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Evaluation of Climate Change Vulnerability and Adaptive Capacity among Turmeric Farmers in Mizoram

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Abstract

This research was conducted during the year August, 2022 to March, 2023 in Mizoram, located in the North Eastern Himalayan region of India, focusing on two districts–Lunglei (a high turmeric producing district) and Mamit (a lower-producing one). To measure livelihood vulnerability, the study applied the Intergovernmental Panel on Climate Change Vulnerability Index (IPCC-VI), and a cost-benefit analysis was used to evaluate adaptation measures. Farming communities in the Himalayan hills and mountains faced heightened risks from climate change due to their distinct environmental and socioeconomic conditions. Understanding the extent of this vulnerability and implementing effective adaptation strategies was essential to minimize adverse impact, as farmers with stronger adaptive capacity were generally better prepared to handle climate-related challenges. Data were gathered from 334 turmeric farmers. The results showed that majority of sampled households (over 90%) in both districts perceived an increase in temperatures during both summer and winter. Similarly, most respondents observed a decrease in rainfall in their areas. Lunglei district had a higher vulnerability index (0.68) compared to Mamit (0.52), due to greater climate exposure, higher sensitivity, and lower adaptive capacity. Adaptive capacity of Mamit was calculated to be higher (0.62) than Lunglei (0.52). In order to reduce the vulnerability to climate variability, majority of the farmers adopted different strategies including cultivate smaller area than usual, change in harvesting time, change in crop cultivar and change in sowing time. The findings highlighted the importance of reducing household sensitivity and strengthening adaptive capacity to effectively manage vulnerability to climate change.

Keywords: Climate change, vulnerability, adaptive capacity, turmeric

1. Introduction

Agricultural production is under threat due to climate change in food insecure regions, especially in Asian countries. (Muhammad et al., 2022). Climate change represents one of the most pressing and intricate environmental challenges faced globally, posing a significant threat to agriculture and, more specifically, to food security (Rao et al., 2016). Among those most at risk are smallholder farmers, particularly in developing nations, due to their limited resources and high dependence on agriculture (Lindoso et al., 2012). Climate change is anticipated to intensify the occurrence of pests and diseases, escalate the frequency and severity of extreme weather events such as droughts and floods, and increase the risks of reduced crop yields, crop failures, and livestock losses (Morton, 2007). Given the strong link between agricultural output and the livelihoods of smallholder farmers, any decline in productivity directly amplifies their vulnerability.

The North-Eastern Region (NER) of India, especially Mizoram, remains relatively underdeveloped but is characterized by a range of agro-climatic zones and challenging mountainous terrain. These features make the region particularly susceptible to climate-induced stresses (Sahoo et al., 2018). Observations from past studies have shown clear signs of climate change in Mizoram, with noticeable impacts on both farming systems and livelihood strategies. Long-term rainfall data reveal significant fluctuations in seasonal and monthly patterns across the state. Moreover, projections indicate a sharp rise (around 26%) in extreme rainfall events annually, accompanied by a steady increase in humidity levels over recent decades (Anonymous, 2016).

In light of these developments, it is evident that climate change will play a pivotal role in shaping the future of global food security. While agriculture is highly vulnerable to climate impacts, it is also a key contributor to climate change (Ahmad et al., 2011). Therefore, evaluating the vulnerability and adaptive capacity of agricultural systems and rural livelihoods in Mizoram is essential for informed development planning and the implementation of effective climate resilience strategies.

Turmeric is a key cash crop in the North Eastern Region (NER) of India, contributing approximately 8.30% to the country's overall turmeric production. In terms of cultivated area, it ranks as the third most important crop in the region. Despite its significance, the productivity of turmeric in the NER remains low at 1.5 t ha^{-1}, compared to the national average of 3.9 t ha^{-1} (Amulya et al., 2024). Mizoram leads the region in both area and production of turmeric, followed by Meghalaya and Manipur. On a global scale, India is not only the top producer and consumer of turmeric but also the largest exporter (Singh et al., 2020).

The Intergovernmental Panel on Climate Change (Anonymous, 2007) describes adaptation as the process of making changes in natural or human systems in response to actual or anticipated climatic impacts, aimed at minimizing harm or taking advantage of beneficial effects. While many farmers understand the long-term implications of climate change, a significant number are hesitant to adopt adaptation measures due to uncertainty about immediate outcomes. One of the main challenges is that climate adaptation cannot follow a universal approach - strategies and farmer responses differ widely depending on the agro-ecological and socioeconomic conditions of each area (Berry et al., 2006; Adger et al., 2009). Adapting to climate change helped reduce feelings of vulnerability and mitigated risks to agricultural practices (Arbuckle et al., 2013).

2. Materials and Methods

This research was conducted during the year August, 2022 to March, 2023 in Mizoram, located in the North Eastern Himalayan region of India, focusing on two districts - Lunglei (a high turmeric-producing district) and Mamit (a lower-producing one).

2.1. Study sites

Mizoram state was selected purposively as it was the largest producer of turmeric in the NE region of India. Out of the eleven districts in Mizoram, Lunglei and Mamit were the two districts selected from the higher and the lower producing districts, respectively. Two blocks namely, West Bungmun and Lungsen were selected from Lunglei district and one block namely, Reiek was selected from Mamit district making a total of three blocks from the state. From each of the selected block, cluster of villages which were known for cultivation of turmeric were selected.

2.2. *Method of data collection*

The primary data was collected by conventional survey method on a well-structured schedule through personal interview covering various climate related factors affecting turmeric cultivation during the year 2022–23. Stratified proportionate random sampling without replacement method was used for the final selection of samples. At first, turmeric growers were enlisted in each of the selected villages. Then the farmers with 10 or more years of experience in turmeric cultivation were identified which made the sampling frame. Accordingly, 20% of turmeric growers from each block were randomly selected. The total population size was 342 in Lungsen block, 301 in West Bunghmun block and 1031 in Reiek block from which a sample of 69, 60 and 205 households was selected. This gave rise to a total sample of 334 households from the state.

2.3. *Livelihood vulnerability assessment*

In the current study, Intergovernmental Panel on Climate change-Vulnerability Index (IPCC-VI) was used to assess the livelihood vulnerability. Hahn et al., (2009) developed an alternative method for calculating the vulnerability index that incorporates the IPCC vulnerability definition (Table 1).

Table 1: Organization of the seven major components in the VI-IPCC framework

IPCC contributing factors to vulnerability	Major components
Exposure	Climate variability
Sensitivity	Water Food Health
Adaptive capacity	Socio-demographic profile Livelihood strategies Social networks

The measurements of various indicators and their hypothesized relationship with contributing factors and vulnerability, presented in Table 2.

IPCC-VI uses a simple approach of applying equal weights to all major components. Each of the sub-components was measured on a different scale; therefore, it was first necessary to standardize them for comparability. Equation for standardization indicator was directly proportional to the contributing factor

Index $S_d=(S_d-S_{min})/(S_{max}-S_{min})$

Equation for standardization when indicator was indirectly proportional to the contributing factor

Index $S_d=(S_{max}-S_d)/(S_{max}-S_{min})$

Where,

S_d = Original sub-component for the district

S_{max} and S_{min} = Maximum and minimum values reflecting low

Table 2: Measurement of indicators used to study exposure, sensitivity and adaptive capacity

Contributing factor	Indicators	Unit	Relation with contributing factor	Relation with vulnerability
Exposure	Summer temperature	No change-0 Increased-1	+	+
	Winter temperature	No change-0 Increased-1	+	+
	Rainfall quantity	No change-0 Decreased-1	+	+
	Change in timing of arrival of rainfall	No change-0 Early/ late-1	+	+
	Unexpected rainfall	No change-0 Increased-1	+	+
	Rainfall duration	No change-0 Increased/ decreased-1	+	+
	Other climatic variation	No change-0 Increased-1	+	+
Sensitivity	Chronic illness	No-0, Yes-1	+	+
	Water conflict	No-0, Yes-1	+	+
	Natural sources are primary water source	No-0, Yes-1	+	+
	Water insufficiency	No-0, Yes-1	+	+
	Crop diversification	Index	-	-
	Land holding	Ha	-	-
	Yield	Kg/ha	-	-
	Access to irrigation	No-0, Yes-1	-	-
	Households getting food from own farm/ family farm	No-0, Yes-1	-	-
Adaptive capacity	Dependency ratio	Number of family members over earners	-	+
	Dwelling structure	Non climate resilient-0, Climate resilient–1	+	-
	Education	Illiterate-0, Literate-1	+	-
	Changed cropping sequence	No-0, Yes-1	+	-
	Changed variety	No-0, Yes-1	+	-
	Net farm returns	Rs.	+	-
	Household cultivating in smaller area than usual	No-0, Yes-1	-	+
	Access to loan	No-0, Yes-1	+	-
	Do you use mobile phone for communication	No-0, Yes-1	+	-
	Association with any organization	No-0, Yes-1	+	-
	Distance of main market from the household	in kms	-	+
	No. of animals rearing	Number	+	-

and high vulnerability, respectively.

An index for each major component of vulnerability was created by averaging the standardized sub-components which are related to it:

$M_d = (\sum^n_{i=1} \text{index } S_{di})/n$

Where,

M_d=Major component for the district

S_{di}=Sub-components

The major components were first combined according to the categorization scheme in Table 2 and then contributing characters were calculated using the following equation.

$CF_d = (\sum^n_{i=1} W_{mi} M_{di})/(\sum^n_{i=1} W_{mi})$

Where,

CF_d=IPCC defined contributing factor (exposure, sensitivity, or adaptive capacity) for the district.

n=Number of major components in each contributing factor

W_{mi}=Weight of each major component

W_{mi} was determined by the number of sub-components that made up each major component and were included to ensure that all sub-components contributed equally to the overall VI-IPCC.

Once exposure, sensitivity and adaptive capacity were calculated, the three contributing factors were combined using the following equation:

$VI_h = (e_h + s_h) - a_h$

Vulnerability index was obtained for each district by taking the average of household vulnerability index (Table 3).

Table 3: Categorization of vulnerability levels

Index value (i)	Sensitivity/ Adaptive capacity/ Vulnerability
0.00 ≤ i ≤ 0.30	Low
0.31 ≤ i ≤ 0.50	Medium
0.51 ≤ i ≤ 0.70	High
0.00 ≤ i ≤ 1.00	Very high

Where VI_h was the LVI for the district expressed using the IPCC vulnerability framework, e_h was the calculated exposure score (equivalent to the climate variability major component), a_h was the calculated adaptive capacity score (weighted average of the socio-demographic, livelihood strategies, and social networks major components), and s_h was the calculated sensitivity score (weighted average of the health, food, and water major components) (Hahn et al., 2009).

2.4. Effectiveness of adaptation measures

Cost-benefit analysis (CBA) was used for the present study. In CBA, all the benefits and costs of the adaptation were expressed in monetary term and the aggregate costs and benefits were compared (Table 4).

Table 4: Partial budgeting technique

Cost	Revenue
Added cost	Reduced cost
Reduced revenue	Added revenue
Total cost	Total revenue
	Net benefit: total cost – total revenue

3. Results and Discussion

3.1. Livelihood vulnerability indicators and their values for turmeric growers

The descriptive statistics for the three contributing factors of vulnerability i.e., exposure, sensitivity and adaptation capacity, presented in Table 5. Majority of the sampled households (>90%) perceived the rise in summer as well as winter temperature in both the districts. Similarly, most of them felt that the amount of rainfall has declined in their areas. They also reported change in the arrival time of rainfall in these districts with response being higher in Lunglei (96.12%) than in Mamit (87.32%). The same was true for unexpected excess rainfall as well. The result is in line with that of Dileepkumar et al. (2018) who reported an increase in temperature along the west coast of India. This temperature rise is attributed to anthropogenic fators such as greenhouse gas emissions, aerosol forcing, and alterations in land use and land cover, as further supported by Krishnan and Ramanathan (2002).

It was found that households of both the districts had good primary health facility. About 24.81% of the households of Lunglei district were found taking care of at least one chronically ill member of the family compared to 20.98% in Mamit district. Harvesting rain water during the monsoon season for the domestic use was found to be common in both the districts. Dependency of households on natural water resources during the non-monsoon seasons was observed to be slightly higher in Lunglei than in Mamit. About 56.59% of the households of Lunglei district reported that there was water insufficiency for domestic usage compared to 47.32% households of Mamit district. As a result, conflicts on water were reported more in Lunglei district (27.91%) than in Mamit district (18.05%). Majority of the respondent households cooked their food items using crops grown at their own farms. The average land holding household^{-1} was also slightly higher in Mamit (1.68 ha) than in Lunglei (1.46 ha). Yield of turmeric was calculated to be significantly higher in Mamit (10,339 kg ha^{-1}) compared to Lunglei district (7806 kg ha^{-1}).

Each of the earning members of a household took care of two dependent members in both the districts. The dwelling structure of about 45.74% sampled households was found to be kutcha in Lunglei compared to 41.95% of the households in Mamit district. Majority of the household heads were found to be literates, the frequency being higher in Mamit (98.05%)

Table 5: Measurement of livelihood vulnerability indicators and their values for turmeric growers of Mizoram

Contributing factor	Indicators	Unit	Lunglei	Mamit
Exposure	Summer temperature	No change-0 Increased-1	93.80	94.63
	Winter temperature	No change-0 Increased-1	92.25	91.22
	Rainfall quantity	No change-0 Decreased-1	89.92	89.76
	Change in timing of arrival of rainfall	No change-0 Early/ late-1	96.12	87.32
	Unexpected rainfall	No change-0 Increased-1	91.47	87.32
	Rainfall duration	No change-0 Increased/ decreased-1	89.92	86.34
	Other climatic variation	No change-0 Increased-1	10.08	8.78
Sensitivity	Chronic illness	No-0, Yes-1	24.81	20.98
	Water conflict	No-0, Yes-1	27.91	18.05
	Natural sources are primary water source	No-0, Yes-1	10.85	7.32
	Water insufficiency	No-0, Yes-1	56.59	47.32
	Crop diversification	Index	5.81	7.59
	Land holding	Ha	1.46	1.68
	Yield	kg ha^{-1}	7805.58	10339.09
	Access to irrigation	No-0, Yes-1	0.00	0.00
	Households getting food from own farm/ family farm	No-0, Yes-1	93.02	93.17
Adaptive capacity	Dependency ratio	Number of family members over earners	3.04	1.91
	Dwelling structure	Non climate resilient-0, Climate resilient-1	54.26	58.05
	Education	Illiterate-0, Literate-1	90.70	98.05
	Changed cropping sequence	No-0, Yes-1	21.71	30.24
	Changed variety	No-0, Yes-1	18.60	24.88
	Net farm returns	Rs	47233	59831
	Household cultivating in smaller area than usual	No-0, Yes-1	48.84	15.12
	Access to loan	No-0, Yes-1	19.38	24.39
	Do you use mobile phone for communication	No-0, Yes-1	88.37	93.66
	Association with any organization	No-0, Yes-1	87.60	88.29
	Distance of main market from the household	in kms	11.72	37.77
	No. of animals rearing	Number	5.13	7.62

than in Lunglei (90.70%). Changing cropping or sowing schedule as a coping strategy was relatively more common in Mamit district (30.24%) than in Lunglei district (21.71%). They cultivated Lakadong, RC-1, RT-1 and local cultivars of turmeric. About 24.88% of the sampled households in Mamit reported changing cultivars compared to 18.60% in Lunglei district. About 24.39% and 19.38% of the households in Mamit and Lunglei availed loans and the facility of banking was found to be well established in Reiek, Buarpui and Tlabung. However, SHG's were found to be active in all the selected villages of two districts. The farmers of Lunglei district did not have proper marketing facility for turmeric. Though in Lungsen block one FPC was active, the farmers were not satisfied with its services hence the turmeric cultivation was perceived to be unprofitable. Because of these reasons about 48.84% of the sampled households in Lunglei reported cultivating turmeric in smaller area than usual. Usage of mobile phone was observed to be slightly high in Mamit (93.66%) than in Lunglei (88.37%). The average net farm return for the household was calculated to be higher in Mamit (₹ 59,831) than in Lunglei (₹ 47,233).

Nearly 88% of the households of both the districts found associated with FPC or SHGs. The sampled households of Mamit district sold their farm produce at Aizawl. Households of Lungsen and West Bunghmun block were found to be dependent on Tlabung and Lunglei, respectively. The average distance of nearby main market from the sampled households of Mamit was 36 km and for Lunglei district, it was 12 km.

The index values of exposure, sensitivity and adaptive captive capacity of two districts were represented using radar diagram in Figure 1. Lunglei was found to be the slightly more exposed district to climatic change (0.81) than Mamit (0.77) district. About 91.47% of the households of Lunglei and about 86.34% of the households in Mamit district were found to be 'very highly' exposed to climate change (Table 6). Similarly, Lunglei (0.39) was also turned out to be marginally more sensitive district than Mamit (0.37). Less than 2% of the households in Lunglei and Mamit were found to be 'very highly' sensitive. Much of the households of both the districts were classified to be under 'medium' sensitive category compared to 'highly' sensitive category and relatively more number of households fell under these two categories in Lunglei than in Mamit.

Adaptive capacity of Mamit was calculated to be higher (0.62) than Lunglei (0.52). Significantly more number of households of Mamit fell under 'very high' category compared to Lunglei

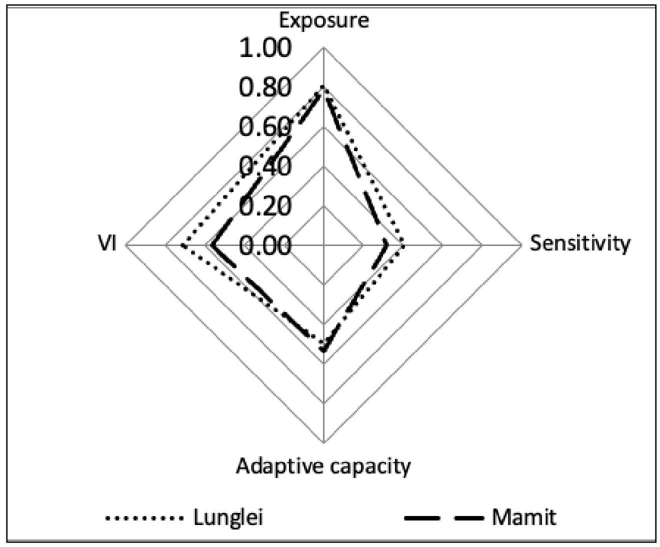

Figure 1: Index values for different sub-components and vulnerability across two districts of Mizoram

(1.55%). The overall vulnerability index of Lunglei was significantly higher (0.68) compared to Mamit district (0.52). Relatively more number of households of Lunglei (31.22%) fell under 'high' category compared to Mamit (22.48%). Majority of the households of both the districts were classified under 'medium' vulnerable category (Table 6).

3.2. *Adaptation strategies and their costs and benefits*

In order to reduce the vulnerability to climate variability majority of the farmers (62.28%) have undergone different changes in turmeric farming (Table 7). About 28.14% of the farmers cultivate smaller area than usual, followed by change in harvesting time (26.95%), change in crop cultivar (22.46%), and change in sowing time (9.58%). About 37.72% of them did not take up any changes in turmeric farming to reduce vulnerability to climate variability.

A study conducted by Tripathi and Mishra (2016) reported that the farmers were changing their agricultural practices (adaptation strategies) without concrete knowledge about the climate variability and extreme climatic events. The changes included changing sowing and harvesting timing, cultivation of crops of short duration varieties, intercropping, changing cropping pattern, investment in irrigation and agro-forestry. Agrawal et al. (2014) also reported that logging bunds, tree planting, agricultural intensification, protected areas, zoning

Table 6: Distribution of households (%) across exposure, sensitivity, adaptive capacity and vulnerability categories in Mizoram

Category	Exposure		Sensitivity		Adaptive capacity		Vulnerability	
	Lunglei	Mamit	Lunglei	Mamit	Lunglei	Mamit	Lunglei	Mamit
Very high	91.47	86.34	1.55	1.95	1.55	22.93	6.98	9.27
High	8.53	12.68	11.63	7.80	61.24	62.44	22.48	31.22
Medium	0.00	0.98	63.57	60.49	34.11	14.63	37.21	42.44
Low	0.00	0.00	23.26	29.76	3.10	0.00	33.33	17.07

Table 7: Adaptation strategies followed by turmeric farmers

Particulars	Percent	Five years back	Three years back	Two years back	Last year	Current year
No change	37.72					
Cultivate smaller area than usual	28.14	8.51	43.62	24.47	15.96	7.45
Change in crop cultivar	22.46	49.33	42.67	8.00		
Change in sowing time	9.58	28.13	62.50	9.38		
Change in harvesting time	26.95	6.67	63.33	30.00		

(for land use), supply networks and agriculture/ forest policy were among the agriculture-forest landscape interventions associated to the mitigation and adaptation of climate change.

The total increased cost and reduced returns was highest for mixed cropping, followed by crop diversification, and change in cultivars (Table 8). The additional returns and reduced costs also followed the same trend. The net change was positive for all the adaptation measures. The highest net change was for change in cultivar (₹ 5563 ha^{-1}), followed by mixed cropping and crop diversification. It was important to note that mixed cropping and crop diversification were change in overall farming not specific to turmeric.

Table 8: Cost and benefit of adaptation measures in Mizoram

Sl. No.	Particulars	Total increased cost and reduced returns (₹ ha^{-1})	Total reduced costs and increased returns (₹ ha^{-1})	Net change in income (₹ ha^{-1})
1.	Change in cultivar	4607.25	10170.11	5562.87
2.	Mixed cropping	9099.00	13064.70	3965.69
3.	Crop diver-sification	8366.57	11528.50	3161.97

4. Conclusion

In Mizoram, vulnerability of Lunglei district was significantly higher (0.68) compared to Mamit district (0.52) as the district was relatively more exposed and sensitive to climatic factors and the adaptive capacity was also lower than Mamit. Reducing sensitivity and improving adaptive capacity of the households was the key to cope up with household vulnerability to climate change.

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