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Climate Risk Management among Smallholder Farmers: A Comparative Analysis of Flood-prone Alappuzha and Drought-affected Gondia in India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscripts.

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ABSTRACT

Climate change poses significant risks to agricultural systems worldwide, particularly in developing countries where smallholder farmers have limited adaptive capacity. This study examines the socioeconomic and demographic factors influencing climate risk management practices among

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smallholder farmers in two contrasting regions of India: the flood-prone Alappuzha district in Kerala and the drought-affected Gondia district in Maharashtra. Using data collected from 150 rice farmers, the research analyzes economic, social, technical, and physical dimensions shaping adaptive responses. Key findings reveal significant regional disparities in adaptive strategies. Alappuzha farmers exhibit greater resilience due to higher incomes, better compensation mechanisms, and stronger community networks. Their strategies primarily involve strengthening bunds, improving drainage infrastructure, adopting flood-resistant rice varieties, and relying on formal credit for support. Conversely, Gondia farmers face lower adaptive capacity, driven by limited access to credit, inadequate compensation, and weaker institutional support. Their climate risk management approaches include drip irrigation, planting drought-resistant crop varieties, and pursuing income diversification to reduce vulnerability. Education levels, access to insurance, and the use of localized weather information also play crucial roles in shaping adaptive capacity across both regions. The study underscores the need for targeted interventions to strengthen institutional support, expand educational programs, facilitate community networks, and improve access to localized weather information to enhance agricultural resilience to climate risks. These findings provide practical policy recommendations aimed at addressing region-specific challenges and leveraging local strengths to bolster adaptive capacity.

Keywords: Climate risk management; smallholder farmers; adaptive capacity; socioeconomic characteristics; agricultural resilience.

1. INTRODUCTION

Climate change is increasingly recognized as a profound threat to global agriculture, with significant implications for food security, livelihoods, and economic development. The Intergovernmental Panel on Climate Change (IPCC) projects that climate-related risks, including rising temperatures, altered precipitation patterns, and increased extreme weather events such as floods and droughts, will intensify in the coming decades, posing substantial challenges to farming systems worldwide [1]. Agriculture in developing countries, where smallholder farmers rely heavily on rain-fed systems, is particularly vulnerable to these risks due to limited adaptive capacity and fewer resources to cope with environmental stressors [2].

In agriculture, climate risk refers to the uncertainties and potential adverse effects arising from the changing climate on farm production, income stability, and overall livelihood security [3]. As climatic conditions become more unpredictable, the frequency of adverse events like floods, heatwaves, and prolonged droughts has surged, exacerbating production risks. For farmers, especially those operating at small scales, such risks manifest as threats to yield stability, increased susceptibility to pest outbreaks, and degraded soil and water resources [4]. These challenges necessitate robust climate risk management practices to safeguard agricultural productivity and ensure sustainable rural development.

Climate risk management in agriculture involves the identification, assessment, and prioritization of risks, followed by the adoption of strategies to minimize potential losses [5]. Effective management not only mitigates the adverse impacts of climate-related events but also enhances the resilience of farming systems by promoting adaptive responses. Understanding the factors that influence how farmers perceive, assess, and respond to these risks is critical for designing context-specific risk management strategies. In this regard, examining the socio-economic and demographic profile characteristics of farmers can provide insights into their adaptive capacity and decision-making behaviors under conditions of climatic stress [6].

Profile characteristics such as education level, farming experience, landholding size, and access to information play a significant role in shaping farmers’ responses to climate risks. For example, younger farmers with higher educational levels may be more inclined to adopt innovative technologies and adaptive practices [7] while larger landholdings and better financial resources can facilitate investments in risk-reducing measures like irrigation infrastructure or crop insurance [8]. Access to climate information, including weather forecasts and early warning systems, has been shown to improve farmers' preparedness and timely response to climatic events, enhancing resilience [9].

This study focuses on understanding the influence of farmers' profile characteristics on climate risk management practices in two regions of India: the flood-prone Alappuzha district in Kerala and the drought-affected Gondia district in Maharashtra. These regions provide contrasting agro-climatic conditions and present diverse challenges to farmers, making them suitable for analyzing the socio-economic determinants of climate risk adaptation. By profiling the socio-demographic characteristics of farmers in these areas, the research aims to identify key factors that enable or constrain effective climate risk management. This analysis is expected to contribute to the development of targeted strategies that address the unique needs and capacities of farmers, thus improving the resilience of agricultural communities to the impacts of climate change.

1.1 Objective

To compare the profile characteristics of farmers in Alappuzha (flood-prone area) and Gondia (drought-prone area) districts and analyze how these characteristics influence their climate risk management decisions.

2. METHODOLOGY

2.1 Location of the study

The study was conducted in Kerala and Maharashtra, chosen for their climate-related risks as identified by the Indian Meteorological Department [10]. Alappuzha district in Kerala, part of the Coastal Plain Agro-Ecological Zone (AEZ 01), is prone to frequent flooding, while Gondia district in Maharashtra, located in the Eastern Vidarbha Agro-Ecological Zone (AEZ 09), faces recurring droughts. Both districts have significant rice cultivation, making them suitable for exploring climate risk management strategies.

2.2 Sampling procedure

The study used purposive sampling to select two districts with high climate-related risks, as per the IMD's Climate Hazards and Vulnerability Atlas (2022). Blocks and villages were then chosen based on significant natural calamity losses from 2018 to 2022 and substantial rice cultivation. A random sampling approach selected 75 rice farmers from each area, resulting in a total sample size of 150, ensuring diverse perspectives on climate risk management strategies.

2.3 Data collection and analysis

The primary dependent variable in this study is climate risk management decision-making, which involves understanding the factors influencing farmers' responses to climate-related risks. Farmers' adaptive behaviors play a critical role in determining agricultural productivity and community resilience in the face of climate variability. To provide a structured analysis, this study categorizes the influencing factors into four dimensions: economic, social, technical, and physical. Each dimension includes specific variables that shape farmers' decision-making processes regarding climate risk management.

To collect data, an interview schedule was developed with expert suggestions and a literature review, ensuring alignment with the study's objectives. The schedule was pretested in a non-study location to identify and implement necessary revisions. Personal interviews were then conducted using the finalized schedule to gather comprehensive data from the respondents. The collected data were systematically scored, tabulated, and analyzed using the Statistical Package for Social Sciences IBM SPSS Statistics V. 25.0., providing insights into the relationships between various attributes and their impact on farmers' climate risk management strategies.

3. RESULTS AND DISCUSSION

3.1 Economic Dimension

3.1.1 Annual income

Table 1 presents the annual income distribution of paddy farmers in Alappuzha, Kerala, and Gondia, Maharashtra. The data reveal that 42.66 percent of farmers earn between ≠1-2 lakhs annually, while 42.00 percent earn less than ≠1 lakh. Notably, 77.33 per cent of Gondia farmers earn below ≠1 lakh, compared to 74.66 per cent in Alappuzha, who earn between ≠1-2 lakhs. A small percentage of farmers in Maharashtra earn between ≠2-3 lakhs, while 5.33 percent in Kerala earn above ≠3 lakhs. These findings align with [11,12], highlighting regional income disparities.

The average annual income for an Indian citizen is ≠1,72,000 [13]. This shows many rice farmers in Maharashtra earn below this average, while many in Kerala meet or exceed it. The income gap reflects deeper regional issues, as noted in the 2019 Situation Assessment of Agricultural Households. Lower incomes in Maharashtra are partly due to the frequency of natural disasters, which result in substantial financial losses. In contrast, higher incomes in Kerala allow for investments in quality agricultural inputs, enhancing productivity and resilience to climate risks. Limited income in Maharashtra restricts farmers' access to quality inputs, affecting yields and climate resilience. Many farmers supplement their income through the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) or as laborers, but these efforts often do not significantly improve their economic standing.

3.1.2 Enrollment in crop insurance

The data in Table 2 indicates that 93.34 percent of farmers are enrolled in crop insurance schemes, underscoring the widespread acceptance of insurance as a protective financial tool in agricultural risk management. Notably, enrollment rates are slightly higher in Alappuzha (94.66%) compared to Gondia (92%), reflecting a strong reliance on insurance programs to mitigate the uncertainties posed by climate risks. Factors driving this high participation include proactive state initiatives like the Pradhan Mantri Fasal Bima Yojana (PMFBY), which offers affordable premiums and broad coverage, along with increased financial literacy efforts that emphasize the benefits of crop insurance.

These findings suggest that high insurance uptake in regions with diverse cropping patterns and dependency on monsoon rains enhances farmers' resilience by providing a safety net against climate-induced losses. As more farmers recognize the necessity of financial protection in areas prone to unpredictable weather, their participation in insurance schemes becomes a critical element of climate risk management. These results are aligned with [14], who found that regions with high variability in weather patterns tend to exhibit higher insurance uptake due to greater awareness of agricultural risks.

3.1.3 Compensation received

Table 3 highlighted that in Alappuzha, 50.66 percent of farmers reported receiving full compensation for crop losses, attributed to the efficient processes of local Krishibhavans, which streamline damage reporting and fund disbursement. This effectiveness has been noted in studies by [15,12], with Kerala's model often regarded as exemplary.

Table 1. Distribution rice farmers based on their net annual income in the states of Kerala and Maharashtra (N=150)

Sl. No	Category of annual income (Rs in lakhs)	District-wise distribution of farmers (%) in the states of			
		Kerala	Maharashtra	Frequency	Percentage
		Alappuzha	Gondia		
1	<01	5 (6.66)	58 (77.33)	63	42
2	1 to 2	56 (74.66)	8 (10.66)	64	42.66
3	02 to 03	10 (13.33)	9 (12)	19	12.66
4	03 to 04	4 (5.33)	0 (0)	4	2.66
5	>04	0 (0)	0 (0)	0	0
	Total	75 (100)	75 (100)	150	100

Table 2. Distribution of rice farmers based on the adoption of crop insurance in the statesof Maharashtra and Kerala (N=150)

Sl. No	Adoption categories of crop insurance	District-wise distribution of farmers (%) in the states of			
		Kerala	Maharashtra	Frequency	Percentage
		Alappuzha	Gondia		
1	Never	0 (0)	0 (0)	0	0
2	Sometimes	4 (5.34)	6 (8)	10	66.66
3	Always	71 (94.66)	69 (92)	140	93.34
	Total	75 (100)	75 (100)	150	100

Table 3. Distribution of rice farmers based on their compensation received in the states of Kerala and Maharashtra (N=150)

Sl. No	Categories of compensation received	District-wise distribution of farmers (%) in the states of			
		Kerala	Maharashtra	Frequency	Percentage
		Alappuzha	Gondia		
1	Fully received	38 (50.66)	23 (30.66)	61	40.66
2	Partially received	27 (36)	44 (58.66)	71	47.33
3	Not at all received	10 (13.33)	8 (10.66)	18	12
	Total	75 (100)	75 (100)	150	100

Conversely, only 40.66 percent of farmers in Gondia, Maharashtra, received full compensation despite a high land ownership rate. Administrative bottlenecks, informal tenant farming arrangements, and inadequate evaluation mechanisms contribute to this discrepancy, leaving many farmers, particularly those on leased land without formal agreements, vulnerable [11,16]. Additionally, Gondia's susceptibility to erratic weather leads to a surge in compensation claims, complicating the distribution process. Notably, 10.66 percent of Gondia's farmers received no compensation at all, whereas only 13.33 percent of Alappuzha farmers were left uncompensated because of the effective coordination between the District Disaster Management Authority (DDMA) and Krishibhavans.

The results conclude that in Alappuzha, timely compensation allows farmers to invest in resilient practices and recover swiftly from climate shocks, enhancing community resilience. In contrast, unreliable compensation in Gondia limits farmers' ability to adopt adaptive measures, hindering productivity and risk mitigation. To improve the situation in Gondia, policy reforms are needed to simplify claims, formalize tenant.

3.1.4 Credit sources

The analysis of credit sources, as shown in Table 4, reveals notable differences between Alappuzha and Gondia in terms of how farmers access credit. Overall, 49.34 percent of farmers rely on formal sources such as banks, 36.66 percent use a combination of formal and informal sources, and 14 percent depend solely on informal channels. In Alappuzha, 64 percent of farmers access credit through formal channels, owing to the region's strong financial infrastructure and supportive government initiatives. Additionally, 30.66 percent use both formal and informal credit sources, while only 5.34 percent depend exclusively on informal sources, indicating lower exposure to high-interest debts.

In contrast, Gondia's farmers show a different trend, with 42.66 percent accessing a mix of credit sources, 34.68 percent using formal sources, and a significant 22.66 percent relying on informal lenders. This reliance is often due to limited formal credit access for farmers lacking collateral, pushing them toward high-interest informal loans, which can exceed 24 percent. This pattern weakens financial resilience and heightens vulnerability to climate risks. These findings align with studies by [17,18], which also observed that limited formal credit access can exacerbate debt cycles and climate risk exposure.

3.1.5 Income diversification

It is evident from the data given in Table 5 that in Alappuzha, approximately 42.66 percent of farmers engage in non-farm activities, making it the predominant source of supplementary income. This is followed by employment opportunities at 36 percent, while labor wages contribute 16 percent and livestock rearing accounts for 4 percent. In contrast, Gondia's income diversification is heavily skewed toward labor wages, with 60 percent of farmers relying on this source. Non-farm income activities constitute 22.66 percent, followed by employment at 9.33 percent and livestock rearing at 8 percent. Overall, non-farm income activities account for 32.66 percent across both regions.

These findings highlight the varying reliance on income diversification strategies between the two districts, influenced by local economic conditions and opportunities. The predominance of non-farm income activities in Alappuzha underscores the region's potential for alternative livelihood

Table 4. Distribution of rice farmers based on their sources of credit in the statesof Maharashtra and Kerala (N=150)

Sl. No	Categories of sources of credit	District-wise distribution of farmers (%) in the states of			
		Kerala	**Maharashtra**	**Frequency**	**Percentage**
		Alappuzha	Gondia		
1	Informal	4 (5.34)	17 (22.66)	21	14
2	Formal and Informal	23 (30.66)	32 (42.66)	55	36.66
3	Formal	48 (64)	26 (34.68)	74	49.34
	Total	75 (100)	75 (100)	150	100

Table 5. Distribution of rice farmers based on their diversification of income in the statesof Maharashtra and Kerala (N=150)

Sl. No	Diversification of income	District-wise distribution of farmers (%) in the states of			
		Kerala	**Maharashtra**	**Frequency**	**Percentage**
		Alappuzha	Gondia		
1	Leasing out of land	1(1.33)	0	1	0.66
2	Livestock farming	3(4)	6 (8)	9	6
3	Labor wages	12 (16)	45 (60)	57	38
4	Non-farm business	32 (42.66)	17 (22.66)	49	32.66
5	Employment	27 (36)	7 (9.33)	34	22.66
6	Rental leasing of machinery	0 (0)	0 (0)	0	0
	Total	75 (100)	75 (100)	150	100

strategies, which can enhance farmers' resilience to climate risks. Conversely, Gondia's heavy dependence on labor wages may expose farmers to economic vulnerabilities, particularly during periods of labor market fluctuations. This aligns with the study by [19], which emphasizes the importance of income diversification for enhancing adaptive capacity and reducing vulnerability to climatic variations among rural households.

3.2 Social Dimension

3.2.1 Education

The analysis of educational qualifications among farmers in Gondia, Maharashtra, and Alappuzha, Kerala, as shown in Table 6 revealed notable regional disparities. Overall, 26.66 percent of the farmers had attended high school, followed closely by 25.33 percent with secondary education. In Alappuzha, 32 percent of farmers completed high school, reflecting Kerala's strong focus on education and a supportive literacy framework. Additionally, 25.33 percent had secondary education, and 10.66 percent were graduates, indicating a trend of educated individuals returning to farming. Conversely, in Gondia, the educational distribution leaned toward lower levels, with 32 percent of farmers having only primary education, 25.33 percent reaching secondary education, and just 5.33 percent holding a graduate degree, suggesting socio-economic challenges and limited access to higher education.

Table 6. Distribution of rice farmers based on their education in the states of Kerala and Maharashtra (N=150)

Sl. No	Level of education	District-wise distribution of farmers (%) in the states of			
		Kerala	**Maharashtra**	**Frequency**	**Percentage**
		Alappuzha	Gondia		
1	Primary education	8 (10.66)	24 (32)	32.00	21.33
2	Secondary education	19 (25.33)	19 (25.33)	38.00	25.33
3	High school	24 (32)	16 (21.33)	40.00	26.66
4	Higher Secondary	16 (21.33)	12 (16)	28.00	18.66
5	Graduate	8 (10.66)	4 (5.33)	12.00	8.00
6	Postgraduate	0 (0)	0 (0)	0	0
	Total	75 (100)	75 (100)	150	100

These findings underscore education's critical role in shaping farmers' capacity to adopt climate-resilient agricultural practices. Higher education levels in Alappuzha enhance farmers' ability to engage with modern farming techniques, access information, and implement effective adaptation strategies, thereby strengthening resilience against climate risks. In contrast, lower education levels in Gondia limit farmers' adaptability to new technologies and climate-smart practices, increasing their vulnerability. These results align with the findings of [20].

3.2.2 Community action

The analysis revealed substantial differences in community action involvement among farmers in Alappuzha, Kerala, and Gondia, Maharashtra as depicted in Table 7. In Alappuzha, 92 percent of farmers participate in community-based initiatives, compared to 72 percent in Gondia, indicating stronger collective efforts in Kerala. Only 8 percent of farmers in Alappuzha do not engage in such activities, while in Gondia, the non-participation rate stands at 28 percent. This disparity suggests a critical influence of community cohesion on fostering resilience, especially in regions vulnerable to climate-related risks.

The higher involvement in community action in Alappuzha reflects the strong tradition of collective farming, supported by initiatives like the Padashekara samithies for managing resources. This collective approach enables farmers to better address shared challenges and climate risks. In contrast, Gondia's lower participation suggests weaker institutional support and reliance on individual decision-making, limiting coordinated responses to climate variability. Strengthening support for Farmer Producer Organizations (FPOs) in Gondia could help enhance community-driven resilience. These findings are aligned with [21], who emphasize social cohesion's role in effective agricultural risk management.

3.2.3 Extension agencies contact

The findings indicate that 49.33 percent of farmers engage with extension services, showcasing the crucial role of these services in providing agricultural guidance. As detailed in Table 8, the patterns of extension contact across Alappuzha and Gondia highlight regional differences in accessibility and utilization.

In Alappuzha, 48 percent of farmers regularly access extension services, while another 49.33 percent visit occasionally. The engagement here is largely driven by the availability of agricultural officers and resources like the Moncompu Rice Research Station, which facilitates the dissemination of up-to-date agricultural practices. In Gondia, the proportion of regular extension contact is slightly higher at 50.66 percent, with farmers frequently consulting agricultural officers, Krishi Vigyan Kendras (KVKs), and agricultural assistants. Occasional visits account for 41.33 percent, with services often accessed through farmers' call centres or recommendations from progressive farmers.

However, a small segment of farmers remains disconnected from extension services—8 percent in Gondia and 2.66 percent in Alappuzha—pointing to gaps in outreach that need addressing. Increasing efforts to engage these non-participating farmers could enhance their adoption of climate-resilient practices, thereby reducing their vulnerability to climate-related risks. These findings align with previous research, such as [22], which suggests that frequent extension contact facilitates the adoption of innovative practices.

Table 7. Distribution of rice farmers based on their involvement in community action in the statesof Maharashtra and Kerala (N=150)

Sl. No.	Involvement in community action	District-wise distribution of farmers (%) in the states of			
		Kerala	Maharashtra	Frequency	Percentage
		Alappuzha	Gondia		
1	Yes	69 (92)	54 (72)	123	82
2	No	6 (8)	21 (28)	27	18
	Total	75 (100)	75 (100)	150	100

Table 8. Distribution of rice farmers based on their extension agency contact in the statesof Maharashtra and Kerala (N=150)

Sl. No.	Extension participation	District-wise distribution of farmers (%) in the states of			
		Kerala	**Maharashtra**	**Frequency**	**Percentage**
		Alappuzha	Gondia		
1	Never	2 (2.66)	6 (8)	8	5.33
2	Occasionally	37 (49.33)	31(41.33)	68	45.33
3	Regularly	36 (48)	38 (50.66)	74	49.33
	Total	75 (100)	75 (100)	150	100

Table 9. Distribution percent rice farmers based on their level of training exposure in the statesof Maharashtra and Kerala (N=150)

Sl. No.	Training exposure	District-wise distribution of farmers (%) in the states of			
		Kerala	**Maharashtra**	**Frequency**	**Percentage**
		Alappuzha	Gondia		
1	High	33 (44)	16 (21.33)	49	32.66
2	Medium	27 (36)	42 (56.00)	69	46.00
3	Low	15 (20)	17 (22.66)	32	21.33
	Total	75 (100)	75 (100)	150	100

3.2.4 Training Exposure

The study reveals that 46.00 percent of farmers have a medium level of training exposure, with 32.66 percent achieving high exposure, as detailed in Table 9. In Alappuzha, 44 percent report high training exposure compared to 20 percent at low exposure, while Gondia shows 56 percent with medium exposure and 21.33 percent high. This variation highlights significant differences in institutional support, with Alappuzha benefiting from robust agricultural extension networks and capacity-building initiatives, such as those from Krishi Bhavans, which enhance farmers' learning opportunities in modern agricultural practices.

The results indicate that training exposure is vital for farmers' ability to adapt to climate risks. The strong extension services in Alappuzha empower farmers to make informed decisions about climate-smart practices and sustainable resource management. In contrast, Gondia's limited training exposure stems from geographical isolation and lower literacy rates, hindering awareness of available training. These findings align with research by [11,23], underscoring the critical role of effective extension services in enhancing adaptive capacity in the face of climate variability.

3.3 Technical Dimension

3.3.1 Access to weather information

The study findings presented in Table 10 indicate that a notable 92.67 percent of farmers have regular access to weather information, underscoring the critical role of timely weather updates in planning agricultural activities, particularly in areas prone to erratic weather patterns. At the district level, access is especially pronounced in Alappuzha, where 94.67 percent

Table 10. Distribution of rice farmers based on the accessibility of weather information to farms in the statesof Maharashtra and Kerala (N=150)

Sl. No	Access to weather information	District-wise distribution of farmers (%) in the states of			
		Kerala	**Maharashtra**	**Frequency**	**Percentage**
		Alappuzha	Gondia		
1	Yes	71 (94.67)	68 (90.67)	139	92.67
2	No	4 (5.33)	7 (9.33)	11	7.33
	Total	75 (100)	75 (100)	150	100

of farmers report receiving consistent weather advisories. In Gondia, this figure is slightly lower but still significant at 90.67 percent. However, a small segment of the farming community remains without this vital information, with 9.33 percent of farmers in Gondia and 5.33 percent in Alappuzha lacking access to crucial weather updates.

The high levels of access to weather information in both districts can largely be attributed to the widespread use of mobile phones and television, which serve as key channels for disseminating weather advisories. In Alappuzha, farmers receive updates from sources such as the Moncomp Research Station and the National Disaster Management Authority (NDMA). Similarly, Gondia farmers rely on the NDMA for regular advisories, typically delivered via SMS in regional languages, making the information accessible even to those with lower literacy levels. This access enables farmers to make timely decisions—such as adjusting sowing and harvesting schedules or implementing protective measures against adverse weather conditions.

These findings resonate with recent research highlighting the importance of timely, accurate, and localized weather information in agricultural risk management. Studies, including those by [24], have shown that localized weather advisories significantly enhance farmers' adaptive capacities.

3.4 Physical Dimension

3.4.1 Farm size

The findings from the present study, as shown in Table 11, reveal that a significant majority of farmers are small landholders, with 80 percent owning between 1-2 hectares of land. The marginal, semi-medium, and medium landholders comprise only 20 percent of the farming community, indicating a pronounced inclination toward small-scale agriculture. This trend is consistent with the national agricultural landscape of India, where small and marginal farmers represent the majority, reflecting a structural characteristic of the sector. A closer examination of district-level data uncovers variations in landholding patterns: in Alappuzha, 73.33 percent of farmers are classified as small landholders, followed by 25.33 percent as semi-medium. Conversely, Gondia presents an even more skewed distribution, with 86.67 percent of farmers identified as small, and only 12 percent as marginal. This predominance of small farmers in both districts highlights a common vulnerability regarding economic returns and decision-making limitations, as smaller landholdings often restrict opportunities for crop diversification and effective risk management strategies.

3.4.2 Tenurial status

As illustrated in Table 12, the study reveals that 48.67 percent of farmers across both districts fully own their farms, while 34.67 percent cultivate entirely leased land. This data underscores a predominant reliance on owned farming, particularly in Gondia, where an impressive 90.67 per cent of farmers own their land, with only a small fraction (5.33%) engaged in mixed ownership and leasing arrangements. The high level of land ownership in Gondia can be attributed to Maharashtra's relatively less fragmented land holdings and effective land tenure policies that promote ownership and discourage informal leasing practices.

In contrast, Alappuzha presents a different scenario, with 65.34 percent of farmers relying on fully leased land for cultivation, indicating a dependency on tenancy arrangements. This reliance on leased land may limit farmers' capacity to diversify crops and implement effective climate risk management strategies.

Table 11. Distribution of rice farmers based on the farm size in the statesof Maharashtra and Kerala (N=150)

Sl. No	Categories for farm size	District -wise distribution of farmers (%) in the states of			
		Kerala	Maharashtra	Frequency	Percentage
		Alappuzha	Gondia		
1	Marginal farmer (<1ha)	0 (0)	9 (12)	9	6
2	Small farmer (1-2ha)	55 (73.33)	65 (86.67)	120	80
3	Semi-medium farmer (2-4 ha)	19 (25.33)	1 (1.34)	20	13.34
4	Medium farmer (4-10 ha)	1 (1.34)	0 (0)	1	0.66
5	Large farmer (>10 ha)	0 (0)	0 (0)	0	0
	Total	75 (100)	75 (100)	150	100

Table 12. Distribution of rice farmers based on the type of tenancy in the states of Kerala and Maharashtra (N=150)

Sl. No	Categories of farm tenancy	District-wise distribution of farmers (%) in the states of			
		Kerala	Maharashtra	Frequency	Percentage
		Alappuzha	Gondia		
1	Fully owned farm	5 (6.66)	68 (90.67)	73	48.67
2	Partly owned and partly leased in	21 (28)	4 (5.33)	25	16.66
3	Fully leased in	49 (65.34)	3 (4)	52	34.67
	Total	75 (100)	75 (100)	150	100

Table 13. Distribution of rice farmers based on the availability of road access to farms in the statesof Maharashtra and Kerala (N=150)

Sl. No	Availability of road	District-wise distribution of farmers (%) in the states of			
		Kerala	Maharashtra	Frequency	Percentage
		Alappuzha	Gondia		
1	Pucca road	52 (69.33)	46 (61.33)	98	65.33
2	Farm paved road	22 (29.33)	26 (34.67)	48	32.00
3	No road	1 (1.33)	3 (4)	4	2.67
	Total	75 (100)	75 (100)	150	100

This trend may stem from historical land reforms that redistributed land but also created a class of smallholders who opt for leasing as a strategy to address the limitations posed by small farm sizes. Additionally, 28.00 percent of Alappuzha's farmers cultivate on a mix of owned and leased land, underscoring the necessity of supplementing small holdings to achieve economies of scale. The findings are in line with [25,26].

3.4.3 Availability of road to farms

The study indicates that road accessibility is a critical factor for farmers in managing climate-related risks, with 65.33 percent having access to pucca roads and 32 percent to farm-paved roads (Table 13). This infrastructure enables effective transportation of agricultural products and essential inputs, which in turn optimizes decision-making regarding market access and resource allocation. Notably, pucca road availability is higher in Alappuzha (69%) than in Gondia (61.33%), largely due to government initiatives like the Pradhan Mantri Gram Sadak Yojana (PMGSY) that enhance rural connectivity.

The findings align with [27], emphasizing that improved road infrastructure reduces transportation costs and fosters market access, ultimately increasing farmers' incomes. Enhanced connectivity allows farmers to engage confidently in distant markets, mitigating risks related to post-harvest losses and price fluctuations.

The study comparing climate risk management practices among smallholder farmers in Alappuzha, Kerala, and Gondia, Maharashtra, underscores the critical role of socioeconomic and demographic characteristics in shaping farmers’ adaptive capacity to climate change. In Latin America, similar patterns emerge, where agricultural resilience is significantly influenced by socioeconomic factors such as income, access to financial services [28], education [29], and institutional support [30]. For example, farmers in higher-income regions, such as the banana-growing areas of Venezuela, Panama, and Colombia, exhibit stronger adaptive responses due to better access to markets and compensation mechanisms, paralleling the resilience seen in Alappuzha [31, 32]. In contrast, rural farmers in drought-prone regions of East Africa often face significant challenges in managing climate risks due to limited resources and institutional support, much like the farmers of Gondia, indicating the importance of targeted, region-specific interventions [33,34].

Socioeconomic inequalities across these regions are closely tied to the capacity for adaptation [35]. In both India and Latin America, access to credit, insurance, and agricultural extension services plays a pivotal role in enhancing farmers' ability to manage climate risks [36, 37].

In India, Alappuzha farmers benefit from better institutional frameworks and access to compensation, which enhances their resilience to climate variability. Comparatively, smallholder farmers in regions like Bolivia or Honduras often face similar challenges as Gondia farmers, where limited institutional support and restricted financial access hinder their capacity to adapt [38, 39,40]. This comparison reveals that while climate risks are geographically distinct, the underlying socioeconomic factors driving adaptive capacity show universal importance in agricultural systems across both regions [41, 42, 43].

Furthermore, the perception of climate risks and engagement in adaptive practices is often shaped by education levels and the effectiveness of community networks, a shared characteristic in both India and Latin America [44, 45]. In Kerala's Alappuzha district, community-based networks foster collaborative adaptation strategies, an approach that could be mirrored in Latin America's smallholder communities to enhance resilience [46, 47]. The study emphasizes the necessity for region-specific policy solutions that consider not only the physical and technical dimensions of climate adaptation but also the social structures and economic conditions that enable effective climate risk management [48, 49, 50]. These insights are highly relevant for Latin American agricultural systems, where both community engagement and institutional support can be crucial in addressing climate vulnerabilities [50, 51, 52].

4. CONCLUSION

This study provides an in-depth analysis of climate risk management among farmers in Alappuzha, Kerala, and Gondia, Maharashtra, revealing critical socio-economic, educational, and institutional factors that shape adaptive responses. The research underscores significant regional disparities in resilience capacities, with farmers in Alappuzha generally exhibiting stronger adaptive behaviors due to higher incomes, robust compensation mechanisms, and enhanced access to formal credit. Conversely, Gondia's farmers face heightened vulnerability, constrained by lower income levels, inadequate compensation for climate-induced crop losses, and a heavy reliance on informal credit networks. These differences illustrate the role of economic security in enabling or limiting effective climate adaptation.

Educational attainment and community engagement also emerge as pivotal elements influencing farmers' ability to respond to climate risks. In Alappuzha, higher levels of education and active community participation facilitate better access to extension services and the adoption of climate-resilient practices. In contrast, Gondia's lower education levels and weaker community networks inhibit the uptake of adaptive measures. These findings suggest that enhancing human and social capital is integral to strengthening resilience across diverse agricultural settings.

Furthermore, the study highlights the critical role of timely weather information in guiding adaptive decisions. While both regions demonstrate considerable access to weather forecasts, there remain gaps in reaching farmers who are less connected to formal extension services. Addressing these informational disparities is essential for empowering all farmers to make informed choices.

The research recommends targeted policy interventions to reduce regional vulnerabilities. Key suggestions include:

1. Strengthening institutional support: Enhancing formal credit access and streamlining compensation mechanisms for crop losses can alleviate financial constraints, especially in underserved regions like Gondia.
2. Expanding educational programs: Investing in agricultural education and training, with a focus on climate risk management, can boost farmers' capacity to adopt adaptive practices effectively.
3. Facilitating community networks: Promoting active community organizations and cooperative societies can enhance knowledge sharing and collective action in climate adaptation efforts.
4. Improving access to weather information: Developing user-friendly, localized weather information services that reach even the most marginalized farmers can ensure that adaptive strategies are timely and effective.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models

(ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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