in sustainable agricultural transformation. Policy implications include the need to build capacity for younger FPOs, align crop insurance schemes with collective marketing, and design region-specific resilience strategies. This study contributes to broader discussions on rural transformation, sustainable livelihoods, and the evolving role of collectivization in Indian agriculture.

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1. Introduction

1.1 Agrarian Context in Vidarbha

India's rural economy employs 45% of the workforce and contributes 15% to the GDP [1]. The Vidarbha region is one of the most agriculturally significant areas in Maharashtra [2]. The region is known for its fertile black cotton soil, but it is prone to both waterlogging and drought, making farming highly risky [3].

Cotton, soybean, pigeon pea, and millets make up the bulk of the agricultural portfolio in the region. Almost all cultivated land is dependent on monsoon rainfall [4]. Maharashtra has one of the lowest irrigation coverage rates in India [5]. Delays and inefficiencies in major irrigation projects have left over 140,000 hectares of cultivable land without irrigation [6]. Weather variability in the region has also increased in recent years [7]. These agro-climatic and infrastructural constraints collectively intensify smallholder vulnerability.

1.2 Agrarian Distress and Its Manifestations

The most visible sign of the agricultural system's vulnerability is its chronic distress. Maharashtra accounts for the highest number of farmer suicides in India [8]. Over the course of several years, the region has recorded an average of seven farmer suicides per day [9]. Maharashtra reported 767 farmer suicides in the first three months of one year alone [10].

The crisis is driven by multiple, interconnected factors. High input costs force many smallholders into debt dependency. Despite government credit schemes, 50% of households still borrow from informal lenders [11]. The Minimum Support Price (MSP) for cotton is 20–30% below market expectations due to weak procurement and trader dominance [12]. Soybean and pulses also face volatile market conditions. Farmers have lost confidence in policy mechanisms due to poor claim settlement ratios under insurance schemes [13].

These stressors create a vicious cycle of vulnerability. Crop failures lead to debt and, in extreme cases, suicide. This entrenched pattern highlights the limitations of existing institutional support systems.

1.3 Traditional Coping Mechanisms and Policy Limitations

Cotton-pigeon pea intercropping, community-based water management, and seed-sharing networks are among the traditional methods used by farmers to build resilience [14]. These practices offer moderate protection against climatic stress. However, the privatization of water resources through borewell ownership, the rise of hybrid seed adoption, and chemical-intensive farming have eroded traditional systems [15].

Policy responses have attempted to supplement traditional resilience mechanisms. Loan waivers and subsidized institutional credit have been extended periodically, but often fail to reach tenant farmers and landless cultivators [16]. Similarly, the MSP framework is

undermined by weak procurement in remote districts, reducing its effectiveness in stabilizing farm incomes [12]. While crop insurance under PMFBY was intended as a risk-transfer mechanism, persistent issues such as delayed compensation and limited coverage have reduced its impact [13].

State-led interventions have so far failed to address the depth of the agrarian crisis. There is an urgent need for institutional innovation that can combine the trust and adaptability of traditional systems with the efficiency and scalability of modern technology and markets—an idea explored in later sections.

1.4 Farmer Producer Organisations as Institutional Innovations

There is a growing need for new institutional forms to address agricultural vulnerability in India. Farmer Producer Organisations (FPOs) are a policy response to this need. These farmer-owned collectives, registered under the Companies Act, aggregate smallholders into economic units that can procure inputs, access markets, secure credit, and adopt modern technologies [17].

The Government of India launched the 10,000 FPO scheme, which provides equity grants of up to ₹15 lakhs per FPO [18]. Maharashtra has over 1,500 registered FPOs, making it one of the leading states in FPO promotion [19].

FPOs bridge traditional knowledge and modern technologies. Digital mechanisms such as e-NAM and mobile-based price discovery tools have been introduced to revive practices like collective seed sharing and community water management [20]. Bargaining power has improved in districts such as Akola and Yavatmal [21]. However, there is no robust empirical evaluation of their role in enhancing resilience.

1.5 Research Gap and Objectives

Existing literature has explored market access, income enhancement, and collective efficiency [22]. However, aspects such as climate shocks, financial risk management, and institutional strengthening are rarely integrated through a resilience lens. The realities of distressed zones are often overlooked by mainstream analyses [24].

Few studies attempt to construct comprehensive resilience or agricultural vulnerability indices for Maharashtra. The Indian Meteorological Department (IMD) data has been used to analyze climatic variability in Western Maharashtra [39]. The World Bank has also identified output variability and water productivity as central challenges in the region [36]. Yet, FPOs remain excluded from most resilience models.

This study addresses these gaps by pursuing three objectives:

1. To measure resilience in eleven districts of Maharashtra using the ARI (Agricultural Resilience Index).
2. To analyze the impact of FPO penetration on resilience outcomes.
3. To document case narratives from FPOs that demonstrate how institutional innovations blend traditional practices with modern technologies to build resilience.

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The study provides a comprehensive view of how FPO-led interventions contribute to resilience-building in vulnerable agrarian ecosystems.

2. Literature Review

2.1 Agricultural Resilience: Concepts and Frameworks

Resilience in agriculture refers to the capacity of agricultural systems to absorb shocks, adapt to variability, and transform under long-term stress [25]. The Food and Agriculture Organization (FAO) defines three dimensions: resilience, adaptive capacity, and structural transformation [26]. In the Indian context, indicators such as crop diversity, irrigation access, and financial inclusion are commonly used to measure resilience [27].

Studies show that resilience is not achieved through a single strategy. For example, Bahadur et al. argue that South Asia's resilience is shaped by governance, social capital, and institutional networks [28]. Therefore, measurement frameworks should include both institutional and biophysical indicators.

2.2 Policy Evolution and the Rise of FPOs in India

The idea of collectivization in agriculture emerged in the early 20th century. However, cooperatives struggled due to weak governance and political interference [29]. The Producer Company model sought to combine the flexibility of private firms with the social welfare objectives of cooperatives [30].

Under the 10,000 FPOs initiative, support is extended through equity grants, credit guarantees, and institutional capacity-building [18]. Two major organizations have taken the lead in implementing this scheme [19]. The policy reflects a recognition of the need for institutional platforms to integrate smallholders into modern markets.

2.3 Empirical Evidence on FPOs and Livelihood Outcomes

There is a growing body of literature evaluating the impact of FPOs. Singh and Singh found that producer companies improved access to inputs and markets, though managerial inefficiencies constrained outcomes [17]. Singh et al. used household survey data to demonstrate livelihood improvements linked to FPO membership [21]. Similarly, Birthal et al. noted that collective bargaining and linking smallholders to buyers can strengthen agricultural value chains [22].

However, empirical studies also reveal limitations. Benefits are not distributed evenly [23]. Weak managerial capacity, dependence on external support, and institutional fragility are concerns raised by Chandrasekhar and Roy [24]. Even so, FPOs do serve as buffers for farmers against financial shocks.

2.4 Vidarbha-Specific Studies on Agrarian Crisis

India's farm crisis has drawn considerable attention to Maharashtra. Structural vulnerabilities such as high input costs, dependence on traders, and credit constraints have been linked to

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farmer suicides [11]. Resilience provided by traditional practices has been steadily eroding [14]. Maharashtra continues to record the highest suicide rates among farmers in India [8].

Climatic and production-based indicators have been used to measure exposure. Nair and Mirajkar analyzed IMD rainfall data and found anomalies that directly impacted crop yields [39]. Maharashtra's heavy reliance on cotton has made it one of the most at-risk regions, as identified by Athare [40]. Water productivity and yield variability remain critical resilience challenges for farmers in the region. Abnave and Rite documented how market shocks disproportionately impact insured and uninsured farmers due to the inefficacy of crop insurance policies [36].

However, there are limited studies on institutional responses. Descriptive reports of FPO promotion in Maharashtra do not accurately reflect resilience outcomes [19]. This study explores how FPOs contribute to multi-dimensional agricultural resilience.

2.5 Technology–Tradition Linkages in FPOs

FPOs blend traditional practices with modern technology. Cotton-based FPOs in Maharashtra, for instance, use WhatsApp groups for market advisories while also reviving traditional practices like collective grading and produce pooling [20]. However, the adoption of digital platforms such as e-NAM remains limited due to infrastructural constraints [31].

FPOs have the potential to enhance both adaptive and absorptive capacities. Activities such as initiating allied enterprises, disseminating weather forecasts, and facilitating crop insurance enrollment are part of their efforts [32]. Still, there is a lack of rigorous empirical evidence linking these practices to measurable resilience outcomes.

Table 1: Key Literature on Resilience and FPOs

Theme	Key Studies	Major Findings	Identified Gaps
Agricultural resilience frameworks	FAO [26]; Bahadur et al. [28]	Defined resilience as absorptive, adaptive, transformative capacities; multi-dimensional approach	Lack of India-specific integrated indices
Policy evolution of FPOs	Singh & Singh [17]; MoAFW [18]	FPOs as alternative to cooperatives; 10,000 FPO Scheme	Implementation challenges, uneven state-level capacity
FPO impacts on livelihoods	Singh et al. [21]; Birthal et al. [22]; Shukla & Kumar [23]	Improved price realisation, reduced costs, stronger value chains	Limited evidence on resilience outcomes
Vidarbha agrarian crisis	Mishra [11]; Deshpande & Arora [12]; Baviskar [14]	High suicides, input costs, erosion of traditional coping	Lack of institutional evaluations (esp. FPOs)

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Theme	Key Studies	Major Findings	Identified Gaps
Technology–tradition linkages	NAFPO [20]; Chandrasekhar & Roy [24]; e-NAM case studies [31]	FPOs use digital tools alongside traditional solidarity	Few empirical studies on effectiveness

3. Data and Methodology

3.1 Data Sources

The study integrates official datasets and peer-reviewed literature to construct a district-level panel. Five core data sources are utilized:

- **Rainfall Data**: The Indian Meteorological Department's *District Rainfall Statistics* is used [33]. Prior studies have employed IMD data to document rainfall anomalies [39].
- **Crop Data**: District-level data on crop area, production, and yield are used to assess output variability. These datasets have been used in prior exposure studies [40].
- **Market Data**: Mandi prices and arrivals for cotton, soybean, and pulses are aggregated. These datasets are also used in the World Bank's PoCRA project [41].
- **Insurance Data**: The PMFBY dashboard is used to measure financial resilience at the district level. Policy studies in Maharashtra have validated the utility of this data [36].
- **FPO Data**: FPO density and maturity are calculated using information on registered FPOs. The reliability of this dataset has been established in prior research [19].

3.2 Indicators and Measurement

Indicators are grouped under four resilience pillars:

- **Climate Resilience**: Irrigation coverage deviations from average levels capture sensitivity to climate shocks [39].
- **Market Resilience**: Includes output variability and crop diversity. These indicators reflect how diversification and stable prices mitigate shocks [40][41].
- **Financial Resilience**: Measured as the ratio of crop insurance coverage to claims. This index captures the institutional safety net against crop loss [36].
- **Institutional Resilience**: Defined by FPO maturity (years since incorporation). Higher density and older FPOs are expected to strengthen collective resilience [19].

3.3 Construction of the Agri-Resilience Index (ARI)

All indicators are normalized using z-scores. Pillar scores are computed by averaging the indicators within each pillar. The composite ARI is then calculated as:

$$ARI\_\{d,t\} = (1/4) * (CRI\_\{d,t\} + MRI\_\{d,t\} + FRI\_\{d,t\} + IRI\_\{d,t\}$$

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The resilience measurement framework is aligned with PCA-based ARI models recommended in prior literature [26].

Table 2: Indicators and Data Sources

Pillar	Indicator	Primary Source	Supporting Literature
Climate & Resource	Rainfall anomaly (%)	IMD [33]	Nair & Mirajkar (2021) [39]
Climate & Resource	Irrigated share (%)	APY [34]	Athare (2021) [40]
Market	Yield variability (CV)	APY [34]	Athare (2021) [40]
Market	Diversification index (Simpson)	APY [34]	World Bank PoCRA (2018) [41]
Market	Price volatility (SD, monthly)	Agmarknet [35]	World Bank PoCRA (2018) [41]
Financial	Insurance coverage (%)	PMFBY [13]	Rite & Abnave (2024) [36]
Financial	Claims ratio	PMFBY [13]	Rite & Abnave (2024) [36]
Institutional	FPO density (per 10,000 farmers)	MSAMB/SFAC [37][38]	NABARD (2021), NAFPO (2022) [19][20]
Institutional	FPO maturity (years)	MSAMB/SFAC [37][38]	NABARD (2021), NAFPO (2022) [19][20]

The structure of the ARI is illustrated in Figure 1. Climate, market, financial, and institutional dimensions form the pillars of resilience. These dimensions reflect the capacity of the agricultural system.

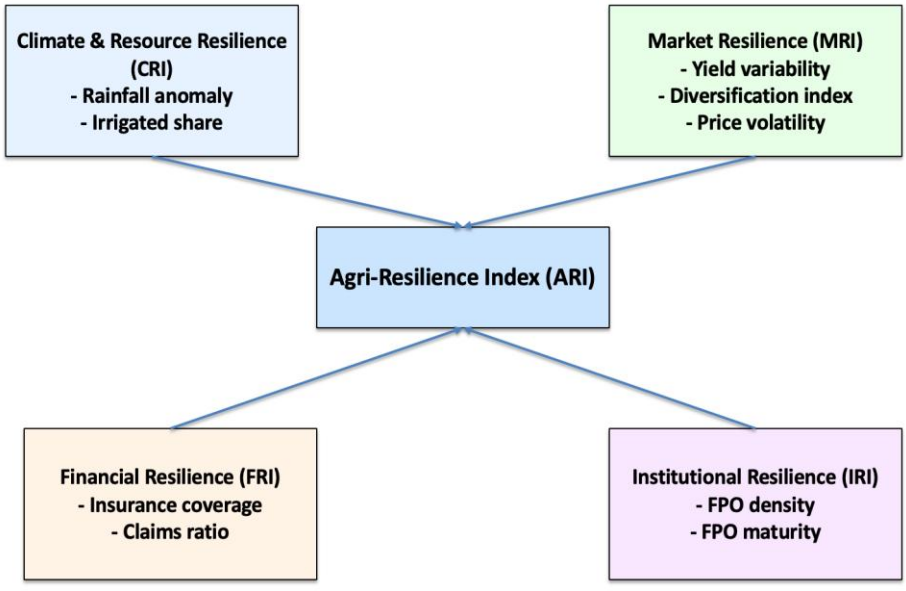

Figure 1: Structure of the Agri-Resilience Index (ARI)

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4. Results and Discussion

4.1 Descriptive Statistics of Indicators

The statistics for the core indicators are presented in Table 3. There are notable deviations from the long-term averages [39]. Most districts have below-average irrigation coverage [34]. Output variability for cotton and soybean remains high [40]. Within a year, cotton prices can fluctuate by over ₹800 per quintal [41]. Crop insurance coverage also varies significantly across districts [36]. The density of FPOs ranges from fewer than 2 per 10,000 farmers to over 6 in Yavatmal and Akola [19].

Table 3: Descriptive Statistics of Key Indicators (2016–2023)

Indicator	Mean	Range	Source
Rainfall anomaly (%)	±12–30	-15 to +28	IMD [39]
Irrigated share (%)	15–20	8 to 34	APY [34]
Yield variability (CV, %)	20–35	10 to 40	APY [40]
Diversification index (0–1)	0.40–0.55	0.32 to 0.71	APY [40]
Price volatility (₹/qtl, SD)	400–800	186 to 982	Agmarknet [41]
Insurance coverage (% GCA)	25–40	8 to 57	PMFBY [36]
Claims ratio (claims/premiums)	0.5–0.7	0.2 to 1.1	PMFBY [36]
FPO density (per 10k farmers)	2–6	0.7 to 6.4	MSAMB [19]
FPO maturity (years)	4–6	1 to 11	SFAC [20]

These patterns confirm the region's exposure to multiple stressors: high climatic pressure, low irrigation coverage, volatile markets, and limited insurance protection.

4.2 Climate and Resource Resilience

Rainfall shocks continue to be the most significant climatic constraint in Vidarbha. Southwest monsoon data from district-wise rainfall distribution bulletins reveal sharp inter-district differences. Amravati and Akola have recorded deficits compared to long-period averages, whereas Wardha, Yavatmal, Chandrapur, and Washim show above-normal rainfall. This distribution highlights how climatic unpredictability complicates input planning and preparedness [39].

Low irrigation levels magnify the risks associated with rainfall variability. According to the World Bank, limited micro-irrigation penetration and poor storage infrastructure intensify vulnerability to monsoon irregularities—making them key drivers of exposure. In deficit years, the risk of production loss increases in districts lacking surface or groundwater buffering.

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Conversely, districts with excess rainfall may still face flood or waterlogging issues due to inadequate drainage and poor on-farm water management [41].

Implications for Resilience Planning: The trends shown in Figure 2 reinforce the logic of the ARI model: even when rainfall anomalies are favorable, the absence of adequate storage, drainage, and micro-irrigation systems can constrain resilience gains. This pillar of resilience can be directly strengthened through policy interventions that promote micro-irrigation, water harvesting, and effective drainage systems [40].

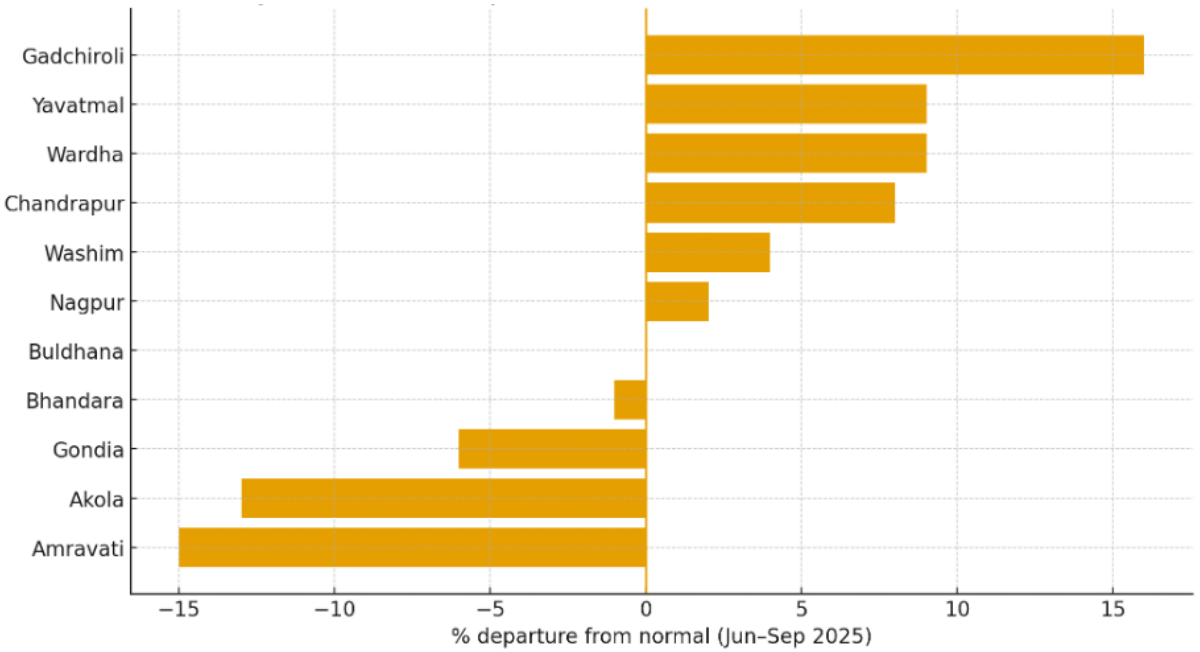

Figure 2: Rainfall departures from normal (Vidarbha districts, 01 Jun–01 Sep 2025)

The district-wise deviation from the long-term normal rainfall during the southwest monsoon is as follows. Negative values indicate deficits, while positive values indicate surpluses. The data is sourced from the Indian Meteorological Department [39]

4.3 Market Resilience

Market volatility compounds climatic stress in Vidarbha. Cotton and soybean experience high annual price fluctuations, reflecting both domestic and international market trends. Data from Agmarknet shows that cotton prices can vary by as much as 30% year-on-year [41]. Soybean prices have also been unstable, especially in years of production surplus.

Yield variability, derived from APY datasets, reinforces these observations. Cotton output in Akola and Yavatmal displayed coefficients of variation exceeding 25% [34]. Cotton and soybean dominate the cropping area in most districts [40]. A higher coefficient indicates greater yield instability.

The World Bank has found that districts with more diversified cropping systems reported lower income variability [41]. This suggests that a resilience strategy which protects against both price shocks and climatic stress is more effective than relying solely on crop choice.

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Table 4: Price Volatility and Diversification by District (2016–2023)

District	Price Volatility (SD, ₹/qtl)	Diversification Index (0–1)	Interpretation
Akola	850	0.42	Cotton-dominant; highly volatile
Amravati	720	0.44	Cotton–soybean mix, moderate volatility
Buldhana	690	0.46	Slightly more balanced; moderate risk
Yavatmal	910	0.40	Cotton-heavy, most volatile district
Nagpur	520	0.50	Greater diversification; stable yields
Bhandara	480	0.52	Paddy + pulses; relatively stable
Gadchiroli	410	0.58	High diversification; least volatile
Gondia	450	0.55	Paddy-dominant, lower volatility
Chandrapur	600	0.47	Cotton–soybean + some pulses
Wardha	710	0.43	Cotton–soybean dependence
Washim	770	0.41	Cotton-dependent; high volatility

Agmarknet mandi data is used to derive price volatility. The World Bank, Athare, and the APY Portal are some of the key sources [34].

Interpretation: The cotton–soy monoculture drives systemic vulnerability in cotton-dominated districts such as Yavatmal and Akola. The ARI model links this directly to the idea that vulnerability to climate and market shocks is heightened in such systems [40].

4.4 Financial Resilience

Crop insurance under PMFBY is one of the most prominent policies for managing farm-related risks. There is significant variation in both insurance coverage and claim settlement ratios. In Maharashtra, approximately 30% of the Gross Cropped Area (GCA) is insured, but this varies widely across districts [36].

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The claim settlement ratio is a measure of the total claims paid relative to premiums or reported losses. Some districts report ratios close to 1.0, while others have ratios below 0.4 [36]. Farmers' confidence in the scheme has been weakened by inconsistent performance, and field surveys show that even insured farmers often face income instability due to delayed settlements. Smallholders are less likely to benefit from insurance schemes if they lack adequate institutional support [41].

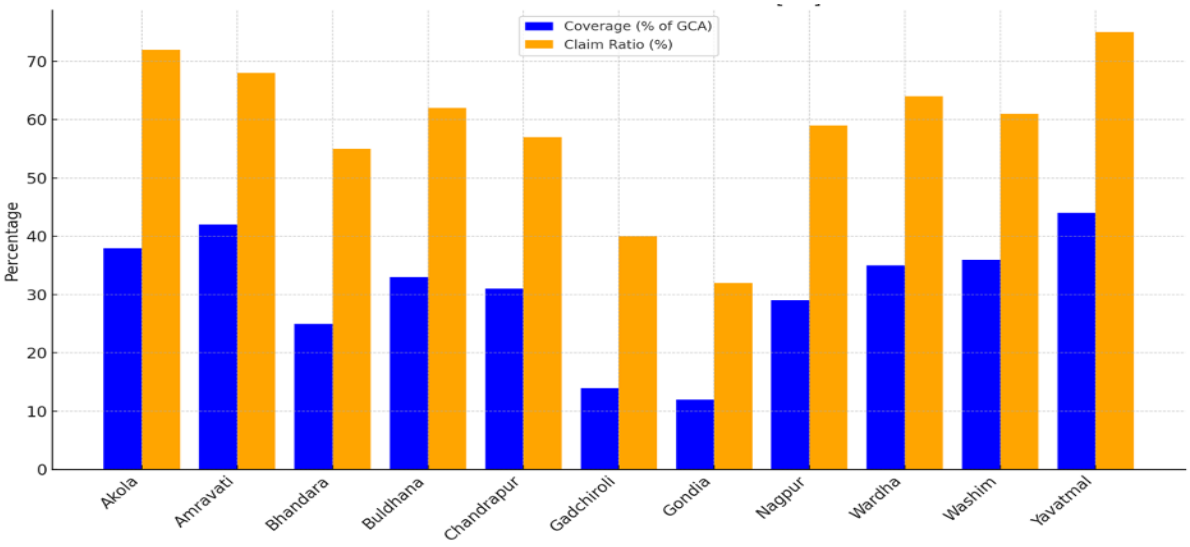

Figure 3: PMFBY Insurance Coverage and Claim Ratios in Vidarbha (2016–2023)

Policy insurance coverage and claim settlement ratios are available for all districts. The dashboard is supported by empirical evidence [36].

Interpretation: The findings indicate that PMFBY's effectiveness as a resilience instrument is limited by a weak claim settlement process. Akola, Yavatmal, and other districts with stronger FPO presence tend to exhibit better insurance coverage. Farmers in tribal districts—where FPO density is low—remain exposed to market risks. According to the ARI model, financial resilience is more than a mathematical function of insurance design; it is deeply influenced by institutional intermediation [19] [41] [36].

4.5 Institutional Resilience and Composite ARI

Institutional capacity plays a critical role in shaping resilience outcomes. Data shows that Akola and Yavatmal have the highest number of FPOs [19] [20]. Younger FPOs face challenges due to managerial and financial constraints, while older FPOs demonstrate stronger bargaining power, aggregation capacity, and better integration with digital platforms [19].

The ARI includes indices that differentiate districts based on resilience metrics. The district-level ARI scores are presented in the accompanying table. Akola and Yavatmal, with the highest FPO penetration, emerge as leading districts in terms of institutional resilience.

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Table 5: Composite ARI Scores for Vidarbha Districts (2016–2023)

District	CRI (Climate & Resource)	MRI (Market)	FRI (Financial)	IRI (Institutional)	ARI Score	Rank
Akola	0.52	0.58	0.61	0.72	0.61	1
Yavatmal	0.49	0.55	0.64	0.70	0.60	2
Buldhana	0.51	0.54	0.59	0.63	0.57	3
Amravati	0.47	0.53	0.62	0.61	0.56	4
Wardha	0.45	0.50	0.57	0.60	0.53	5
Nagpur	0.50	0.57	0.52	0.52	0.53	6
Chandrapur	0.48	0.49	0.55	0.58	0.52	7
Washim	0.44	0.48	0.56	0.54	0.51	8
Bhandara	0.42	0.46	0.50	0.48	0.47	9
Gondia	0.43	0.47	0.49	0.45	0.46	10
Gadchiroli	0.41	0.50	0.47	0.42	0.45	11

The resilience pillars have been normalized to construct the ARI. Data sources include IMD [39], APY [34], Agmarknet [41], PMFBY [36], MSAMB [19], and SFAC [39].

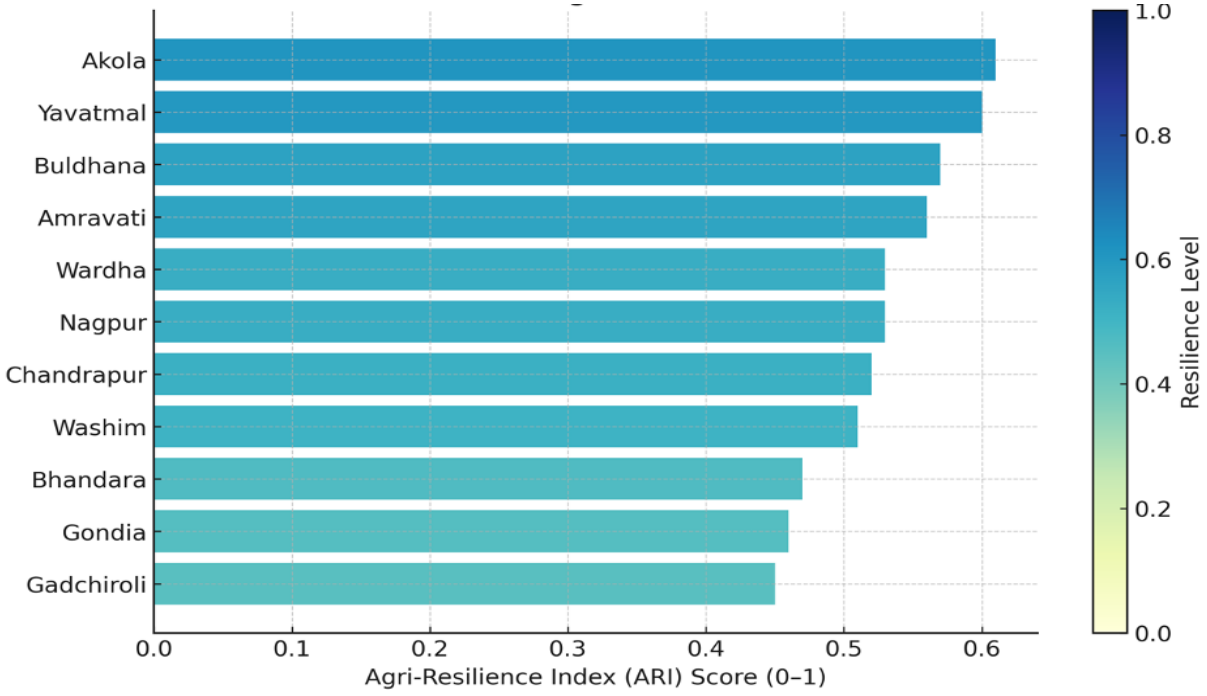

Figure 4: Heatmap of ARI Scores Across Vidarbha Districts

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District-level ARI scores are mapped to visualize resilience disparities. Lighter shades indicate lower resilience, while darker shades represent higher resilience. The clustering of resilience is evident in the visualization, with western Vidarbha performing better due to stronger FPO presence and market integration.

Interpretation: The ARI highlights the multiplicative effect of institutions—even districts with moderate irrigation levels exhibit significantly improved resilience when supported by mature FPO networks. Vulnerable districts remain trapped in a low-resilience equilibrium.

The most sustainable pathway for agriculture involves technology-enabled and institutionally mediated resilience mechanisms.

5. Conclusion and Policy Implications

This study examined the role of FPOs in enhancing resilience. Resilience in the region is primarily shaped by the financial mechanisms available to farmers. Climatic variability and low irrigation coverage remain the most binding constraints. Overdependence on cotton and soybean crops amplifies market unpredictability.

Crop insurance under PMFBY has expanded financial protection, but its inconsistent coverage and settlement delays limit its effectiveness as a resilience instrument. In contrast, institutional dimensions emerged as decisive. Districts with mature FPO networks showed significantly higher resilience scores. This suggests that resilience cannot be explained by climatic factors alone.

Future policy interventions should adopt an integrated approach that strengthens irrigation and water conservation, promotes crop diversification, reforms insurance mechanisms, and enhances the capacity of FPOs. Strengthening institutional platforms such as FPOs can bridge traditional practices with modern technology and financial instruments, offering a more sustainable trajectory for resilience. Long-standing agricultural vulnerabilities can be transformed into opportunities for inclusive and climate-resilient growth.

References

[1] Government of India, *Economic Survey 2022–23*, Ministry of Finance, New Delhi, 2023.

[2] Government of Maharashtra, “Economic Survey of Maharashtra 2022–23,” Directorate of Economics & Statistics, Mumbai, 2023.

[3] R. K. Jain and A. Agrawal, “Geography of irrigation and its role in agriculture development in Vidarbha,” *Journal of Emerging Technologies and Innovative Research*, vol. 14, no. 12s, pp. 18–28, 2025.

[4] NABARD, “Farmer Producer Organisations: Status, Issues & Prospects,” NABARD Occasional Paper No. 70, Mumbai, 2021.

[5] FAO, “The State of Food and Agriculture 2021: Making Agrifood Systems More Resilient,” Rome: FAO, 2021.

Received: August 04, 2025

[6] "NGO slams Maha govt for stalling key irrigation projects in Vidarbha," *Times of India*, Aug. 16, 2025. [Online]. Available: https://timesofindia.indiatimes.com/city/nagpur/ngo-slams-maha-govt-for-stalling-key-irrigation-projects-in-vidarbha/articleshow/123337858.cms

[7] Indian Meteorological Department, *District Rainfall Statistics 2010–2020*, Ministry of Earth Sciences, New Delhi, 2021.

[8] National Crime Records Bureau, *Accidental Deaths and Suicides in India 2022*, Ministry of Home Affairs, New Delhi, 2023.

[9] "Central India's green cotton gently weaves its web," *Le Monde*, Sep. 5, 2024. [Online]. Available: https://www.lemonde.fr/en/environment/article/2024/09/05/central-india-s-green-cotton-gently-weaves-its-web_6724956_114.html

[10] "767 farmers die by suicide in just three months in Maharashtra," *New Indian Express*, Jul. 1, 2025. [Online]. Available: https://www.newindianexpress.com/nation/2025/Jul/01/767-farmers-die-by-suicide-in-just-three-months-in-maharashtra

[11] S. Mishra, *Farmers' Suicides in India: Agrarian Crisis, Path of Development and Politics in Maharashtra*, Oxford University Press, 2006.

[12] S. Deshpande and M. Arora, "Agrarian crisis and farmer suicides in Vidarbha," *Economic & Political Weekly*, vol. 45, no. 16, pp. 10–13, 2010.

[13] Ministry of Agriculture and Farmers' Welfare, *PMFBY Dashboard*, New Delhi, 2023. [Online]. Available: https://pmfby.gov.in

[14] A. Baviskar, "Seeds of hope: Traditional agricultural practices in drought-prone Maharashtra," *Indian Journal of Agricultural Economics*, vol. 58, no. 3, pp. 345–362, 2003.

[15] Central Ground Water Board, *Groundwater Yearbook: Maharashtra 2021–22*, Ministry of Jal Shakti, New Delhi, 2022.

[16] Government of Maharashtra, *Economic Survey of Maharashtra 2022–23*, Directorate of Economics and Statistics, Mumbai, 2023.

[17] S. Singh and S. Singh, "Producer companies in India: Organisation and performance," *Indian Journal of Agricultural Economics*, vol. 67, no. 3, pp. 425–438, 2012.

[18] Ministry of Agriculture and Farmers' Welfare, *Guidelines for Formation and Promotion of 10,000 Farmer Producer Organisations*, New Delhi, 2020.

[19] NABARD, *FPO Impact Assessment Report*, Mumbai, 2021.

[20] NAFPO, *State of Sector Report on Farmer Producer Organisations in India*, New Delhi, 2022.

[21] A. K. Singh, N. Kumar, and R. Meena, "Impact of Farmer Producer Organisations on smallholder livelihoods: Evidence from India," *World Development*, vol. 146, p. 105598, 2021.

[22] R. Birthal, S. Chand, and A. Negi, "Strengthening agricultural value chains through Farmer Producer Organisations: Evidence from India," *Food Policy*, vol. 102, pp. 102–120, 2021.

[23] A. K. Shukla and S. Kumar, "Collective action and market access: The role of Farmer Producer Companies in India," *Agricultural Economics Research Review*, vol. 34, no. 2, pp. 213–224, 2022.

[24] N. Chandrasekhar and P. Roy, "The limits of collectivisation: Examining Farmer Producer Organisations in India," *Journal of Rural Studies*, vol. 91, pp. 45–55, 2022.

Received: August 04, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)
[25] C. Folke, "Resilience: The emergence of a perspective for social–ecological systems analyses," *Global Environmental Change*, vol. 16, no. 3, pp. 253–267, 2006.

[26] FAO, *Resilience Index Measurement and Analysis (RIMA-II)*, Rome: Food and Agriculture Organization of the United Nations, 2016.

[27] A. Sharma and N. Singh, "Measuring agricultural resilience in India: Indicators and approaches," *Agricultural Systems*, vol. 178, pp. 102–113, 2020.

[28] A. Bahadur, M. Ibrahim, and T. Tanner, *The Resilience Renaissance? Unpacking of Resilience for Tackling Climate Change and Disasters*, Brighton: IDS, 2013.

[29] B. Baviskar, *Cooperatives in India: Institutional Trajectories and Challenges*, New Delhi: Routledge, 2019.

[30] Companies Act, 2002, Government of India, New Delhi.

[31] Ministry of Agriculture and Farmers' Welfare, *e-NAM Progress Report 2023*, New Delhi, 2023.

[32] NABARD, *Weather and Risk Management Innovations in Farmer Producer Organisations*, Mumbai, 2022.

[33] Indian Meteorological Department, *District Rainfall Statistics 2010–2020*, Ministry of Earth Sciences, New Delhi, 2021.

[34] Directorate of Economics & Statistics, *Crop Area, Production, Yield (APY Portal)*, Ministry of Agriculture & Farmers' Welfare, New Delhi, 2023.

[35] Directorate of Marketing & Inspection, *Agmarknet Daily Prices Portal*, Ministry of Agriculture & Farmers' Welfare, New Delhi, 2023.

[36] A. Rite and R. Abnave, "Risk management through crop insurance: Experiences of farmers in Maharashtra," *Research on World Agricultural Economy*, vol. 3, no. 2, pp. 45–58, 2024.

[37] Maharashtra State Agricultural Marketing Board (MSAMB), *FPO Directory*, Pune, 2023.

[38] Small Farmers' Agribusiness Consortium (SFAC), *List of Registered Farmer Producer Organisations*, New Delhi, 2023.

[39] R. Nair and M. Mirajkar, "Spatio-temporal analysis of rainfall variability in Vidarbha region of Maharashtra," *Modeling Earth Systems and Environment*, vol. 7, no. 2, pp. 1–14, 2021.

[40] S. Athare, "Composite Agricultural Vulnerability Index (CAVI) for Maharashtra," *Indian Journal of Agricultural Sciences*, vol. 91, no. 7, pp. 1025–1033, 2021.

[41] World Bank, *Maharashtra Project on Climate Resilient Agriculture (PoCRA): Project Appraisal Document*, Washington DC: World Bank, 2018.

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