Ethiopian Journal of Environmental Studies & Management 19(3): 349 – 364, 2026
ISSN:1998-0507 doi: https://ejesm.org/doi/v19i3.8
Submitted: April 20, 2026 Accepted: June 2, 2026

CROP-SPECIFIC CLIMATE CHANGE ADAPTATION STRATEGIES AMONG MARGINALISED FARMERS IN INDIA

KAMBLE, R. K.
Centre for Higher Learning, Research and Specialized Studies in Environmental Science,
Sardar Patel College, Chandrapur 442 402, India
Email: rahulkk41279@yahoo.com

Abstract
A purposive random sampling approach was employed to conduct a comparative assessment of crop-specific climate change adaptation strategies among marginalised farmers in India. The study focused on farmers cultivating paddy, cotton, and pulses in Maharashtra, and wheat, mustard, and barley in Rajasthan. A specially designed, field-tested questionnaire was administered to 280 farmers to assess their willingness to adopt various adaptation strategies. The results indicated that farmers' willingness to adopt climate change adaptation strategies varied across crops, with the highest willingness observed in cotton (90%), followed by paddy (89%), pulses (77%), and wheat, mustard, and barley (68%). A relatively higher proportion of farmers cultivating wheat, mustard, and barley (28%) expressed reluctance toward adopting such strategies. The willingness to adopt adaptation measures also varied across agricultural practices. The highest levels were observed during harvesting, with 94% for paddy and 88% for pulses, followed by irrigation practices, with 83% for cotton and 78% for wheat, mustard, and barley. In terms of future strategies, all respondents (100%) expressed willingness to adopt high-yielding crop varieties. This was followed by water storage practices, particularly among pulse growers (96%), and crop diversification, with 93% and 83% of paddy and pulse farmers, respectively, indicating readiness to adopt such measures. The findings suggest that marginalised farmers are increasingly aware of climate change impacts and are willing to adopt adaptation strategies. However, these strategies vary across crops and practices, indicating that a one-size-fits-all approach is unsuitable. Therefore, policy interventions must be crop-specific and context-sensitive to promote sustainable agriculture and resilient livelihoods.

Keywords: *Agricultural resilience, Crop specific strategies, Climate change adaptation, Marginalised farmers, Sustainable agriculture*

Introduction

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as a long-term alteration in the state of the climate, identifiable through statistical changes in the mean and/or variability of climate properties, persisting for decades or longer (IPCC, 2014). The

IPCC assessment reports highlight significant global shifts in temperature, precipitation patterns, and the frequency of extreme weather events, positioning climate change as one of the most complex and urgent environmental challenges globally. Agriculture and food security are particularly vulnerable sectors facing substantial risks from these climatic changes (Rama Rao *et al*., 2016).

Climate change-induced changes are expected to intensify the occurrence of extreme events like droughts, floods, and cyclones, severely impacting agricultural productivity (Rama Rao *et al*., 2016). Projections specific to India indicate an overall temperature rise of 1 to 4°C and an increase in precipitation by 9 to 16% by the 2050s (Krishna Kumar *et al*., 2011). The increasing variability in climate factors threatens food security by placing additional pressure on agricultural systems. Nevertheless, there remains considerable uncertainty in the assessment of climate change impacts, adaptation strategies, and mitigation measures, largely due to non-standardised and sometimes imprecise methodologies (Singh *et al*., 2017).

Beyond physical impacts, climate change also influences the economic dimensions of agriculture, affecting farm profitability, commodity prices, supply and demand dynamics, trade flows, and regional competitive advantages. The interdependent relationship between climate change and agriculture is particularly critical in developing countries such as India, where a large proportion of the population depends on agriculture for their livelihoods and where adaptive infrastructure is limited (Singh *et al*., 2017). India's vulnerability is further compounded by small landholdings, limited financial resources, and insufficient technological and institutional capacity to manage climatic shocks (Shirsath *et al*., 2017).

Agriculture remains a significant contributor to India's economy, accounting for 17.1% of Gross Domestic Product (Economic Survey, 2016–2017). According to the Indian Council of Agricultural Research, crop yields are projected to decline by 4.5% to 9% by 2039 under medium-term climate change scenarios. Simultaneously, food grain demand is expected to increase by 30 to 35% by 2020, underscoring the urgency of addressing climate change impacts on agriculture to ensure food security (Paroda and Kumar, 2000).

Agriculture is one of the most climate-sensitive sectors due to its heavy reliance on weather conditions. The impact of climate change on agriculture is expected to be heterogeneous and complex, varying significantly across crops, regions, and socio-economic groups (Knox *et al*., 2012). Vulnerability is influenced not only by ecological factors but also by social inequalities and oppression, with poorer farming communities typically bearing the brunt of adverse effects compared to urban populations (Dow *et al*., 2013; Jayaraman and Murari, 2014).

In India, where agriculture predominantly depends on rainfall, climatic shocks pose a substantial threat. Approximately 45% of the country's cropped area is rainfed, and these systems are particularly susceptible to fluctuations in rainfall and temperature (Easterling *et al*., 2007). The frequency and intensity of such climatic shocks have increased recently and are projected to rise further, potentially exacerbating negative impacts on agriculture and rural livelihoods unless adequate adaptation measures are implemented (World Bank, 2013).

Small and marginal farmers (Table 1), who constitute about 80% of India's farming community, often lack the financial resources and risk tolerance needed to invest in adaptive technologies or practices (Birthal and Hazrana, 2019; Dev, 2012). This is especially critical since most agricultural land lies within the semi-arid tropics, regions characterised by low and unpredictable rainfall, poor soils, limited infrastructure, and extreme poverty (Ryan and Spencer, 2001; Walker and Ryan, 1990). These factors collectively increase vulnerability and pose serious environmental, economic, and social challenges.

Table 1: Distribution of farmers according to the land size [in hectare (ha)]

S. No.	Group	S. No.	Classes (in ha)
I.	Marginal	1.	Below 0.5 ha
		2.	0.5 < 1.0 ha
II.	Small	3.	1.0 < 2.0 ha
III.	Semi-medium	4.	2.0 < 3.0 ha
		5.	3.0 < 4.0 ha
VI.	Medium	6.	4.0 < 5.0 ha
		7.	5.0 < 7.5 ha
		8.	7.5 < 10.0 ha
V.	Large	9.	10.0 < 20.0 ha
		10.	and above.

Source: Ministry of Agriculture and Farmers Welfare (2019)

A review of existing literature indicates a noticeable gap in the understanding of climate change adaptation strategies adopted by marginalised farmers across different crop types and growth stages in India. While broad studies on agricultural adaptation exist, few have systematically examined how these strategies differ according to the specific stages of crop development or among various crops cultivated by small and marginal farmers, who are particularly vulnerable to climate variability and extreme weather events. Recognising this gap, the present study was designed to assess and document the climate change adaptation practices of marginalised farmers in diverse agro-climatic regions of India. Special attention was given to how adaptation strategies vary not only between regions and farming systems but also across different stages of crop growth. The findings from this study aim to enrich the current knowledge base on localised adaptation measures and provide insights that could inform region and crop-specific policy interventions to enhance climate resilience in the agricultural sector.

Study Area

The study was conducted across selected districts in Maharashtra and Rajasthan, representing diverse agro-climatic conditions and major cropping systems. Paddy-growing Chandrapur district (Figure 1) is characterised by a dry sub-humid climate (1142 mm annual rainfall) and red-black soils, with small and marginal farmers constituting 64.5% of cultivators. Cotton-growing districts—Amravati district, Wardha district, and Yavatmal district (Figure 2)—experience semi-arid conditions, high temperature variability, and heavy reliance on rainfed agriculture, with cotton as the dominant cash crop supported by black soils. Pulse-growing regions (Figure 3), including

Beed district, Latur district, Osmanabad district, and Parbhani district, are characterised by dry climates (600–800 mm rainfall), variable soil types, and predominantly rainfed farming systems, where agriculture supports the majority of the population. In contrast, Alwar district and Jhunjhunu district (Figure 4) represent wheat–mustard–barley systems under arid to semi-arid conditions, with low and erratic rainfall (<650 mm) and a greater dependence on irrigation, mainly through tubewells. Across all regions, small and marginal farmers dominate agricultural activities, operating under constraints such as limited landholdings, water scarcity, and climate variability. These districts were selected due to their high vulnerability to climate change and their representation of diverse cropping patterns, making them suitable for assessing crop-specific adaptation strategies among marginalised farming communities.

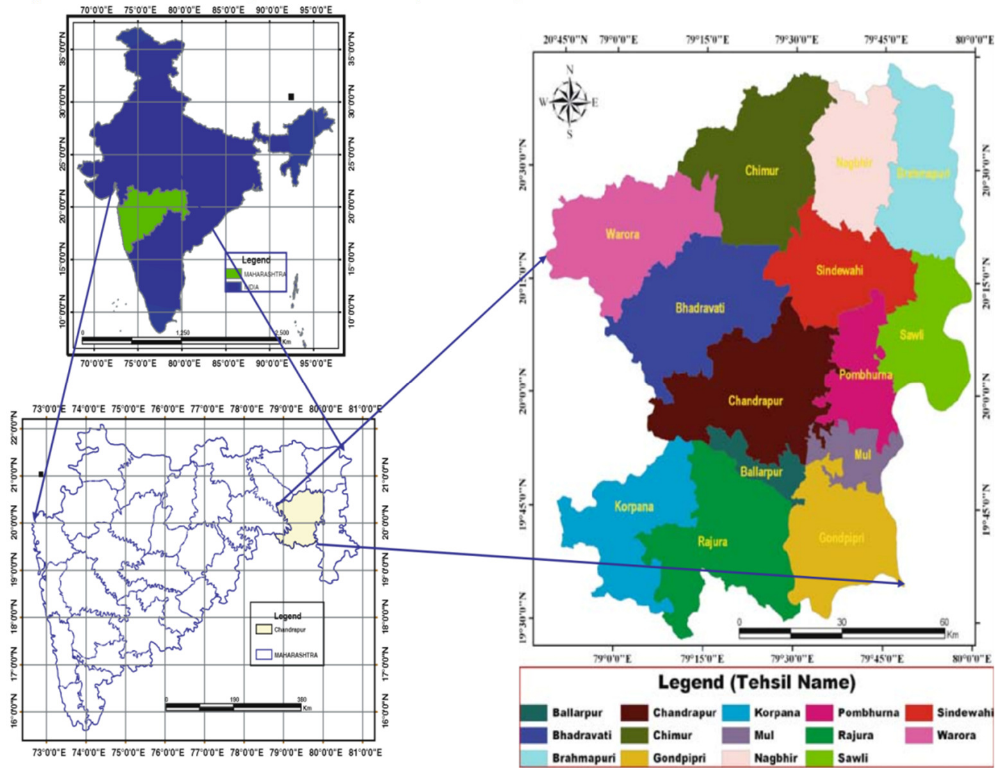

Fig. 1: Paddy cultivating study area

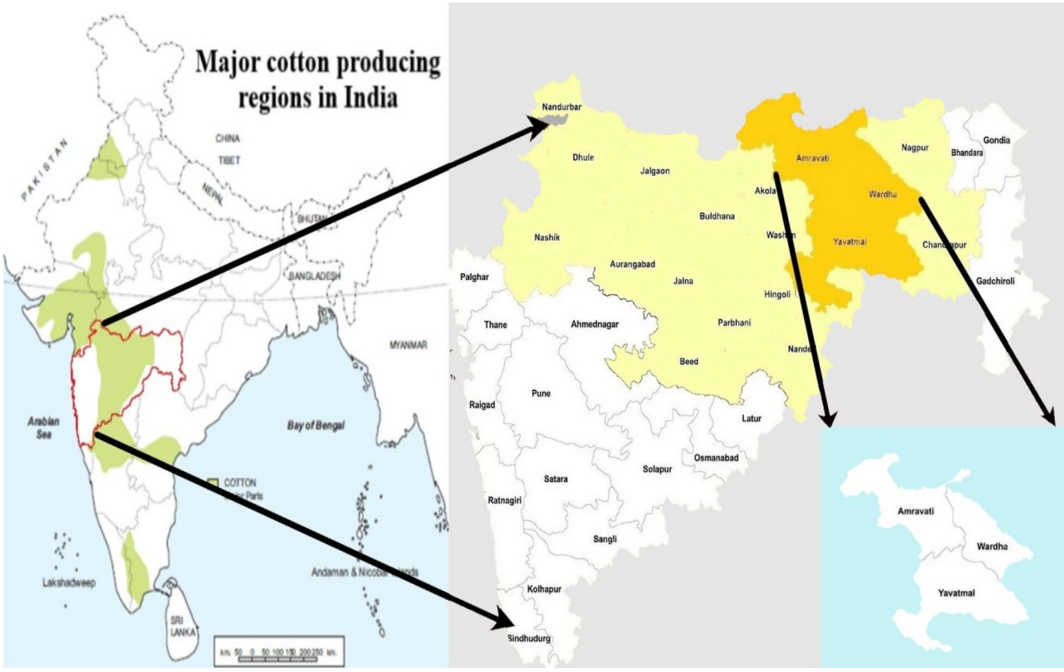

Fig. 2: Cotton cultivating study area

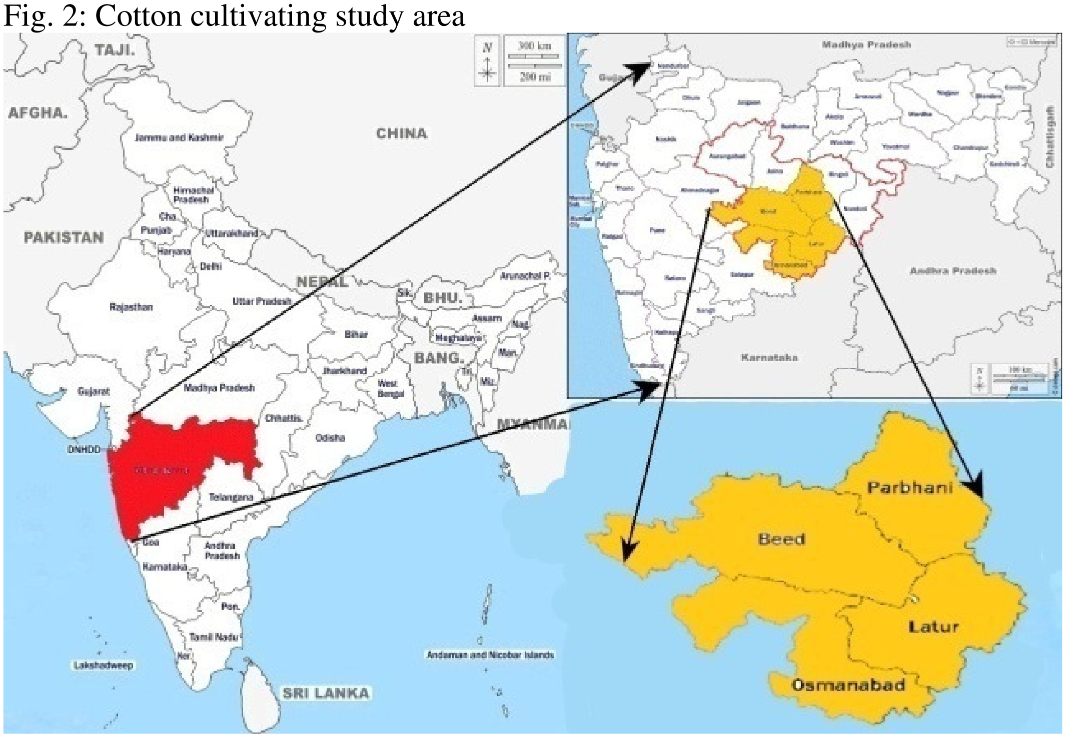

Fig. 3: Pulses cultivating study area

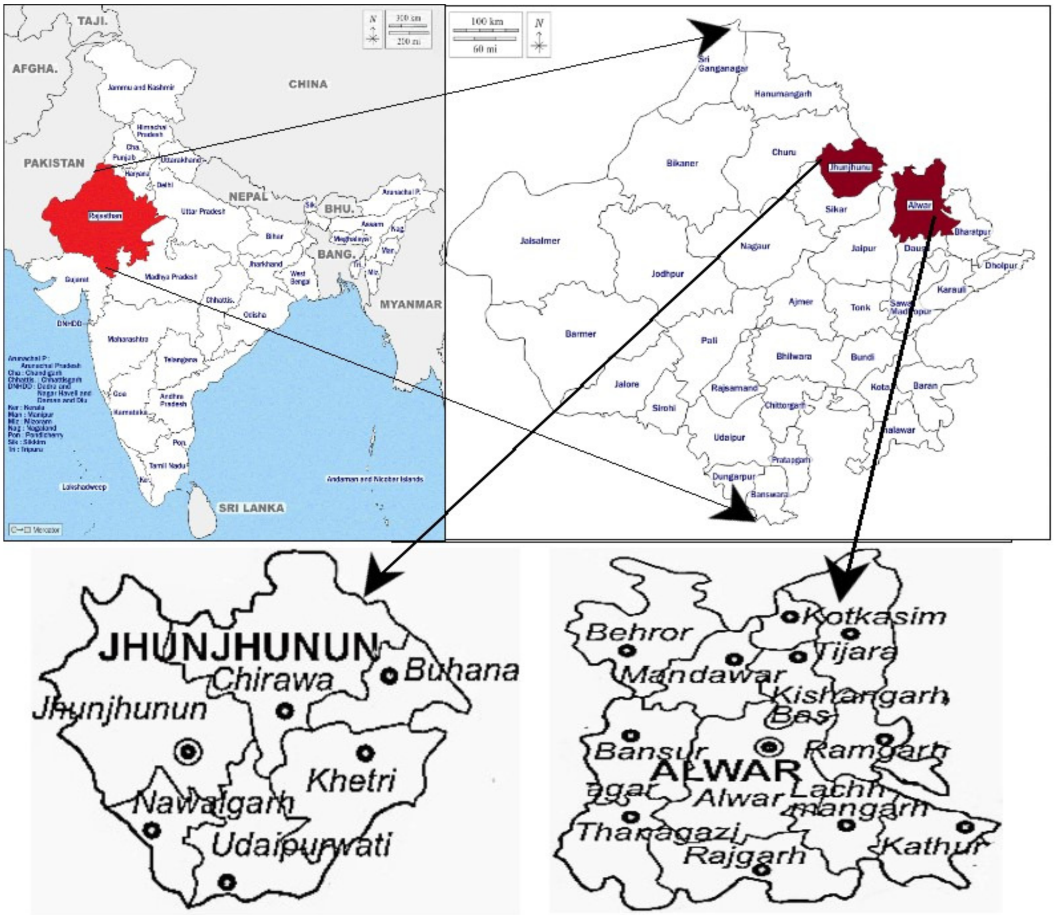

Fig. 4: Wheat, mustard, barley cultivating study area

Materials and Methods

In order to evaluate and compare climate change adaptation strategies among marginalised farming communities, a comprehensive field study was undertaken across selected districts in the states of Maharashtra and Rajasthan. These regions were purposively chosen based on their agro-climatic diversity, exposure to climate-induced risks, and the predominance of small and marginal farming households. The study aimed to document region, crop, crop growth stages, specific adaptive practices, and comparative assessment of the same. The detailed profile of the selected study areas is presented below.

Construction of the Tool

To gather primary data on the climate change adaptation strategies of marginalised farmers, a specially designed interview schedule was developed. This comprehensive tool consists of four key sections: socio-economic profile of respondents, their perceptions of climate variability, observed impact of climate change during critical agricultural stages (sowing, crop growth, harvesting, and livestock management), and adaptation strategies employed. Each section includes carefully crafted questions with response options based on a Likert scale to facilitate the collection of quantitative data. This approach ensures the data is robust, comparable, and suitable for drawing meaningful conclusions about climate change effects on vulnerable farming communities.

Pilot Study

Before implementing the tool in the field survey, its effectiveness was evaluated through a pilot study conducted with marginalised farmers from nearby villages in Chandrapur district. Feedback from these participants was carefully reviewed, and necessary modifications were made to ensure the tool was clear, comprehensive, yet concise. These revisions aimed to enable farmers to respond easily without confusion, while still ensuring the collection of essential quantitative data for the study.

Sampling Locations Identification

The study was conducted in the states of Maharashtra and Rajasthan. The selection is based on the “Vulnerability of Indian Agriculture to Climate Change (2071–2098)” as assessed by the Atlas on the Vulnerability of Indian Agriculture. This classification divides districts into five vulnerability categories, ranging from very high to low. Maharashtra and Rajasthan have 12 and 25 districts, respectively, in the very high vulnerability category. These states represent regions with the greatest climate risks. Maharashtra’s diverse cropping system ranges from water-intensive sugarcane to drought-prone soybean, while Rajasthan’s arid climate with scanty rainfall underscores the need to assess climate impacts on marginalised farmers.

In Maharashtra, sampling districts were selected based on dominant crops: Chandrapur (paddy), Amravati, Wardha, and Yeotmal (cotton), and Beed, Latur, Osmanabad, and Parbhani (pulses). In Rajasthan, Alwar and Jhunjhunu districts, known for wheat, mustard, and barley cultivation, were chosen for the study.

Sample Population Identification

Climate change is expected to significantly impact agriculture, with marginalised farmers - those holding < 1 ha (<2.5 acres) of agricultural land - being particularly vulnerable due to their limited resources and reliance on agriculture and livestock. To assess their perceptions of climate change, its impacts on crops and livestock, and the adaptation measures they adopt, this group was purposively selected as the study’s sample population. Additionally, only farmers engaged in agriculture as their primary occupation for more than 15 years were included. From the two selected states, 10 sub-districts across 10 districts and 29 villages were chosen for the study. A total of 280 farmers participated, with the detailed distribution of sample locations and demographics presented in Table 2. Although efforts were made to include both male and female farmers, field constraints limited the participation of female respondents.

Table 2: Sampling design and sample population distribution

State	District	Sub-district	Sampling location	Male	Female	SC	ST	OBC	NT	General	Total
Maharashtra	Chandrapur	Chandrapur	Mamla	9	1	2	-	7	1	-	10
			Nimbada	14	-	6	-	5	3	-	14
			Borda	9	-	4	1	2	2	-	9
			Pimpalkhuta	7	-	-	3	4		-	7
			Lohara	6	1	-	5	1	1	-	7
			Nandgur	11	-	3	8	-	-	-	11
			Walni	12	-	2	10	-	-	-	12
Maharashtra	Wardha	Seloo	Sindhi Railway	4	-	-	-	4	-	-	4
			Palegaonbai	6	1	4	2	1	-	-	7
			Pimpra	7	2	7	-	1	1	-	9
	Yavatmal	Ghatanji	Nukti	13	1	3	3	7	1	-	14
			Murli	9	-	1	2	5	1	-	9
	Amravati	Bhatkuli	Bhatkuli	4	-	1	2	1	-	-	4
			Sayat	18	-	9	1	7	1	-	18
Maharashtra	Osmanabad	Bhoom	Bhongiri	14	-	-	-	9	1	4	14
			Songiri	9	-	-	-	6	-	3	9
	Beed	Wadwani	Vahegaon	17	2	6	-	-	-	13	19
			Hivargaon		1	-	-	-	-	-	1
			Pusra	4	-	-	-	-	-	4	4
	Parbhani	Jintur	Mathla	14	-	-	-	4	-	10	14
			Panjri	9	1	-	-	6	-	4	10
	Latur	Renapur	Kalewadi	12	1	-	-	11	-	2	13
			Kalegaon	6	-	-	-	1	-	5	6
			Renapur	5	-	-	-	-	-	5	5
Rajasthan	Alwar	Bansur	Chatarpura	10	-	1	1	8	-	-	10
			Girudi	10	-	8	2	-	-	-	10
			Gyanpura	5	-	1	1	2	-	1	5
	Jhunjhunu	Nawalgarh	Jhajhar	11	-	4	2	4	-	1	11
			Parsrampura	13	1	6	2	6	-	-	14

Field Survey

Field investigations were conducted at the selected sampling locations. Upon arrival in each village, the village head was consulted to identify marginalised farmers meeting the study's inclusion criteria. Identified farmers were informed about the study's purpose and assured of confidentiality regarding their responses. One-on-one interviews were conducted, with the questionnaire explained in the local languages - Marathi and Hindi - to ensure accurate and clear responses. Research assistants recorded the responses to minimise errors. Additionally, Focus Group Discussions were held during fieldwork to gather collective insights. Photographs were also taken to document and support the study findings.

Data Analysis

The data collected from marginalised farmers were quantitative and analysed according to the major crops cultivated - paddy, cotton, pulses, wheat, mustard, and barley. Since these crops are grown across diverse regions within the selected states, each experiencing different climatic conditions, variations in farmers' perceptions, impact, and adaptation strategies were expected. To facilitate comparison and enhance clarity, the data were processed and presented as percentages.

Statistical Methods Used

Data analysis for the study was carried out with the help of various statistical tools. This includes Microsoft Excel, SPSS, and OriginPro.

Results and Discussion

Sample Population Profile

This study focused on marginalised farmers (landholding <1 ha) cultivating key crops - paddy, cotton, pulses, wheat, mustard, and barley - in Maharashtra and Rajasthan. The sample population profile is presented in Table 3. The majority of paddy cultivating farmers were male 97%, with female participation limited due to field constraints. Paddy farmers are mainly engaged in rainfed cultivation (90%) with limited irrigation (10%), relying heavily on family labour, especially spouses. Most (73%) lived in nuclear families, with 36% illiterate and only 4% possessing soil health cards. Cell phone usage was low, with 57% not using phones.

Table 3: Sample population profile

Characteristic	**Crops**			
	Paddy	**Cotton**	**Pulses**	**Wheat, Mustard, Barley**
Gender				
a) Male	97	94	95	98
b) Female	3	6	5	2
Education				
a) Illiterate	36	14	25	30
b) Primary	30	34	23	6
c) Middle School	9	13	20	22
d) High School	13	21	13	26
e) Secondary	10	6	12	10
f) Graduate and Above	3	11	11	6
Land ownership				
a) Own land	93	99	98	90
b) On lease	4	-	-	4
c) Both	3	1	2	6
Agriculture type				
a) Rainfed	90	70	91	52
b) Irrigated	10	30	9	48
Cell phone use				
a) Yes	43	57	63	36
b) No	57	43	34	64
If Yes, phone type				
a) Feature phone	34	44	55	24
b) Smartphone	9	13	8	12
Social group				
a) SCs	24	37	6	40
b) STs	39	13	-	16
c) OBC	27	43	40	40
d) Others	10	7	53	4

Values are presented in percentages

A high proportion of farmers depend primarily on agriculture as their main source of livelihood, with limited supplementary income opportunities. The educational attainment of respondents is generally low to moderate, which may affect their access to formal climate information services and advanced agricultural technologies. However, experiential knowledge plays a significant role in farm decision-making. In terms of irrigation access, the table shows that a considerable number of farmers rely on rainfed agriculture, particularly in cotton and pulse-growing areas. Only a smaller segment has access to assured irrigation facilities, mainly in wheat–mustard–barley systems. This disparity in water access directly impacts adaptation choices and crop selection. Institutional support indicators such as access to credit, crop insurance, and extension services appear limited among respondents. Many farmers depend on informal credit sources and local advisory networks rather than formal institutions.

The table highlights the vulnerability context within which adaptation decisions are made. The predominance of small landholdings, rain dependence, and limited institutional access underscores the need for targeted policy interventions to enhance resilience among marginalised farming communities.

Farmers' Willingness for Climate Change Adaptation

Among the crops studied, the highest willingness to adopt climate-resilient strategies was observed among cotton growers, with 90% expressing readiness to implement adaptation measures (Table 4). This was closely followed by paddy cultivators (89%), pulse growers (77%), and farmers cultivating wheat, mustard, and barley, who showed a comparatively lower combined adaptation willingness of 68%. It is also noteworthy that a segment of the farming population remained uncertain about climate change and the need for adaptation, indicating potential gaps in awareness or limited access to relevant information.

Further disaggregation of the data by crop growth stages provides additional insights into farmers' adaptation behaviour. Among paddy cultivators, willingness to adopt adaptation measures was highest during the harvest stage (94%), followed by the crop growth stage (89%), irrigation stage (79%), and post-harvest operations (70%). In the case of cotton, farmers demonstrated the greatest willingness during the irrigation stage (83%), followed by the harvest stage (73%) and the sowing stage (67%). For pulse, the harvest stage (88%) again emerged as the most critical point for adaptation, with notable willingness reported for irrigation (80%), post-harvest activities (78%), and crop growth (77%). In contrast, farmers cultivating wheat, mustard, and barley indicated their strongest willingness to adapt during the irrigation stage (78%), while substantially lower willingness was observed for seed change (44%).

Overall, the table demonstrates that adaptation strategies are closely linked to agro-climatic conditions and socio-economic capacity. The variation across crops reinforces the argument that climate adaptation policies must be crop-specific, resource-sensitive, and regionally tailored rather than uniform in design.

Table 4: Marginalised farmers' willingness for adaptation to climate change

Crop	**Paddy**	**Cotton**	**Pulses**	**Wheat, Mustard, Barley**
Ready for the adaptation to cope with climate change				
Yes	89	90	77	68
No	-	-	4	4
Not sure	11	10	19	28
Willingness for adaptation during				
Sowing	64	67	71	24
Crop growth	89	51	77	18
Harvest	94	73	88	28
Post-harvest	70	36	78	24
Irrigation	79	83	80	78
Seed change	60	34	41	44

Values are presented in percentages

Climate Change Adaptation Strategies Comparison

The climate change adaptation options preferred by marginalised farmers, as presented in Table 5, varied according to crop type and farmers' perceptions of climate change impacts on crop performance. Across all crop groups, high-yielding varieties were consistently identified as the most important adaptation strategy, with a 100% response rate among all crops considered.

For paddy cultivation, the leading adaptation strategies included high-yielding varieties (100%), crop diversification (93%), and support from non-governmental organisations (89%). Cotton growers primarily prioritised high-yielding varieties (100%) and early-maturing crop varieties (60%) as key adaptation measures. In the case of pulse, farmers reported a strong preference for high-yielding varieties (100%), drought-resistant crop varieties (100%), and water storage methods (96%). Meanwhile, farmers cultivating wheat, mustard, and barley indicated a broader set of adaptation strategies, including high-yielding varieties (100%), drought-resistant crop varieties (100%), crop and livestock diversification (82%), and early-maturing crop varieties (76%).

Overall, the table reveals that adaptation strategies are not static but evolve with crop growth stages. It confirms that farmers strategically respond to climatic stress at different production phases, emphasising the need for stage-specific advisory services and crop-sensitive policy interventions.

Table 5: Marginalised farmers' climate change adaptation options

Crop / Adaptation options	Paddy	Cotton	Pulses	Wheat, Mustard, Barley
Drought-resistant crop varieties	9	46	100	100
Crop diversification	93	37	83	82
Livestock diversification	46	9	68	82
Early maturing crop varieties	36	60	59	76
High-yielding varieties	100	100	100	100
Irrigating crops	69	49	16	8
Organic manure	43	53	27	52
Water use change	64	30	45	50
Water storage method	60	-	96	58
Food storage	53	-	26	36
Assistance from relatives	21	-	-	16
Assistance from NGO	89	-	20	6
Livestock rearing & Fattening	24	-	27	44
Organic seeds	-	-	27	4
Mulching	-	27	76	42

Values are presented in percentages

Fig. 5: Hierarchical cluster analysis of climate change adaptation strategies

Figure 5 presents the hierarchical cluster analysis of climate change adaptation strategies based on similarity in their adoption patterns across crop growth stages. The dendrogram indicates five major clusters, reflecting distinct but interrelated adaptation pathways followed by marginalised farmers. The first cluster deals with a productivity-oriented strategy. This is the most prominent cluster, which consists of the use of high-yielding varieties (100% adoption across crops). Its isolated yet dominant position in the dendrogram indicates universal acceptance and central importance. This suggests that farmers prioritise yield security as the primary response to climate variability. The second cluster deals with climate-resilient crop strategy, which includes drought-resistant varieties.

The third cluster is associated with the diversification strategies, which include crop diversification and livestock diversification clusters together, indicating a risk-spreading mechanism. Farmers adopting one diversification strategy are more likely to adopt another, reflecting livelihood resilience thinking. The water management strategies are the fourth cluster, which deals with irrigation, and water use change. This highlights the critical role of water management in climate adaptation, especially in rainfed regions. The fifth cluster is associated with the resource-conserving practices. This includes the use of organic manure, suggesting that soil moisture conservation and sustainable nutrient management are often adopted together.

Overall, the clustering pattern reveals that farmers adopt adaptation strategies in functional bundles rather than in isolation. The prominence of productivity and water-related clusters underscores the centrality of yield stability and moisture management in climate resilience planning.

The findings of the study highlight the differentiated nature of climate change adaptation among marginalised farmers across diverse agro-climatic regions of Maharashtra and Rajasthan. The findings clearly demonstrate that adaptation is neither uniform nor random; rather, it is shaped by crop type, growth stage sensitivity, local climatic stressors, and resource accessibility. The predominance of rainfed agriculture in several districts significantly influences adaptation choices, particularly for cotton and pulse growers who rely heavily on monsoon performance. In contrast, farmers cultivating wheat–mustard–barley systems exhibit relatively higher adoption of irrigation-based coping strategies, reflecting differences in infrastructure access and seasonal water availability.

The crop-stage-specific analysis offers an important insight: adaptation strategies are dynamic and vary from sowing to maturity. For example, adjustments in sowing dates and seed selection are more prominent during the initial stages, while irrigation management and input intensification become critical during vegetative and reproductive phases. This stage-wise variability reinforces the argument that generalised adaptation policies are inadequate for small and marginal farmers.

Socio-economic constraints - limited landholding size, restricted access to institutional credit, and dependence on informal knowledge systems - also shape adaptation behaviour. Farmers tend to prefer low-cost, locally accessible strategies such as crop diversification, mixed cropping, and traditional water conservation techniques. These practices reflect adaptive resilience built through experiential learning rather than formal extension mechanisms.

The comparative inter-state findings further suggest that regional climatic variability and policy environments influence adaptive capacity. Differences in extension outreach, irrigation infrastructure, and state-level agricultural schemes contribute to varied adaptation intensities.

Overall, the study underscores the need for crop-specific, region-sensitive, and stage-based adaptation frameworks. Strengthening institutional support, enhancing climate information services, and promoting inclusive agricultural policies will be essential to build long-term resilience among marginalised farming communities under increasing climatic uncertainty.

Fadina and Barjolle (2018) reported that Benin farmers adopted many strategies in response to climate change, which include crop diversification, mulching, organic fertiliser, use of improved varieties, chemical fertiliser and pesticides, agro-forestry, perennial plantation, and diversification. Wheat-growing farmers have implemented several strategies, with a greater propensity to modify the dates of sowing (61%), crop varieties (54%), irrigation systems (49%), and fertiliser kinds (44%), according to Mirgol *et al*. (2025). Improved cultivars, altered planting dates, and intensive inputs (fertilisers) were among the adaptation strategies used by 87% of the farmers. Issues, including the high cost of agricultural inputs and restricted finance availability, hindered farmers' adoption of adaptation measures (Teklay *et al*., 2025). Crop diversification, drought-tolerant crops, drip irrigation, micro-catchment rainwater gathering, and animal diversification are all economically feasible approaches in light of the changing climate, according to Sewando (2025).

Conclusion

The findings from this study underscore that adaptation to climate change is strongly influenced by crop type and the growth stage at which climatic stresses are most acutely felt. High-yielding and drought-resistant crop varieties have emerged as the most universally adopted strategies across all crop types, reflecting farmers' emphasis on ensuring productivity under changing climatic conditions. Other adaptation strategies, such as crop diversification, water management, and early maturing varieties, were selected based on specific vulnerabilities associated with each crop. This crop-specific understanding of adaptation willingness and preferences provides valuable insights for designing targeted climate-resilient agricultural interventions and extension services, particularly aimed at supporting marginalised farmers in vulnerable regions, thus paving the way for sustainable agriculture, leveraging sustainable livelihood.

Acknowledgement

This study was carried out with the funding support provided by the Indian Council of Social Science Research (ICSSR), New Delhi, India, under the Impactful Policy Research in Social Sciences (IMPRESS) scheme (IMPRESS/P759/280/SC/2018-19/ICSSR). The author is grateful to ICSSR for this purpose.

References

Birthal, P.S. and Hazrana, M. (2019). Crop diversification and resilience of agriculture to climatic shocks: Evidence from India. *Agricultural Systems*, 173: 345-354.

Census of India (2011). District Census Handbook. Government of India.

Dev, S.M. (2012). Smallholder farmers in India: Challenges and opportunities. *Economic and Political Weekly*, 47(23): 36–43.

Dow, K.*et al*., (2013) Vulnerability to climate change in India. *Climatic Change*, 116(2): 263–274.

Economic Survey (2016–2017). Ministry of Finance, Government of India. Retrieved from https://www.indiabudget.gov.in/economicsurvey/

Easterling, W. E.*et al*., (2007). Food, fibre and forest products. In Climate Change 2007: Impacts, Adaptation and Vulnerability. Cambridge University Press.

Fadina, A. and Barjolle, D. (2018). Farmers' adaptation strategies to climate change and their implications in the Zou department of South Benin. *Environments*, 5: Article No. 15. https://doi.org/10.3390/environments5010015

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the IPCC. Geneva, Switzerland.

Jayaraman, T. and Murari, K. (2014). Social inequality and vulnerability in Indian agriculture. *Development Policy Review*, 32(5): 567–583.

Knox, J., Hess, T., Daccache, A. and Wheeler, T. (2012) Climate change impacts on crop productivity in Africa and South Asia. *Environmental Research Letters*, 7(3): 034032.

Krishna Kumar, K., Sahai, A.K., Nanjundiah, R.S. and Rastogi, D. (2011). Climate change projections for India. *Current Science*, 101(3): 340–350.

KVK (Krishi Vigyan Kendra) (2016). District agricultural profile–Alwar. ICAR.

Ministry of Agriculture and Farmers Welfare. (2019). All India report on agriculture census 2015–16 (Phase I). Government of India. https://agcensus.nic.in

Mirgol, E., Dieppois, B., Northey, J., Eden, J., Jarlan, L., Khabba, S., Le Page, M. and Mahe, G. (2025).

Understanding wheat farmers' climate change adaptation in the Middle East and North Africa: The role of socioeconomic factors and perceptions in decision-making. *Journal of Agriculture and Food Research*, 23: 102290. https://doi.org/10.1016/j.jafr.2025.102290

Paroda, R.S. and Kumar, P. (2000). Impact of climate change on agriculture and food security. Indian Council of Agricultural Research.

Rama Rao, K. V., Reddy, S.K. and Ramesh, T. (2016). Climate change: Impacts and adaptation strategies for Indian agriculture. *Journal of Agrometeorology*, 18(2): 75–84.

Ryan, J. and Spencer, D. (2001). Climate change and agriculture in the semi-arid tropics. *Global Environmental Change*, 11(4): 361–367.

Sewando, P.T. (2025). Climate-proofing agriculture: Economic feasibility of adaptation strategies for agro-pastoral farmers in Tanzania. *Climate Services*, 39: 100600. https://doi.org/10.1016/j.cliser.2025.100600

Shirsath, P.B., Mudalkar, S. and Lamaddala, N. (2017). Vulnerability of Indian agriculture to climate change and adaptation strategies. *Agricultural Economics Research Review*, 30(2): 119–126.

Singh, P., Kumar, S. and Singh, R. (2017). Assessment of climate change impacts on Indian agriculture: Methodological issues and future research directions. *Journal of Environmental Management*, 197: 255–266.

Teklay, A., Ayalew, A., Abate, A., Ashenafi, M., Marye, A.T., Tilahun, A., Bayabil, H.K., Kassa, A., Birara, H., Gurebiyaw, K. and Sisay, K. (2025). Climate change perceptions and adaptation responses among smallholder farmers across three locations in Megech Watershed, Ethiopia. *Climate Services*, 38: 100566. https://doi.org/10.1016/j.cliser.2025.100566

Walker, T. and Ryan, J. (1990). Village and household economies in India's semi-arid tropics. Johns Hopkins University Press.

World Bank (2013). Turn down the heat: Climate extremes, regional impacts, and the case for resilience. World Bank Publications.