Biological Forum – An International Journal **14(1): 411-415(2022)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Measuring Vulnerability Index to Climate Change: A Case of Tamil Nadu

Bharath D.[1*], Velusamy R.[2], Amarnath J.S.[3] and Sivasankari B.[4]

[1]Ph.D. Scholar, Department of Agricultural Extension & Rural Sociology, AC&RI, Madurai, (Tamil Nadu), India.
[2]Professor, Department of Agricultural Extension & Rural Sociology, AC&RI, Madurai, (Tamil Nadu), India.
[3]Professor, Department of Agricultural Economics, AC&RI, Madurai, (Tamil Nadu), India.
[4]Associate Professor, Department of Agricultural Economics, AC&RI, Madurai, (Tamil Nadu), India.

(Corresponding author: Bharath D.)*
(Received 19 October 2021, Accepted 17 December, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Index is an indicator or measurement of something. The word 'index' is a statistical measure of change in a representative set of individual data points. These numbers can come from various of sources, prices, productivity and employment. The term index has various meanings. For our purpose, it is a numerical scale computed from a collection of indicators chosen by the researcher for each district and used to compare them to one another or to some reference point. Climate change is a contentious issue right now. Vulnerability is an exposure of individuals or collective groups to livelihood stress as a result of the impacts of such environmental change. Objective of this research is to develop the vulnerability index to climate change. The study implemented the vulnerability method according to Iyengar and Sudarshan to evaluate vulnerability for 04 various components. The various sectors according to the different indicators are used to progress a hierarchy of vulnerability classification. The study conducted to evaluate the vulnerability of selected districts in Tamil Nadu by constructing the vulnerability indices during a year. As per Iyenger and Sudarshan's projections the primary contributor for the overall vulnerability of the climate change is agricultural sector. The different degrees of vulnerability of the districts are classified and provided in this study.

Keywords: Index, Vulnerability, Measurement, Climate change, Indicator.

INTRODUCTION

Climate change and agriculture are inherently tied in numerous ways, as climate change is the primary cause of biotic and abiotic pressures, both of which have negative consequences for a region's agriculture (Raza *et al.,* 2019). Where, perennial crop production is sensitive to temperature, water availability, solar radiation, air pollution and CO_2. The quantity as well as the quality of the harvested product determine the value of perennial horticulture crops. Perennial crop cultivation is difficult to relocate when a region's climate changes owing to a variety of socio-economic issues such as extended re-establishment times, proximity to processing factories, labour availability and market accessibility (Glenn *et al*., 2014). In quantitative social science research, indexes are extremely important because they allow a researcher to generate a composite measure that summarizes responses to numerous rank-ordered related questions or statements. This composite measure provides the researcher with information regarding a study participant's perspective on a certain belief, attitude or experience. An index is constructed simply by accumulating the scores assigned to individual items (Crossman, 2020). IPCC conceives vulnerability as degree of a system which liable and incompetent to cope with, adverse effects of climate variability and extremes (Parry *et al.,* 2007). Vulnerability is defined as an internal risk factor of a subject or system exposed to a hazard that corresponds to the subject's or system's intrinsic inclination to be impacted or exposed to damage (Cardona, 2003). Vulnerability is the destruction from exposure to stresses connected with environmental and social change with absence of dimensions to adapt (Adger, 2006). It describes a community's physical, economic, and social susceptibility to destruction in the event of hazardous natural or manmade circumstances (Emrich and Cutter, 2011). The purpose of the present paper is to assessing the highly vulnerable area among the designated districts with selected indicators. Climate change is a vulnerability phenomenon influenced several indicators, thus it's important to quantify the vulnerability index for Tamil Nadu's different districts. Totally 8 districts have been selected (Coimbatore, Dharmapuri, Krishnagiri, Salem, Ariyalur, Cuddalore, Thanjavur and Pudukkottai). The principal crops are coconut, mango, arecanut and cashewnut. The important and major available indicators were designated from 2011 decade. It contributes to the discussion on vulnerability measurement by contrasting a narrow focus on economic or environmental vulnerability with a multi-dimensional approach to assessing districts.

METHODOLOGY

The data pertaining to various indicators (population, literacy rate, rainfall, food grains, livestock population etc.,) were gathered from various sources, *viz*., Department of Economics and Statistics, Tamil Nadu and Department of Horticulture, Tamil Nadu. The meteorological data were collected from the Regional meteorological centre, Chennai. Hence though vulnerability index has been calculated by two methods (With weights and Without weights). For finding the vulnerability index (Without weights) Normalisation and Simple average of scores are used and for assessing index (With weights) Iyenger and Sudarshan's method were used (Iyenger and Sudarshan 1982). The list of possible indicators is provided in Table 1.

Table 1: Vulnerability Indicators for Climate Change.

Sr. No.	Components	Indicators
1.	Demographic	a. Density of population (persons per sq.km)
		b. Literacy rate (per cent)
2.	Climatic	a. Variance of annual rainfall (mm^2)
		b. Variance of Southwest monsoon (mm^2)
		c. Variance of minimum temperature (°C^2)
		d. Variance of maximum temperature (°C^2)
3.	Agricultural	a. Total food grains (Kg/ha)
		b. Productivity of coconut (Kg/ha)
		c. Productivity of mango (Kg/ha)
		d. Productivity of arecanut (Kg/ha)
		e. Productivity of cashewnut (Kg/ha)
		f. Cropping intensity (per cent)
		g. Irrigation intensity (per cent)
		h. Forest area (per cent to geographic area)
		i. Total food crops (per cent)
		j. Total non-food crops (per cent)
		k. Net sown area (hectares)
		l. Livestock population (number per hectare of gross cropped area)
4.	Occupational	a. Total main workers (per hectare of net area sown)
		b. Number of cultivators (per hectare of net area sown)
		c. Agricultural labourers (per hectare of net sown area)
		d. Industrial workers (per hectare of net sown area)
		e. Marginal workers (per hectare of net sown area)
		f. Non-workers (per hectare of net sown area)

Construction of Vulnerability Index (Without weights)

There are various steps involved for developing an index. The first step is to choose a research area, which may be divided into numerous areas. For each of the four components of vulnerability, a set of indicators is chosen in each region. Vulnerability is dynamic over time; it is important that all the indicators for the particular year.

Arrangement of Data

The collected data were organised into a rectangular matrix for each component of vulnerability, were rows and columns indicate districts and indicators respectively. Let's assume there are M as districts and K as indicators. Let X_{ij} represent the value of the indicator j for area i.

Normalisation of Indicators

$$x_{ij} = \frac{x_{ij} - M_{in}\{X_{ij}\}}{\text{Max}\{X_{ij}\} - \text{Min}\{X_{ij}\}}$$

Vulnerability and the normalization were evaluated using the formula, the scores will lie between 0 and 1. The value 1 indicates maximum and 0 indicates minimum.

Iyenger and Sudarshan's Method for Construction of Vulnerability Index

The index was developed using the Iyenger and Sudarshan's method. It helps to rank the districts in terms of economic performance, using a technique for calculating a composite index from multivariate data. This method is statistically relevant and could also be used to construct a composite index of climate change vulnerability. All the 24 indicators were used to develop a vulnerability index for the year 2018 in the selected districts of Tamil Nadu, based on data availability. Based on 24 indicators 2 for demographic vulnerability, 4 for climatic vulnerability, 12 in agricultural vulnerability, and the remaining 6 were occupational vulnerability component.

A brief methodology is given below. It is assumed that M as regions/districts, K as indicators of vulnerability and x_{ij}, i= 1, 2, ….M; j=1, 2, ….k are the normalized scores.

The level of development of i-th zone, $\overline{y_1}$ is assumed to be a linear sum x_{ij} is

$$\bar{y}_1 = \sum_{j=1}^{k} w_j x_{ij}$$

Where $w's$ ($0<w<1$ and $\Sigma^k_{j=1} w_j=1$) are the weights. The weights are assumed to vary inversely as the variance over the areas in the corresponding indicators of vulnerability in Iyenger & Sudarshan's method . That is, the weight w_j is determined by

$$w_j = c/ \sqrt{var(x_{ij})}$$

where c is a normalizing constant such that

$c= [\Sigma^k_{j=1} 1/ \sqrt{var(x_{ij})}]^{-1}$

The choice of the weights would ensure that large variation of the indicators have disproportionately dominate the contribution of the rest of the indicators and distort inter regional comparisons. The vulnerability index lies between 0 and 1, were 1 indicating maximum and 0 indicating no vulnerability at all.

For classification, a simple ranking of the distics based on the indices viz., $\overline{y_i}$ would be enough. However, characterization of the different stages of vulnerability, suitable fractile classification from an assumed probability distribution is required. A probability distribution which is suitable for this purpose is the Beta distribution, which is generally skewed and takes values in the interval (0,1) as followed by Iyengar and Sudarshan (1982) has been applied. This distribution has the probability density given by

$$f(z) = \frac{za-1(1-z)b-1}{\beta(a,b)}, 0 < z < 1 \text{ and } a, b>0$$

where $\beta(a, b)$ is the beta function defined by

$$\beta(a, b) = \int x^{a-1} (1-x)^{b-1} dx$$

Parameters a and b of the distribution can be estimated by Iyengar and Sudharshan method (or) by using software packages. The Beta distribution is skewed. Let $(0, z_1)$, (z_1, z_2), (z_2, z_2), (z_3, z_4) and $(z_4,1)$ be the linear intervals such that each interval has the same probability weight of 20 per cent. These fractile intervals can be used to describe the various stages of vulnerability.

1. Less vulnerable if $0 < \overline{y_i} < z_1$
2. Moderately vulnerable if $z_1 < \overline{y_i} < z_2$
3. Vulnerable if $z_2 < \overline{y_i} < z_3$
4. Highly vulnerable if $z_3 < \overline{y_i} < z_4$
5. Very highly vulnerable if $z_4 < \overline{y_i} < 1$

RESULTS AND DISCUSSION

Vulnerability is frequently reflected in the economic situation and socio-economic features of the people who live there. The result of its exposure (to the external difficulty that causes vulnerability), sensitivity of the outcome to the external stressor and adaptive capability in dealing with the stressor's negative influence on the entity's outcome. The results of vulnerability indices for selected districts of Tamil Nadu (Coimbatore, Dharmapuri, Krishnagiri, Salem, Ariyalur, Cuddalore, Thanjavur and Pudukkottai) for the year 2018 are presented. The vulnerability index was created in order to capture a wider range of vulnerability. This was accomplished by including a number of indicators that provided as proxies for assessing various components of vulnerability. The four major specific components of vulnerability were taken. It included the demographic factors, climatic factors, agricultural factors and occupational factors. The final worked indicators for the districts data are shown in Table 2 & 3.

Table 2: Vulnerability indices for year 2018 normalized score-without weights.

Districts	Density of Population	Literacy Rate	Variance of Annual Rainfall	Variance of SW Monsoon	Variance of Minimum Temperature	Variance of Maximum Temperature	Food Grains
Coimbatore	1	1	0.134	0.007	0	0	0.127
Dharmapuri	0	0	0	0	0.31	0.277	0
Krishnagiri	0.08	0.188	0.09	0.002	1	1	0.589
Salem	0.906	0.279	0.169	0.005	0.308	0.277	0.118
Ariyalur	0.136	0.181	0.352	0.006	0.612	0.779	1
Cuddalore	**0.931**	**0.616**	**1**	**1**	**0.604**	**0.983**	**0.824**
Thanjavur	0.934	0.915	0.129	0.094	0.612	0.779	0.838
Pudukkottai	0.032	0.564	0.225	0.146	0.612	0.779	0.107

Districts	Productivity of Coconut	Productivity of Arecanut	Productivity of Mango	Productivity of Cashewnut	Cropping Intensity	Irrigation Intensity	Forest area
Coimbatore	0.615	1	0.128	0.84	0.043	0	0.025
Dharmapuri	0.797	0.954	0.223	0	0.043	0	0.314
Krishnagiri	0	0.541	1	2	0.574	0.586	1
Salem	0.473	0.008	0	0.88	0.652	0.673	0.604
Ariyalur	0.002	0	0.443	0.88	0.228	0.521	0
Cuddalore	**1**	**0.833**	**0.445**	**0.76**	**0.898**	**0.76**	**0.005**
Thanjavur	0.697	0.091	0.443	1	1	1	0.015
Pudukkottai	0.467	0.833	0.443	0.24	0	0.021	0.118

Districts	Food crops	Non-food crops	Net sown area	Livestock population	Main workers	Cultivators	Agrl. Labourers
Coimbatore	0	1	0.616	1	1	0	0
Dharmapuri	1.166	0.207	0.459	0.446	0.251	0.689	0.361
Krishnagiri	0.813	0.186	0.648	0.542	0.241	0.705	0.134
Salem	0.725	0.273	0.865	0.43	0.875	0.651	0.789
Ariyalur	0.812	0.182	0	0.025	0	0.403	0.512
Cuddalore	**1**	**0**	**1**	**0**	**0.169**	**0.232**	**0.983**
Thanjavur	0.819	0.18	0.757	0.006	0.276	0.178	0.747
Pudukkottai	0.804	0.195	0.215	0.445	0.421	1	1

Districts	Industrial workers	Marginal workers	Non-workers	Sum of scores	Vulnerability index	Rank
Coimbatore	0.416	0.071	1	10.02	0.417	6
Dharmapuri	0.138	1	0.153	7.78	0.325	8
Krishnagiri	0.166	0.122	0.258	12.46	0.519	2
Salem	1	0	0.698	11.65	0.485	4
Ariyalur	0	0.326	0	7.40	0.308	7
Cuddalore	**0.208**	**0.908**	**0.38**	**15.53**	**0.647**	**1**
Thanjavur	0.236	0.081	0.52	12.34	0.514	3
Pudukkottai	0.152	0.346	0.438	9.60	0.400	5

Table 3: Vulnerability indices for year 2018- with weights.

Districts	Vulnerability index
Coimbatore	0.316
Dharmapuri	0.245
Krishnagiri	0.393
Salem	0.368
Ariyalur	0.233
Cuddalore	**0.461**
Thanjavur	0.389
Pudukkottai	0.303

The fractile intervals were used to characterise the different stages of vulnerability as shown below:

0.2<0.233≤0.4-Ariyalur
0.2<0.245≤0.4-Dharmapuri
0.2<0.303≤0.4-Pudukkottai
0.2<0.316≤0.4-Coimbatore
0.2<0.368≤0.4-Salem
0.2<0.389≤0.4-Thanjavur
0.2<0.393≤0.4-Krishnagiri
0.4<0.461≤0.6-Cuddalore

As results shown in Table 2 and 3 among the districts, Cuddalore district ranked in first position in the overall vulnerability of climate change, followed by Krishnagiri and Thanjavur district. These might be due to the agricultural and occupational indicators were the major factors contributing respectively. The Ariyalur district were the least vulnerable, followed by Dharmapuri. Agricultural and occupational played a predominant role for the ranking in cuddalore district at the first position.

CONCLUSION

Vulnerability differs significantly across regions, it is recognised that "even within regions, impacts, adaptive capacity and vulnerability will vary and the Tamil Nadu state of cuddalore district is no exemption to this. District wise results reveal the primary contributor for the overall vulnerability of the climate change is agricultural sector. Because the agricultural sector has the largest impact, investments in research capacity adaptation are needed, notably in the creation of climate proof crops (drought resistant and heat tolerance types) that can withstand a broad variety of climatic circumstances. Vulnerability index was developed by using Iyenger and Sudarshan's method and it led to find most vulnerable area among these districts.

Acknowledgement. I hereby convey my sincere thanks to University Grants Commission for funding me to carry out my research work for my entire completion of study.
Conflict of Interest. None.

REFERENCES

Adger, W. N. (2006). Vulnerability. Global Environmental Change, *16*(3): 268–281.

Cardona, O. D. (2003). The need for rethinking the concepts of vulnerability and risk from a holistic perspective: a necessary review and criticism for effective risk management. Mapping vulnerability: Disasters, development and people, pp.17.

Crossman, Ashley (2020). The Differences Between Indexes and Scales. Thought Co, thoughtco.com/indexes-and-scales-3026544.

Emrich, C. T., and Cutter, S. L. (2011). Social vulnerability to climate sensitive hazards in the southern United States. Weather, *Climate, and Society, 3*(3): 193-208.

Glenn, M., Kim, S. H., Ramirez-Villegas, J., and Laderach, P. (2014). Response of Perennial Horticultural Crops to Climate Change. In: Janick J, ed. Horticultural Reviews Vol. *41*. Hoboken, USA: Wiley-Blackwell. p. 47-130.

Iyenger, N. S. and P. Sudarshan (1982), "A Method of Classifying Regions from Multivariate Data", Economic and Political Weekly, Special Article, pp. 2048-2052.

Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J. and Hanson, C. E. (2007). IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Raza, A., Razzaq, A., Mehmood, S. S., Zou, X., Zhang, X., Lv, Y., and Xu, J. (2019). Impact of Climate Change on Crops Adaptation and Strategies to Tackle Its Outcome: A Review. *Plants (Basel, Switzerland)*, *8*(2), 34.

How to cite this article: Bharath D., Velusamy R., Amarnath J.S. and Sivasankari B. (2022). Measuring Vulnerability Index to Climate Change: A Case of Tamil Nadu. *Biological Forum – An International Journal*, *14*(1): 411-415.