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Current status and mapping of districts for agricultural vulnerability to climatic change in Maharashtra

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Abstract

Vulnerability of a system is determined not only by the severity of climate change but also by the system's own sensitivity and adaptive capacity to cope with new change in climatic condition. This study while examining the agricultural vulnerability of Maharashtra State in India to climate change, tries to improve upon the vulnerability assessment methodology. It chooses the district level data on climate and socio-economic indicators to compute potential impact and vulnerability index, conceptualized as a combination of crop production loss, sensitivity, exposure and adaptive capacity index. Kumar *et al*. (2016) method was adopted for estimating crop production loss. In order to determine the net effect of climate variations, both area and yield were first de-trended using a linear model. The normalized indicators are assigned weights based on inverse of variance in each district with respect to the State. The weighted component indicators are then aggregated into a single index. In addition this study also categorizes the districts beyond ranking to have a meaningful characterization of the different stages of vulnerability. The present study found 7 out of 34 districts were highly vulnerable to the changing climatic conditions with Sindhudurg, Thane and Palghar having the highest degree of vulnerability. It reveals the fact that all districts in an agro climatic zone does not fall under the same category of vulnerability which exemplifies the need for the State to prioritize research and development issues and effective decision making through "Location-Performance-Vulnerability" based adaptation strategies.

Keywords: Climate change, Vulnerability, Agriculture, Performance indicator

Introduction

Numerous studies on socioeconomic vulnerability to climate change employ diverse methodologies and indicators. Regional assessments often follow the IPCC approach, with modifications for local contexts. Brenkert and Malone (2005) [2] used the Vulnerability-Resilience Indicator Prototype, adapted for Indian dietary customs and freshwater data, finding nine states somewhat resilient. Das (2013) [4] examined regional vulnerability in Indian agriculture, producing a Socio-Economic Vulnerability Index based on indicators like irrigation strength and poverty.

Focused on city-level vulnerability, categorizing indicators into infrastructure, technology, finance, social, and space. Studied Mumbai's fishing communities, revealing vulnerability due to resource limitations. Ayanlade *et al.* (2018) explored rainfall variability in African agro-climatic zones, while assessed agrarian vulnerability in Maharashtra. Developed a socio-economic vulnerability index, and found drought impacting household nutrition. Studied farmers' perceptions in Bundelkhand. mapped drought-related climate change in Tamil Nadu, revealing varying vulnerability across districts.

Materials and Methods

Data sources: Time series data on crop acreage, production, productivity, gross cropped area, and economic indicators are sourced from government publications, including the Statistical Abstract of Maharashtra State, Epitomes of Agriculture in Maharashtra, and Socio-economic Review. District-level daily average rainfall data spanning 40 years (1980 to 2021) is collected from 'Solar Radiation Data (SoDa)3 - Solar energy services for professionals' online web services.

The choice of vulnerability indicators

Exposure indicators

Trends in *kharif, rabi and zaid* rainfall
Trends in *kharif, rabi and zaid* relative humidity
Trends in *kharif, rabi and zaid* maximum temperature.
Trends in *kharif, rabi and zaid* minimum temperature.

Sensitivity indicators

Average size of operational holdings for marginal farmers (%)
Average size of operational holdings for small farmers (%)
Density of population (Number)
Percent of gross irrigated area to gross cropped area
Net Sown Area (ha)
Urbanization (%)
Average size of holding (ha)
Percentage of main workers to the total population (%)
Total bovine population (Per ha.)
Cropping intensity (%)

Percent of small and marginal farmers

Crop Production Loss
Total cereal production loss
Total pulses production loss
Total oilseeds production loss
Total cash crops production
Total fruits and vegetables production loss.

Adaptive capacity indicators and their relationships
Forest area to the geographical area
FERT/"00" ha GCA
Number of tractors
No. of markets/ "00" GCA
Road density
Electric pump
Rural electrification
Literacy (%)

Arrangement of data
Data for sector-wise and composite vulnerability, with M districts and K indicators, are organized in a rectangular matrix. Each row represents a region, and each column represents an indicator, denoted as Xij for the value of indicator j in region i.

Table 1: Indicator

Region/ District	Indicator					
	1	2	.	J	.	K
1	X_{11}	X_{12}	.	X_{1j}	.	X_{1K}
2	.	.	.	.	.	.
.	.	.	.	.	.	.
I	X_{i1}	X_{i2}	.	X_{ij}	.	X_{iK}
.	.	.	.	.	.	.
M	X_{M1}	X_{M2}	.	X_{Mj}	.	X_{MK}

Normalisation of indicators / variables
The methodology developed by Anand and Sen (1994) for calculation of Human Development Index and used by UNDPs for preparation of Human Development Index report (HDI) for the year 2006 was used to normalise the indicators. The normalised indicators were laid in between 0 to 1. Formulae to normalise the variable having positive and negative functional relationship with vulnerability are as follows:

For positive functional relation

$$Y_{ij} = \frac{X_{ij} - Min\,(X_{ij})}{max(X_{ij}) - min\,(X_{ij})}$$

For negative functional relation

$$Y_{ij} = \frac{Max(X_{ij}) - (X_{ij})}{max(X_{ij}) - min\,(X_{ij})}$$

The value 1 corresponds to that region with maximum vulnerability and 0 correspond to the region with minimum vulnerability.

Construction of Vulnerability Index (Unequal Weight)
After normalising the indicators, the weights are assumed to vary inversely as the variance over the regions/districts in the respective indicators of vulnerability. That is, the weight w_j is determined by

$$w_j = c \Big/ \sqrt{\underset{i}{\operatorname{var}}\left(x_{ij}\right)}$$

Where c is a normalizing constant such that

$$c = \left[\sum_{j=1}^{j=K} 1 \Big/ \sqrt{\underset{i}{\operatorname{var}}\left(x_{ij}\right)} \right]^{-1}.$$

The vulnerability index so computed was laid between 0 and 1. A value of one indicated maximum vulnerability and zero indicated no vulnerability at all.

Aggregation of component indices
Potential Impact (PIi) - Exposure i+ Sensitivity i + Crop production loss i

AVIi = (Exposure + Sensitivity + (1 - Adaptive capacity)

Ranking of districts
The calculated vulnerability indices were used to rank the different districts in terms of vulnerability. A district with highest index is said to be most vulnerable and it was given the rank 1, the district with next highest index was assigned rank 2 and so on.

Classification of districts
For classificatory purpose, a simple ranking of the districts based on their respective index would be enough. However for a meaningful characterization of different stages of vulnerability, suitable fractile classification from an assumed distribution is needed (Palanisami *et al*. 2010) [13]. Beta distribution, a continuous probability distribution is suitable for this purpose. It is generally skewed and takes values in the interval (0, 1), parameterized by two shape parameters, denoted by α and β (Iyengar and Sudarshan 1982) [9].

Mapping of Districts
With the help of Q-GIS, spatial data for each of the variables was processed to create a set of single-factor maps. Based on the map, The vulnerability of each area will be assessed and locate several high risk areas to low risk areas (1 to 0). Identifying the risks in each case and associating them with a specific region will be useful for decision makers.

Results and Discussion

District wise exposure index in Maharashtra

Exposure scores calculated from 1980 to 2020 indicate Palghar with the highest (0.5657) and Latur with the lowest (0.2936) exposure in Maharashtra. Thane, Raigad, Sindhudurg, and Nashik are most vulnerable due to increased kharif rainfall, relative humidity, and temperatures, mainly in the coastal region. Conversely, districts like Amaravati, Gadchiroli, Yavatmal, and others in central Maharashtra and Vidarbha exhibit lower exposure due to consistent climatic conditions.

Table 2: District wise exposure index in Maharashtra

S. No.	Districts	Exposure Index
1.	Palghar	0.5657
2.	Nashik	0.5377
3.	Thane	0.5244
4.	Raigad	0.5187
5.	Sindhudurg	0.5032

District wise sensitivity index in Maharashtra

In Maharashtra's district-level sensitivity index (Table 2), Yavatmal (0.1388) ranks least sensitive, attributed to a higher proportion of main workers and larger average size of holdings. Thane (0.2878) tops as highly sensitive due to increased urbanization and population density. Raigad, Kolhapur, Palghar, Sindhudurg, and Bandhara are identified as most vulnerable due to a higher percentage of small and marginal farmers. Conversely, Latur, Beed, Parbhani, Solapur, Osmanabad, Ahmednagar, and Yavatmal are deemed least vulnerable, characterized by larger net sown areas and cropping intensity.

Table 3: District wise sensitivity index in Maharashtra

S. No.	Districts	Sensitivity index
1.	Thane	0.2878
2.	Raigad	0.2531
3.	Kolhapur	0.2389
4.	Palghar	0.2381
5.	Sindhudurg	0.2358

District wise crop production loss index in Maharashtra

Jalna tops district-level crop production loss (0.1051), with significant losses in cereals and pulses. Palghar ranks lowest (0.0025). Godia and Gadchiroli are highly susceptible, facing substantial losses in various crops. Sindhudurg is at risk due to notable losses in pulses and oilseeds. Hingoli is vulnerable with significant output losses in cash crops, fruits, and vegetables. Yavatmal, Sangli, Kolhapur, Wardha, Raigad, Nagpur, Thane, Washim, and Palghar are least vulnerable with comparatively lower crop production losses.

Table 4: District crop production loss index in Maharashtra

S. No.	Districts	CPL-Index
1.	Jalna	0.1051
2.	Gadchiroli	0.0899
3.	Gondia	0.0762
4.	Hingoli	0.0528
5.	Sindhudurg	0.0739

District wise adaptive capacity index in Maharashtra

Nashik leads in adaptive capacity (0.4434) due to more tractors, electric pumps, large market facilities, and rural electrification. Dhule ranks lowest (0.1891), with fewer tractors, electric pumps, and poor electrification. Osmanabad, Hingoli, Jalna, Washim, and Parbhani are most vulnerable due to low adaptive capacity. Parbhani's low literacy rate, Osmanabad's limited forest and fertilizer use, and Hingoli/Jalna's inadequate rural power and road infrastructure contribute to their vulnerability. Ahmednagar, Nashik, and Pune are least vulnerable with greater adaptive capacity.

Table 5: District wise adaptive capacity index in Maharashtra

S. No.	Districts	ACI
1.	Nashik	0.4434
2.	Pune	0.4244
3.	Ahmednagar	0.4236
4.	Nagpur	0.4223
5.	Satara	0.4142

Agricultural Vulnerability Index (AVI) of a district

Sindhudurg is the most vulnerable district (VI score 0.5285) due to low adaptive capacity (28th rank) and high exposure, sensitivity, and crop production loss index (CPLI) scores. Yavatmal is the least vulnerable (VI score 0.0853). Palghar, Thane, Ratnagiri, Raigad, Dhule, and Jalna fall under the 'extreme degree' of vulnerability. Palghar, Thane, Ratnagiri, and Raigad are highly exposed and sensitive, while Dhule and Jalna have low adaptive capacity. Yavatmal, Amaravati, Nanded, Nagpur, Latur, Wardha, and Jalgaon exhibit low vulnerability due to low exposure and high adaptive capacity.

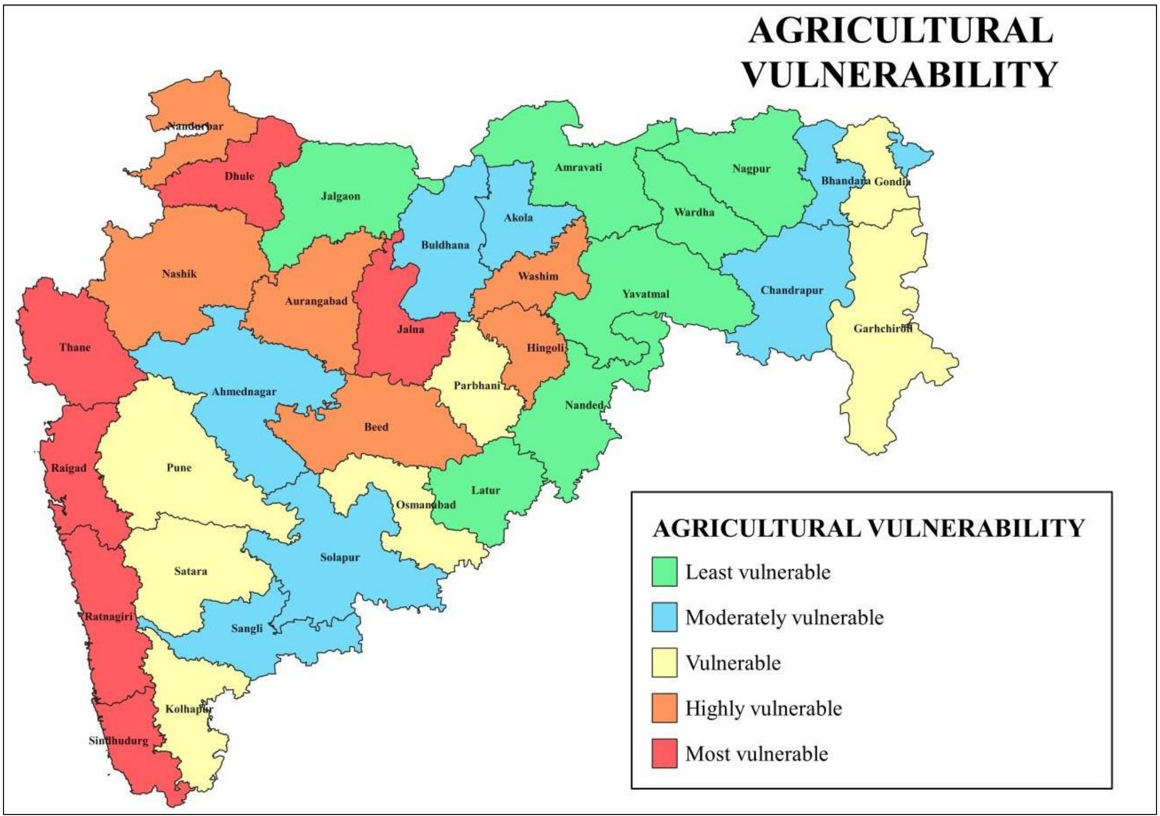
AVIi = (Exposure i + Sensitivity i + Crop production loss i) - Adaptive capacity i

Table 6: District wise agricultural vulnerability index in Maharashtra

Districts	PI	ACI	AVI	Rank
Sindhudurg	0.8129	0.2844	0.5285	1
Palghar	0.8062	0.3109	0.4953	2
Thane	0.8158	0.367	0.4488	3
Ratnagiri	0.7186	0.299	0.4196	4
Raigad	0.7772	0.3649	0.4123	5

Table 7: Classification of Districts into most vulnerable to least vulnerable district as per the magnitude of agricultural vulnerability index

1	Least vulnerable	**Jalgaon**
		Wardha
		Latur
		Nagpur
		Nanded
		Amaravati
		Yavatmal
2	Moderately vulnerable	Sangli
		Bhandara
		Akola
		Buldhana
		Chandrapur
		Solapur
		Ahmednagar
3	Vulnerable	Kolhapur
		Pune
		Gondia
		Gadchiroli
		Parbhani
		Osmanabad
		Satara
4	Highly vulnerable	Nandurbar
		Washim
		Beed
		Aurangabad
		Nashik
		Hingoli
5	Most vulnerable	Sindhudurg
		Palghar
		Thane
		Ratnagiri
		Raigad
		Dhule
		Jalna



Map 1: District wise map of Agricultural vulnerability index in Maharashtra

Suggestions and Recommendations

- District-level variations in sensitivity, exposure, and vulnerability exist in Maharashtra's Vidarbha, Marathwada, and Konkan regions, emphasizing the need for targeted district-level policies. To address climate change impacts, strategies include water conservation, proper credit distribution, early warnings, climate-proof shelters for animals, immunization, health checks, and diversified farming. Evaluating and disseminating local coping mechanisms is crucial for effective climate change.
- In districts like Jalna, Gadchiroli, and Sindhudurg, increasing crop production losses threaten regional food security. Government intervention is crucial to ensure optimal food grain land and may involve support mechanisms like providing farmers with "Cultivation Allowance" in cash or subsidies for food-grain crops.
- Significant oilseed and cash crop production losses highlight the inadequacy of current technologies in stabilizing yields amid shifting climatic conditions. Urgent promotion of large-scale stabilizing measures such as insurance and adoption of new technologies are essential to mitigate the impact of ongoing volatility
- Climate change significantly impacts agriculture, food security, and rural development in Maharashtra, hindering the district's ability to adapt. Mitigation is possible through adopting new technology, expanding irrigation on dry-land farms, increasing mechanization, and educating farmers on mitigation and adaptation measures.
- Policy interventions should focus on enhancing climate risk management at household and public levels through risk mitigation and coping methods. Mitigation plans should include crop diversification and "climate-smart" agricultural practices. Public involvement should emphasize building water harvesting structures, utilizing irrigation potential in rainfed regions, implementing early warning systems, and providing timely disaster information and weather-based crop insurance.
- Enhancing short-term variability and long-term climate change adaptation involves risk management through insurance plans and improved weather forecasting. Upgrading irrigation systems, adopting new technologies, and investing in agricultural R&D are crucial for improving farmer resource utilization and reducing risks. Diversifying crop rotations, integrating agricultural and livestock systems, and diversifying food systems contribute to building climate change resilience and improving farming efficiency.

References

1. Balasubramanian TN, Arivudai Nambi A, Diya Paul. A suggested index assessment of vulnerability of a location to climate change. Journal of Agrometeorology. 2009;9(2):129-137.
2. Brenkert AL, Malone EL. Modelling vulnerability and resilience to climate change a case study of India and Indian states. Climate Change. 2005;72:57-102.
3. Cuddy JDA, Della Valle PA. Measuring the instability of time series data. Oxford Journal of Economics and Statistics. 1982;40(1):79-85.
4. Das A. Mapping the regional variation in potential vulnerability in Indian agriculture to climate change - An exercise through constructing vulnerability index. African Journal of Environmental Science and Technology. 2013;7(4):112-121.
5. Deressa T, Hassan RM, Ringler C. Measuring Ethiopian farmers' vulnerability to climate change across regional states. IFPRI discussion paper No.806, Washington; c2008.
6. Fusel HM. Vulnerability: A generally applicable conceptual framework for climate change research. Global Environmental Change. 2007;17:155-167.
7. Gbetibouo GA, Claudia Ringler. Mapping South African farming sector vulnerability to climate change and variability: A sub national assessment. Discussion paper 00885, Environment and Production Technology Division, IFPRI; c2009.
8. IPCC (Intergovernmental panel on Climate Change). Climate Change 2013: The Physical science basis. Contribution of working group I to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA; c2013.
9. Iyengar NS, Sudarshan P. A method of classifying regions from multivariate data. Economic and Political Weekly. 1982;Special Article:2048-52.
10. Kavi Kumar KS. Climate change and adaptation, Dissemination Paper-10, Centre of Excellence in Environmental Economics, Madras School of Economics, Chennai, India; c2010.
11. Mendelsohn R, Soa SN. An integrated farm model of crops and livestock: Latin American agricultural impacts and adaptations to climate change, World Bank Policy Research Series Working Paper 4161. World Bank, Washington DC., USA; c2007.
12. O'Brien KL, Leichenko RM, Kelkar U, Venema HM, Aandahl G, Tompkins H, *et al*. Mapping vulnerability to multiple stressors: Climate change and globalization in India. Glob Environ Change. 2004;14:303-313.
13. Palanisami K, Kakumanu KR, Nagothu US, Ranganathan CR, David NB. Impacts of climate change on agricultural production: Vulnerability and adaptation in the Godavari river basin, India, Report No.4, Climate water; c2010.
14. Patnaik U, Narayanan K. Vulnerability and climate change: An analysis of the eastern coastal districts of India, Human security and climate change: An International Workshop Holmen Fjord Hotel, Asker, near Oslo; c2005 Jun 21-23.
15. Sridevi G, Jyotishi A, Jagadeesh G, Bedamatta S. Climate change vulnerability in agriculture sector: Indexing and mapping of four southern Indian states. Bologm, Italy: Department of Economics, Alma Mater Studiorum University of Bologm; c2014.
16. Swami D, Parthasarathy D. Dynamics of exposure, sensitivity, adaptive capacity and agricultural vulnerability at district scale for Maharashtra, India. Ecological Indicators; c2020. p. 121. DOI: 10.1016/j.ecolind.2020.107206.
17. Tesso G, Emana B, Katema M. Analysis of vulnerability and resilience to climate change induced shocks in north Shewa, Ethiopia. Agricultural Sciences.

2012;3(6):871-888.
18. Vijayasarathy K. Impact of Climate Variability on Agriculture and the Determinants of Climate Adaptation through Agricultural Technologies in the Western Zone of Tamil Nadu, Ph.D. Thesis, Department of Agricultural Economics, Tamil Nadu Agricultural University, Coimbatore; c2013.
19. Varadan JR, Kumar P. Mapping agricultural vulnerability of Tamil Nadu, India to climate change: A dynamic approach to take forward the vulnerability assessment methodology. Climatic Change. 2015;129(1-2):159-181.