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Climate variability vulnerability among Fig (*Ficus carica* L.) Growers in Maharashtra: Composite index analysis

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Abstract

In Maharashtra's semi-arid fig cultivation hubs of Pune and Chatrapati Sambhajnagar, where *Ficus carica* L. underpins vital rural economies through its nutritional value and market demand, intensifying climate variability—characterized by erratic monsoon patterns, rising temperature extremes, persistent water scarcity and heightened pest pressures—poses profound threats to orchard productivity, fruit quality and growers' livelihoods. Employing an ex-post facto research design with multistage sampling, this study gathered primary data via structured interviews from 300 fig growers (150 per district) and applied a robust composite vulnerability index (CVI) framework, integrating normalized Exposure Index (EI), Sensitivity Index (SI) and Adaptive Capacity Index (ACI) components through min-max scaling and equal weighting, as per IPCC standards: $CVI = (EI + SI + (1 - ACI)) / 3$. Findings reveal stark district disparities Chatrapati Sambhajnagar exhibits high vulnerability (CVI=0.66) driven by elevated EI (0.66) from rainfall deficits and heat stress, high SI (0.70) due to yield instability and resource dependence and low ACI (0.38) amid weak institutional and financial support; Pune shows moderate vulnerability (CVI=0.41) with lower EI (0.42), SI (0.50) and stronger ACI (0.68) bolstered by better social capital and extension access—yielding an overall moderate CVI (0.54) that signals widespread intermediate risks and the imperative for targeted interventions like enhanced irrigation, FPOs and climate advisories.

Keywords: Climate variability, vulnerability index, fig growers, adaptive capacity, exposure, sensitivity, Maharashtra

1. Introduction

Climate change is increasingly recognized as a major threat to agricultural sustainability, particularly in developing countries where farming systems are highly dependent on climatic conditions. Variability in rainfall patterns, rising temperatures and increased frequency of extreme weather events such as droughts and heat waves significantly affect crop productivity and farmer livelihoods.

Fruit crops are particularly sensitive to climate variability due to their perennial nature and specific environmental requirements. Fig (*Ficus carica* L.) is an important fruit crop cultivated in tropical and subtropical regions, valued for its nutritional and economic significance. In India, fig cultivation is largely concentrated in Maharashtra, especially in Pune and Chatrapati Sambhajnagar districts. Despite favourable agro-climatic conditions, fig cultivation

is increasingly affected by climate-induced stresses such as irregular rainfall, water scarcity, temperature fluctuations and pest and disease incidence. These factors adversely influence flowering, fruit set, fruit quality and yield stability. Given the perennial nature of fig orchards, the impact of climate variability is long-term, making fig growers particularly vulnerable.

Vulnerability to climate change is defined as the degree to which a system is susceptible to or unable to cope with adverse climatic effects (IPCC, 2014) ^[1]. It is a function of three key components: exposure, sensitivity and adaptive capacity. While exposure and sensitivity increase vulnerability, adaptive capacity reduces it.

Despite several studies on climate change impacts in agriculture, empirical evidence on vulnerability assessment of perennial fruit crops, particularly fig growers in semi-arid

regions, remains limited. Therefore, the present study was undertaken to assess the exposure of fig growers to climate variability, analyse the sensitivity of fig production systems, evaluate their adaptive capacity and compute a composite vulnerability index (CVI) to classify vulnerability levels.

2. Methodology

This study, conducted during 2023-25, targeted Pune and Chatrapati Sambhajinagar districts in Maharashtra - key fig-growing hubs under semi-arid conditions. An ex-post facto research design facilitated analysis of existing climate impacts, employing multistage sampling: purposive district selection based on fig acreage, followed by two tehsils and

five villages per district, then random selection of 150 fig growers per district (total n=300).

Primary data came from structured, pre-tested interviews conducted during 2023-25. The structured schedule demonstrated high reliability (Cronbach's $\alpha = 0.87$) and content validity, verified through expert review and pilot testing with 30 non-sampled growers.

Vulnerability assessment followed an integrated composite index approach with Exposure Index (EI), Sensitivity Index (SI) and Adaptive Capacity Index (ACI), where indicators were selected and adapted from established frameworks and modified as per the context of present study.

Table 1: Vulnerability Indicators, Measurement and Relationship to Vulnerability

Sr. No.	Component	Indicator	Description of Indicator	Measurement Unit/Method	Relationship to Vulnerability	Reference
Exposure Index (EI) - 10 indicators						
1	Exposure	Delay in onset of monsoon	Late monsoon arrival disrupting crop calendar and irrigation	Days (farmer perception)	Positive	Adhav <i>et al.</i> (2021)
2	Exposure	Frequency of dry spells	Prolonged dry periods during critical growth stages	Events/season	Positive	Adhav <i>et al.</i> (2021)
3	Exposure	Unseasonal rainfall	Rainfall during flowering/harvest affecting fruit quality	Events	Positive	Rao <i>et al.</i> (2011)
4	Exposure	Heat stress days	High temperatures impairing fruit set and growth	Days	Positive	Salem (2024)
5	Exposure	Frost/hailstorm events	Extreme weather causing physical orchard damage	Events	Positive	Adhav <i>et al.</i> (2021)
6	Exposure	Rainfall deficit	Deviation from long-term rainfall average	% deviation	Positive	Rao <i>et al.</i> (2011)
7	Exposure	Groundwater depletion	Declining groundwater levels affecting irrigation	Depth (meters)	Positive	Adhav <i>et al.</i> (2021)
8	Exposure	Irrigation supply deficit	Inadequate water during critical stages	Farmer perception score	Positive	Adhav <i>et al.</i> (2021)
9	Exposure	Climatic hazards	Droughts, floods, storms impacting agriculture	Events	Positive	Adger (2006) ^[2]
10	Exposure	Pest/disease outbreaks	Climate-linked increase in biotic stresses	Farmer perception score	Positive	Salem (2024)
Sensitivity Index (SI) - 12 indicators						
11	Sensitivity	Orchard age	Older orchards more susceptible to stress	Years	Positive	Salem (2024)
12	Sensitivity	Yield variability	Fluctuations in fig production due to climate	% variation	Positive	Rao <i>et al.</i> (2011)
13	Sensitivity	Fruit cracking incidence	Moisture stress/rainfall causing fruit damage	% fruits affected	Positive	Salem (2024)
14	Sensitivity	Soil organic carbon	Low soil fertility reduces drought tolerance	%	Positive	Rao <i>et al.</i> (2011)
15	Sensitivity	Soil depth	Shallow soils limit water holding capacity	cm	Positive	Rao <i>et al.</i> (2011)
16	Sensitivity	Soil moisture stress	Frequent moisture deficits affecting growth	Farmer perception score	Positive	Adhav <i>et al.</i> (2021)
17	Sensitivity	Income dependence on fig	High reliance on single crop increases risk	% household income	Positive	Adhav <i>et al.</i> (2021)
18	Sensitivity	Cropping diversity	Limited crop alternatives buffer climate shocks	Diversity index	Positive	Adhav <i>et al.</i> (2021)
19	Sensitivity	Labour shortage	Insufficient labor for critical operations	Farmer perception score	Positive	Adhav <i>et al.</i> (2021)
20	Sensitivity	Loan dependence	Heavy borrowing indicates financial fragility	Amount (₹)	Positive	Adhav <i>et al.</i> (2021)
21	Sensitivity	Insurance gap	Lack of risk protection through insurance	Yes/No	Positive	Adhav <i>et al.</i> (2021)
22	Sensitivity	Storage limitation	Poor post-harvest infrastructure	Farmer perception score	Positive	Adhav <i>et al.</i> (2021)

Adaptive Capacity Index (ACI) - 15 indicators						
23	Adaptive Capacity	FPO membership	Collective bargaining and resource sharing	Yes/No	Negative	Adhav <i>et al.</i> (2021)
24	Adaptive Capacity	Collective irrigation	Community water management systems	Yes/No	Negative	Adhav <i>et al.</i> (2021)
25	Adaptive Capacity	Institutional trust	Confidence in agricultural support systems	Likert scale	Negative	Adger (2006) [2]
26	Adaptive Capacity	Extension access	Contact with advisory services	Contacts/year	Negative	Adhav <i>et al.</i> (2021)
27	Adaptive Capacity	Climate advisory access	Weather forecasts and early warnings	Yes/No	Negative	Rao <i>et al.</i> (2011)
28	Adaptive Capacity	Governance participation	Involvement in local decision-making	Yes/No	Negative	Adger (2006) [2]
29	Adaptive Capacity	Credit access	Institutional financing availability	Yes/No	Negative	Adhav <i>et al.</i> (2021)
30	Adaptive Capacity	Crop insurance adoption	Participation in risk protection schemes	Yes/No	Negative	Adhav <i>et al.</i> (2021)
31	Adaptive Capacity	Farm asset ownership	Irrigation equipment and infrastructure	Asset index	Negative	Adhav <i>et al.</i> (2021)
32	Adaptive Capacity	Education level	Years of schooling affecting decision-making	Years	Negative	Rao <i>et al.</i> (2011)
33	Adaptive Capacity	Digital literacy	ICT skills for information access	Score	Negative	Adhav <i>et al.</i> (2021)
34	Adaptive Capacity	Innovation adoption	Use of improved technologies	Number adopted	Negative	Salem (2024)
35	Adaptive Capacity	Indigenous knowledge	Traditional coping strategies	Score	Negative	Rao <i>et al.</i> (2011)
36	Adaptive Capacity	Risk perception	Climate risk awareness guiding adaptation	Likert scale	Negative	Adger (2006) [2]
37	Adaptive Capacity	Occupational diversification	Alternative income sources reducing risk	Income sources	Negative	Adhav <i>et al.</i> (2021)

Note: Positive relationship indicators increase vulnerability when higher; negative relationship (adaptive capacity) indicators reduce vulnerability when higher. Total: 37 indicators (EI: 10, SI: 12, ACI: 15).

All indicators underwent min-max normalization to a 0-1 scale:

Positive indicators:
$$X_{ij} = \frac{x_{ij} - x_{min}}{x_{max} - x_{min}}$$

Negative indicators:
$$X_{ij} = \frac{x_{max} - x_{ij}}{x_{max} - x_{min}}$$

Normalized values aggregated via equal weighting (justified by balanced representation across biophysical/socio-economic dimensions, per Hahn *et al.*, 2009) [8]. The Composite Vulnerability Index (CVI) calculated as:

$$CVI = \frac{EI + SI + (1 - ACI)}{3}$$

This inverts ACI's protective role, aligning with IPCC protocols [IPCC, 2014] [1]. Vulnerability categories followed Hahn *et al.* (2009) [8]: low (<0.33), moderate (0.33–0.65), high (≥0.66). These indices enable district-level comparisons while laying groundwork for targeted interventions detailed in subsequent sections.

3. Results and Discussion

3.1 Exposure Index of Fig Growers

The Exposure Index (EI) reflects the degree to which fig growers are subjected to climatic stressors such as rainfall variability, temperature extremes, water stress and climatic hazards.

Table 2: Exposure Index of Fig Growers towards Climate Variability

Sr. No.	Exposure Components	Pune	Chatrapati Sambhajnagar
A. Rainfall & Weather Variability			
1	Delay in onset of monsoon	0.55	0.72
2	Frequency of dry spells	0.53	0.71
3	Unseasonal rainfall events	0.48	0.62
B. Temperature Extremes			
4	Heat stress days	0.42	0.66
5	Frost / hail events	0.22	0.49
C. Water Stress			
6	Rainfall deficit	0.46	0.74
7	Groundwater depth deviation	0.44	0.76
8	Irrigation reliability deficit	0.41	0.69
D. Acute Hazards			
9	Drought/flood/storm incidence	0.36	0.71
10	Pest and disease outbreaks	0.31	0.64
Overall EI		0.42	0.66

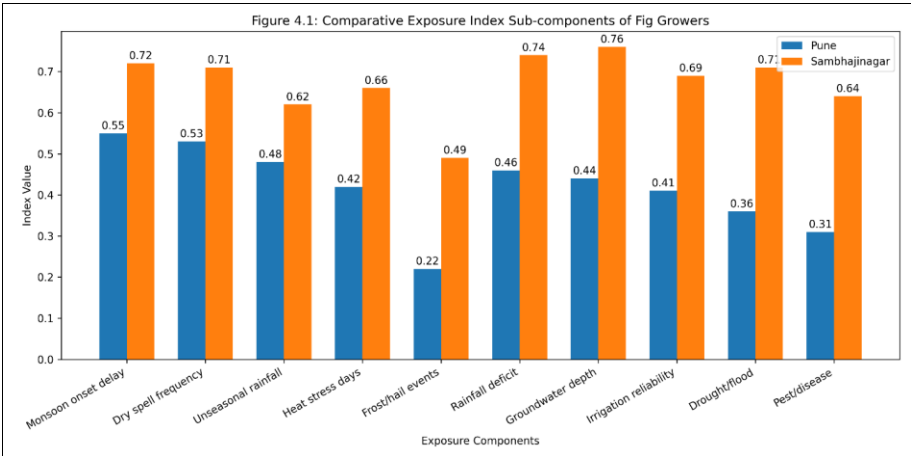


Fig 1: Exposure Index Comparison

3.2 Exposure Index of Fig Growers

Figure 1 illustrates the comparative exposure levels of fig growers in Pune and Chatrapati Sambhajinagar districts across major climatic, hydrological and hazard-related stressors contributing to overall climate vulnerability. The results reveal a clear spatial variation, with Chatrapati Sambhajinagar experiencing relatively higher exposure across most components.

3.2.1 Rainfall and Weather Variability

Rainfall-related indicators demonstrate pronounced variability in Chatrapati Sambhajinagar, particularly in delay in onset of monsoon (0.72), frequency of dry spells (0.71) and unseasonal rainfall events (0.62), compared to Pune (0.55, 0.53 and 0.48, respectively). This reflects increasing irregularity in monsoon patterns and intra-seasonal rainfall distribution. Such fluctuations disrupt key phenological stages of fig cultivation, including flowering, fruit set and fruit development, thereby affecting productivity and quality.

3.2.2 Temperature Extremes

Temperature-related stress is more intense in Chatrapati Sambhajinagar, as indicated by higher exposure to heat stress days (0.66) and frost/hail events (0.49), in contrast to Pune (0.42 and 0.22, respectively). These extremes are likely to induce physiological disorders such as sunburn injury, fruit cracking and premature fruit drop, ultimately leading to yield instability.

3.2.3 Water Stress Conditions

Water stress emerges as a critical factor influencing exposure. Chatrapati Sambhajinagar records higher values for rainfall deficit (0.74), groundwater depth deviation (0.76) and irrigation reliability deficit (0.69), whereas Pune shows relatively moderate levels (0.46, 0.44 and 0.41, respectively). This indicates persistent water scarcity, declining groundwater availability and limitations in irrigation infrastructure, which together intensify production risks under semi-arid conditions.

3.2.4 Climatic and Biotic Hazards

Exposure to acute hazards is also more pronounced in

Chatrapati Sambhajinagar, with higher incidence of droughts, flood, sandstorms (0.71), along with pest and disease outbreaks (0.64), compared to Pune (0.36 and 0.31, respectively). This suggests greater susceptibility to extreme climatic events and biotic stresses, contributing to instability in fig production systems.

3.2.5 Overall Exposure

The overall Exposure Index is considerably higher in Chatrapati Sambhajinagar (0.66) than in Pune (0.42), indicating greater climatic stress in the former region. Water stress, rainfall variability and temperature extremes emerge as the dominant drivers influencing exposure. These findings align with previous studies highlighting increased climatic vulnerability in semi-arid regions (Jamshidi *et al.*, 2019)^[9].

3.3 Sensitivity Index of Fig Growers

Sensitivity reflects the degree to which fig production systems respond to climatic stress based on crop, soil and socio-economic factors.

Table 3: Sensitivity Index of Fig Growers

Sr. No.	Sensitivity Components	Pune	Chatrapati Sambhajinagar
A. Orchard & Crop Characteristics			
1	Orchard age	0.41	0.72
2	Yield variability	0.52	0.79
3	Fruit cracking incidence	0.49	0.81
B. Soil & Water Dependence			
4	Soil organic carbon	0.23	0.52
5	Soil depth	0.32	0.61
6	Irrigation dependence	0.43	0.71
C. Livelihood & Labour			
7	Income concentration	0.58	0.82
8	Cropping diversity	0.34	0.47
9	Labour shortage	0.42	0.71
D. Market & Institutional Dependence			
10	Loan reliance	0.29	0.63
11	Insurance gap	0.38	0.71
12	Storage limitation	0.41	0.69
Overall SI		0.50	0.70

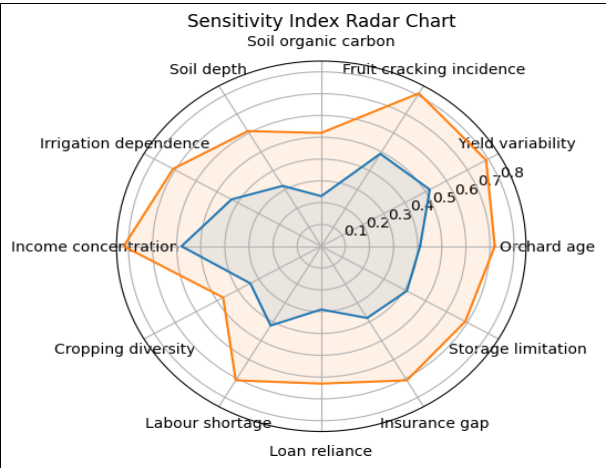


Fig 2: Sensitivity Index Components

Figure 2 presents a comparative analysis of sensitivity components of fig growers in Pune and Chatrapati Sambhajinagar districts. Each axis of the radar chart represents a specific biophysical, socio-economic, or institutional factor influencing sensitivity, where higher values indicate greater vulnerability. The overall pattern reveals a broader spread of values in Chatrapati Sambhajinagar, indicating a more fragile and stress-prone production system.

3.3.1 Orchard and Crop Characteristics

Indicators related to orchard and crop performance show elevated sensitivity in Chatrapati Sambhajinagar, particularly with respect to orchard age (0.72), yield variability (0.79) and fruit cracking incidence (0.81), compared to Pune (0.41, 0.52 and 0.49, respectively). These patterns reflect unstable productivity conditions influenced by erratic rainfall and temperature fluctuations. In contrast, relatively moderate values in Pune suggest better orchard management practices and comparatively stable production conditions.

3.3.2 Soil and Water Dependence

Soil and water-related parameters further highlight disparities between the two districts. Higher sensitivity values in Chatrapati Sambhajinagar for soil organic carbon (0.52), soil depth (0.61) and irrigation dependence (0.71) indicate degraded soil health and increased reliance on irrigation under water-scarce conditions. Pune, on the other hand, demonstrates comparatively favourable resource conditions, contributing to lower sensitivity levels.

3.3.3 Livelihood and Labour Factors

Socio-economic dimensions also play a significant role in shaping sensitivity. In Chatrapati Sambhajinagar, higher income concentration (0.82) and labour shortage (0.71) suggest a greater dependence on fig cultivation and constraints in labour availability, which can hinder timely farm operations. Conversely, relatively lower values in Pune reflect better livelihood diversification and improved access to labour resources, thereby reducing vulnerability.

3.3.4 Market and Institutional Dependence

Market and institutional factors exhibit notable differences between the districts. Elevated values in Chatrapati Sambhajinagar for loan reliance (0.63), insurance gap (0.71) and storage limitation (0.69) indicate weaker financial resilience and limited access to risk mitigation mechanisms. In contrast, Pune benefits from relatively better institutional support and financial access, which contribute to lower sensitivity.

3.3.5 Cropping Diversity and System Stability

Cropping diversity is comparatively lower in Chatrapati Sambhajinagar, limiting alternative income sources and increasing dependence on a single crop system. In contrast, greater diversification in Pune enhances system stability and provides a buffer against climatic and economic shocks.

3.3.6 Overall Sensitivity

The overall Sensitivity Index is higher in Chatrapati Sambhajinagar (0.70) than in Pune (0.50), indicating greater susceptibility to both climatic and socio-economic stresses. The results suggest that sensitivity is driven by a combination of biophysical constraints and limited resource access. These findings align with the conceptual understanding that higher sensitivity increases the vulnerability of agricultural systems to climate-related risks (IPCC, 2014) [1].

3.4 Adaptive Capacity Index of Fig Growers

Adaptive capacity represents the ability of farmers to cope with and recover from climatic stresses.

Table 4: Adaptive Capacity Index of Fig Growers

Sr. No.	Components	Pune	Chatrapati Sambhajinagar
A. Social Capital			
1	FPO membership	0.71	0.23
2	Collective water management	0.62	0.31
3	Institutional trust	0.59	0.33
B. Institutional Capacity			
4	Extension access	0.61	0.29
5	Early warning systems	0.63	0.32
6	Governance participation	0.47	0.21
C. Financial Capacity			
7	Credit access	0.82	0.41
8	Insurance coverage	0.69	0.28
9	Asset ownership	0.61	0.34
D. Human Capacity			
10	Education level	0.72	0.51
11	Digital literacy	0.64	0.29
12	Innovation adoption	0.58	0.33
13	Indigenous knowledge	0.52	0.31
14	Risk perception	0.61	0.42
15	Occupational flexibility	0.49	0.24
Overall ACI		0.68	0.38

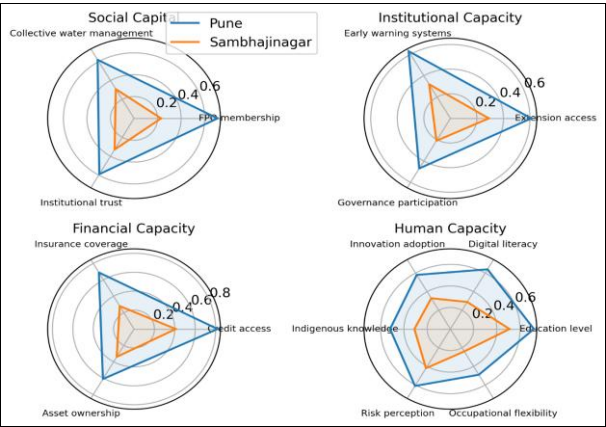


Fig 3: Adaptive Capacity Comparison

Figure 3 presents a comparative analysis of adaptive capacity components of fig growers in Pune and Chatrapati Sambhajinagar districts across social, institutional, financial and human dimensions. The overall pattern reveals a pronounced disparity between the two regions, with Pune demonstrating stronger adaptive capacity, while Chatrapati Sambhajinagar reflects comparatively limited ability to cope with and respond to climate variability.

3.4.1 Social Capital

Indicators related to social capital indicate stronger collective engagement in Pune, particularly in terms of FPO/cooperative membership, collective water management and institutional trust. These factors suggest well-developed farmer networks, effective cooperation and greater confidence in institutions. In contrast, relatively lower values in Chatrapati Sambhajinagar reflect weaker social cohesion and limited collective action, which may constrain the implementation of community-based adaptation strategies.

3.4.2 Institutional Capacity

Institutional support systems are more accessible in Pune, as evidenced by better extension access, availability of early warning systems and participation in governance processes. These elements facilitate timely dissemination of information and support informed decision-making under changing climatic conditions. Conversely, limited institutional reach in Chatrapati Sambhajinagar indicates restricted access to advisory services and climate-related information, thereby reducing the effectiveness of adaptive responses.

3.4.3 Financial Capacity

Financial indicators highlight notable differences in resilience between the two districts. Higher levels of credit access, insurance coverage and asset ownership in Pune reflect a stronger capacity to absorb climatic shocks and invest in adaptive measures. In contrast, lower financial capacity in Chatrapati Sambhajinagar, particularly in terms of insurance and asset base, increases economic vulnerability and limits the ability to recover from adverse events.

3.4.4 Human Capacity

Human capital plays a critical role in shaping adaptive responses. Pune exhibits relatively higher levels of education, digital literacy, innovation adoption, indigenous knowledge, risk perception and occupational flexibility. These attributes enhance farmers’ ability to adopt improved technologies, access information and diversify livelihood strategies. In comparison, constraints in knowledge access and technological adoption in Chatrapati Sambhajinagar may hinder effective adaptation and decision-making.

3.4.5 Overall Adaptive Capacity Pattern

The overall Adaptive Capacity Index is substantially higher in Pune (0.68) than in Chatrapati Sambhajinagar (0.38), indicating a stronger capacity to manage climatic risks in the former. The observed disparity suggests that adaptive capacity is influenced by a combination of social organization, institutional access, financial strength and human capital. These findings support the view that adaptive capacity plays a crucial role in reducing vulnerability by enhancing coping and recovery mechanisms (Adger, 2006)^[2].

3.5 Composite Vulnerability Index (CVI)

Table 4: Composite Vulnerability Index (CVI) of Fig Growers

Sr. No.	District	EI	SI	ACI	CVI	Category
1	Pune	0.42	0.50	0.68	0.41	Moderate
2	Chatrapati Sambhajinagar	0.66	0.70	0.38	0.66	High
	Overall Avg.	0.54	0.60	0.53	0.54	Moderate

The Composite Vulnerability Index (CVI) integrates exposure, sensitivity and adaptive capacity to assess the overall climate vulnerability of fig growers in the study area. The results indicate a clear inter-district variation in vulnerability levels.

Chatrapati Sambhajinagar district falls under the high vulnerability category (CVI = 0.66), reflecting the combined effect of elevated climatic exposure, higher sensitivity of production systems and limited adaptive capacity. The greater vulnerability observed in this district can be attributed to recurrent climatic stresses, dependence on climate-sensitive resources and constraints related to institutional access, financial resilience and human capital. In contrast, Pune district exhibits a moderate level of vulnerability (CVI = 0.41), despite being exposed to similar climatic conditions. This relatively lower vulnerability is primarily influenced by stronger adaptive capacity, supported by better access to extension services, financial resources and social capital, which help offset climatic risks. At the aggregate level, the overall CVI of 0.54 indicates a moderate vulnerability status among fig growers. This suggests that while a proportion of farmers possess adequate adaptive capacity, a significant segment remains vulnerable due to the combined influence of climatic and socio-economic constraints.

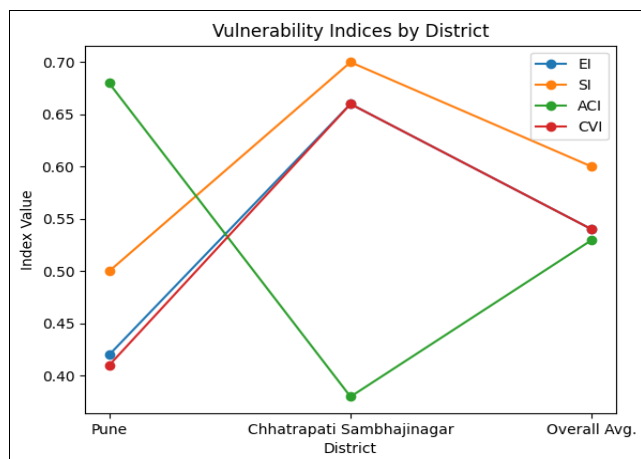


Fig 4: Comparative Exposure Index (EI), Sensitivity Index (SI) and Adaptive Capacity Index (ACI)

Figure 4 further illustrates the comparative pattern of exposure, sensitivity and adaptive capacity across districts. The results demonstrate that vulnerability increases with rising exposure and sensitivity, while it declines with improvements in adaptive capacity. This inverse relationship highlights the critical role of adaptive capacity in moderating climate vulnerability (IPCC, 2014)^[1].

Overall, the findings confirm that vulnerability is not solely determined by climatic exposure but is strongly mediated by adaptive capacity (Adger, 2006)^[2]. Therefore, strengthening institutional support systems, improving access to financial services, promoting climate-resilient technologies and enhancing farmer organizations are essential strategies for reducing vulnerability, particularly in high-risk regions such as Chatrapati Sambhajnagar.

3.6 Distribution of Fig Growers by Vulnerability Category

Table 5: Distribution of Fig Growers

Category	Frequency	Percentage
Low	83	27.67
Moderate	176	58.67
High	41	13.66

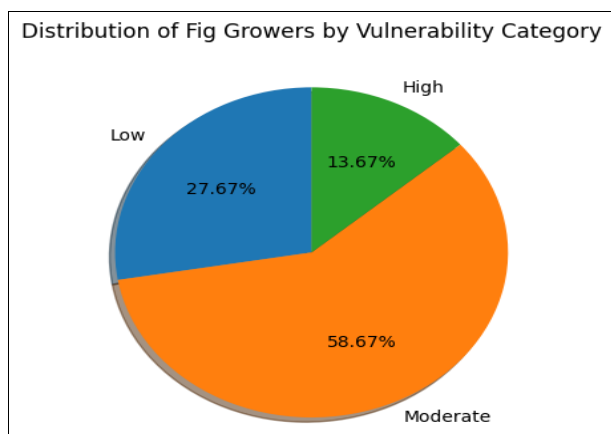


Fig 5: Distribution of Fig growers by Vulnerability Category

The distribution of fig growers across vulnerability categories reveals that a majority (58.67%) fall under the

moderate vulnerability group, indicating that most farmers operate under intermediate risk conditions where they are neither fully resilient nor highly vulnerable to climate variability.

Approximately 27.67 per cent of farmers are categorized under low vulnerability, suggesting relatively stronger adaptive capacity supported by better access to resources, institutional services and livelihood diversification. In contrast, 13.66 per cent of farmers fall under the high vulnerability category, representing a critically exposed group characterized by higher sensitivity and limited adaptive capacity.

This distribution highlights the heterogeneity in vulnerability among fig growers, reflecting unequal access to financial, institutional and knowledge resources across the study area. The presence of a vulnerable segment, though relatively smaller in proportion, is significant and requires targeted policy interventions to reduce risk and enhance resilience.

The findings further reinforce that vulnerability is not solely determined by climatic exposure but is strongly moderated by adaptive capacity factors such as access to resources, institutional support, financial resilience and knowledge systems. Farmers with stronger adaptive capacity are better able to cope with climatic stress, resulting in lower overall vulnerability despite similar exposure conditions.

4. Limitations of the Study

The study is based on cross-sectional data and farmer perceptions, which may involve recall bias. The use of equal weighting for indicators may not fully reflect their relative importance. Additionally, the findings are region-specific and may not be generalizable to other agro-climatic conditions.

5. Policy Implications

The findings highlight the need for targeted interventions to reduce vulnerability, including strengthening micro-irrigation and water harvesting systems, improving access to crop insurance and institutional credit, promoting farmer producer organizations (FPOs), enhancing climate advisory and early warning services and building farmers' capacity through training and digital extension.

6. Conclusion

The study reveals that fig growers in Maharashtra experience moderate to high vulnerability to climate variability, with Chatrapati Sambhajnagar being more vulnerable due to higher exposure and sensitivity and lower adaptive capacity. Enhancing adaptive capacity through institutional, financial and technological support is essential for improving resilience and ensuring sustainable fig production.

7. Acknowledgement

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8. Conflict of Interest

The author declares no conflict of interest.

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