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Mapping Climatic Vulnerability in Cauvery Delta Region of Tamil Nadu

Susmitha K., Velmurugan D., Sita Devi K., Babu S.

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ABSTRACT

Climatic vulnerability is an emerging concept for understanding the impacts of climate change and its policy implications. It refers to the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes. Climate change significantly impacts agriculture, causing damage to crop productivity, food security, and economic stability. In India, about 80% of the population resides in highly vulnerable districts. The southern part of India is particularly susceptible to extreme climate events. This study attempts to map the vulnerability of the Cauvery Delta Region in Tamil Nadu using the Composite Vulnerability Index (CVI) and to classify districts into categories ranging from highly vulnerable to least vulnerable. The results of the study identify district as the most vulnerable, Cuddalore with a CVI of 0.65, followed by Nagapattinam (CVI: 0.52), Thiruvarur (CVI: 0.49), Perambalur (CVI: 0.44), Ariyalur (0.36). Pudukkottai and Tiruchirappalli (CVI: 0.34 each) and Thanjavur (CVI: 0.32) are categorized as less vulnerable districts. This classification is crucial for planning effective remedial measures to mitigate the impacts of climate change and enhance the resilience of the region.

Keywords Climate change, Vulnerability, Cauvery delta region, Composite Vulnerability Index, Mapping.

INTRODUCTION

Climatic vulnerability is an emerging concept for climate change impact and for policy implications. It is intrinsically linked to the variability and trends of key climate variables such as temperature, precipitation, humidity, and wind patterns. These variables influence the exposure and sensitivity of systems, regions, and population to climate risks. For instance, increasing temperatures, shifting rainfall patterns, and intensified extreme weather events directly impact water availability, agricultural yields, and ecosystem stability (IPCC 2014).

Analyzing climate vulnerability through the lens of climate variables provides a quantitative and spatially explicit understanding of risk. For example, regions experiencing higher variability in rainfall coupled with rising temperatures may face heightened vulnerability due to their dependence on rainfed agriculture and limited adaptive capacity. Similarly, coastal zones subjected to increased frequency of cyclones and sea-level rise are disproportionately ex-

Susmitha K.[1]*, Velmurugan D.[2], Sita Devi K.[3], Babu S.[4]

[2,4]Associate Professor, [3]Professor
[1,2,3]Department of Agricultural Economics, Annamalai University, Chidambaram 608002, India

[4]Department of Agronomy, Agricultural College and Research Institute, Vazhavachanur, Thiruvannamalai, India

Email: susmithakanagaraj2510@gmail.com
*Corresponding author

posed to the compounded effects of climate variables (Mall *et al.* 2006).

The integration of climate variables into vulnerability assessments allows for the identification of hotspots with exposure and sensitivity converge at low adaptive capacity. Understanding the trends and anomalies in climate variables, such as reduced monsoon precipitation or prolonged heatwaves, helps in framing adaptive strategies to mitigate vulnerability (Krishnan *et al.* 2020).

The southern part of India, including regions like Tamil Nadu, Kerala, Karnataka, and Andhra Pradesh, is highly vulnerable to extreme climate events due to a combination of geographic, climatic, and socio-economic factors. This region heavily relies on the Northeast and Southwest monsoons for rainfall. However, shifting monsoon patterns, increasing rainfall intensity, and prolonged dry spells have exacerbated the frequency of floods and droughts. Tamil Nadu, for instance, has experienced erratic rainfall trends, leading to both water scarcity and flooding (Krishnan *et al.* 2020).

It is crucial to inform farmers in advance about climate change risks and assist policymakers in developing effective adaptation strategies to mitigate its impacts (Varadan and Kumar 2015). This is possible by mapping of vulnerability. So, in this, an attempt to mapping the climate vulnerability in Cauvery Delta Region of Tamil Nadu and classify the districts from less vulnerable to highly vulnerable districts.

MATERIALS AND METHODS

Study area

The Cauvery Delta region, often referred to as the 'Rice Bowl of Tamil Nadu,' is one of the most agriculturally fertile and significant areas in South India. It encompasses seven districts: Thanjavur, Thiruvarur, Nagapattinam, Mayiladuthurai and parts of Trichy, Perambalur, Ariyalur, Cuddalore, and Pudukottai. Located in the lower reaches of the Cauvery River basin, the region plays a crucial role in Tamil Nadu's agricultural economy, food security, rural livelihoods, and cultural heritage. Covering approximately 1.4 million hectares of agricultural land, the delta's eastern boundary meets the Bay of Bengal.

Table 1. Variables contributing to climate vulnerability.

Sl. No.	Variables	Unit of measurement
1	Annual rainfall	Millimeter
2	Minimum temperature (ºC)	Celsius
3	Maximum temperature (ºC)	Celsius
4	Relative humidity (%)	Percentage

Data collection

District-level data on climate variables, including rainfall, temperature, and relative humidity, were collected from the Statistical Handbooks of the respective districts in the Cauvery Delta region of Tamil Nadu. Mayiladuthurai district, which was bifurcated in December 2020, is not considered as a separate district in this study.

Tools of analysis

Methodology for calculating composite vulnerability index

Climate Vulnerability of Cauvery Delta Composite Vulnerability Index has been analyzed using the Composite Vulnerability Index as used in previous studies (Palanisami *et al.* 2009).

Selection of climate vulnerability indicators

The assessment begins with the selection of suitable indicators that contribute to climate vulnerability. For this study, the following variables are considered.

The indicators listed in the Table 1 are chosen for their relevance in assessing climatic changes in the Cauvery Delta Region (CDR).

Data normalization

The variables are measured in different units, necessitating standardization to a uniform scale between 0 and 1. The following formula is used for normalization:

$$V_{Ij} \frac{(X_{ij} - \text{Min } X)}{(\text{Max } X_i - \text{Min } X_i)}$$

Where,
V_{ij}: Standardized value for the i[th] variable in the j[th] district.
X_{ij}: Original value of the i[th] variable in the j[th] district.
Min X_i: Minimum value of the i[th] variable across all districts.
Max X_i: Maximum value of the i[th] variable across all districts.

Assignment of weights

The weights for each variable are calculated based on their variability. Variables with higher variability are assigned lower weights to ensure balance in the index. The weight (w_i) for the i[th] variable is determined using:

$$w_i = \frac{k}{\sqrt{\text{var}(y_i)}}$$

Where,
Var (y_i): Variance of the i[th] variable.
k: Normalization constant calculated as:

$$k = \left| \sum_{i=1}^{n} \frac{1}{\sqrt{\text{var}(y_i)}} \right|^{-1}$$

This ensures that the sum of weights equals 1.

Calculation of composite vulnerability index

The composite vulnerability index for each district is calculated as a weighted sum of the normalized values of the indicators:

$$Index = \frac{\sum_{i=1}^{n} X_i w_i}{\sum_{i-1}^{j} w_i}$$

Where,
X_i: Normalized value of the i[th] variable.
W_i: Weight assigned to the i[th] variable

Table 2. Categorization of vulnerability.

Sl. No.	Category	Ranges
1	Highly Vulnerable	Index value >(Mean +0.5 SD)
2	Moderately Vulnerable	(Mean -0.5 SD) < Index value < (Mean +0.5 SD)
3	Least Vulnerable	Index value < (Mean -0.5 SD)

Categorization of vulnerability

The computed vulnerability index is used to classify the districts into three categories based on the distribution of the index values (Balaganesh *et al.* 2020, Sendhil *et al.* 2018). Different Categories of vulnerability classified are listed in the Table 2.

Where,
Mean: Mean of the composite index values across all districts.
SD: Standard deviation of the composite index values.

This study utilizes Quantum Geographic Information System (QGIS), an open-source Geographic Information System (GIS) software, to map vulnerabilities in the Cauvery Delta region.

RESULTS AND DISCUSSION

The vulnerability index for all eight delta districts were constructed using the methodology described earlier. Based on these index value, the districts were ranked (Table 3).

Cuddalore ranks first and Thanjavur at the last, others in between. The vulnerability indices were analyzed further to categorize the districts according

Table 3. Vulnerability index and ranks for the Delta districts of Tamil Nadu.

Sl. No.	Districts	CVI	Rank
1	Thanjavur	0.32	VII
2	Thiruvarur	0.49	III
3	Cuddalore	0.65	I
4	Tirchy	0.34	VI
5	Nagapattinam	0.52	II
6	Perambalur	0.44	IV
7	Puttukottai	0.34	VI
8	Ariyalur	0.36	V

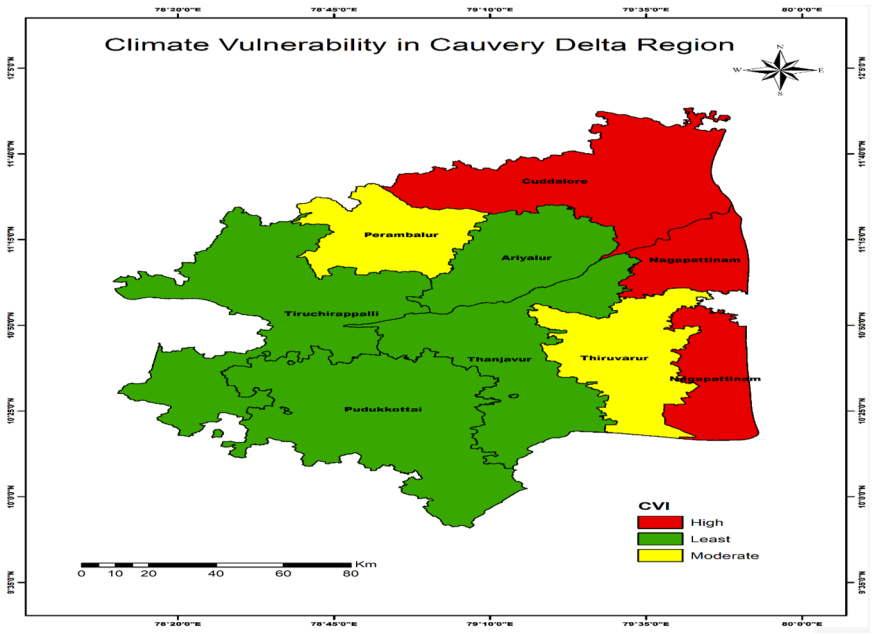

Fig. 1. Mapping climatic vulnerability in Cauvery Delta region.

Table 4. Classification of Delta districts in terms of vulnerability.

Sl. No.	Classification	Districts
1	Less vulnerable	Thanjavur, Tirchy, Puttukottai, Ariyalur
2	Moderately vulnerable	Thiruvarur, Perambalur
3	Highly vulnerable	Cuddalore, Naggapattinam .

to the distribution of the composite index values (Table 4).

Cuddalore and Nagapattinam are categorized as highly vulnerable, with vulnerability indices of 0.65 and 0.52, respectively. Thiruvarur and Perambalur districts fall under the moderately vulnerable category, with indices of 0.49 and 0.44, respectively. Ariyalur, Puttukottai, Tiruchirappalli, and Thanjavur are categorized as less vulnerable, with indices of 0.36, 0.34 and 0.32, respectively. The classifications discussed above are visually represented using QGIS (Fig. 1).

The red color indicates the highly vulnerable districts within the Cauvery Delta Zone (CDZ), the yellow color represents districts with moderate vulnerability, and the green color denotes districts with low vulnerability in the zone.

CONCLUSION

The study highlights the critical disparities in climatic vulnerability across the Cauvery Delta Region of Tamil Nadu by employing the Composite Vulnerability Index (CVI). The findings reveal that districts like Nagapattinam and Cuddalore, are highly vulnerable whereas Thiruvarur and Perambalur are moderately vulnerable, while others such as Pudukkottai, Tiruchirappalli, and Thanjavur are less vulnerable. This classification is crucial for planning effective remedial measures to mitigate the impacts of climate change and enhance the resilience of the region and serves as a valuable tool for policymakers and stakeholders to identify priority areas and devise region-specific strategies.

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