BEFORE THE NATIONAL GREEN TRIBUNAL WESTERN ZONE BENCH, PUNE
Execution Application 04/2022

IN Appeal No. 25/2014

Sarang Yadwadkar &Anr. ... Applicant

Versus

The State of Maharashtra,

Through Water Resources Department ... Respondent

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(1)

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REPLY AFFIDAVIT TO REJOINDER AFFIDAVIT DATED 23/05/2023 FILED BY THE APPLICANT AND AS PER THE DIRECTIONS DATED 25/05/2023 & 06/09/203 OF THIS HON'BLE COURT

I, Shri Sanjiv Arunkant Tatu, Age: 55 years, Occupation: Service, currently serving as Chief Engineer & Joint Secretary, Water Resources Department, Government of Maharashtra, having office at Mantralaya, Mumbai, do hereby beg to state on solemn affirmation as under:

I say and submit that I have gone through the records of the present matter and after going through the

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relevant office records, I am filing the present Affidavit.

1. I hereby affirm and submit that, as stated by the Water Resources Department in the reply Affidavit dated 08/02/2023, the districts of Jalgaon, Dhule, Nandurbar and Washim do not fall within the category of rivers flowing through Highly Flood Prone Zone. Consequently, these districts had not been included in the Affidavit dated 28.07.2015 & Affidavit dated 08.02.2023. I am hereby submitting following detailed information along with the documents in support of the statement.

i. I, state and submit that, in response to Annexure No. 1 as annexed in the rejoinder dated 23.05.2023, the enclosed news documents are pertinent to Chalisgaon Taluka of Jalgaon District. The geographical features of Chalisgaon Taluka include its southern boundary adjoining the Ajanta Hills in Chhatrapati Sambhajinagar District (formerly known as Aurangabad District). During the aforementioned period in August and September 2021, there was cloud bursting near Bangaon on the Ajanta Hills. As a result, flash floods transpired due to the heavy rainfall, accompanied with lightning and storms. Numerous individuals sustained injuries within Chalisgaon Taluka of Jalgaon District due to these circumstances. However, the occurrence of cloud-bursting is a rare event.

ii. I further state and submit that, in direct response to Annexure No. 2 as appended in the rejoinder dated 23.05.2023, an identical circumstance akin to the aforementioned Annexure - 1 manifested itself in Jamner Taluka of Jalgaon District during the month of September 2021. The intrinsic state of Jamner Taluka's surroundings entails its southern demarcation seamlessly abutting the Ajanta Hills of Chhatrapati Sambhajinagar District (formerly recognized as Aurangabad District). Such occurrence is rare in nature.

iii. In the aforementioned rejoinder dated 23.05.2023, the Applicant has duly appended a total of three Annexures, specifically Annexure 3, Annexure 4, and Annexure 5 pertaining to the prevailing circumstances within Dhule District.

iv. I further submit that, in reply to Annexure No. 3 included in the rejoinder dated 23.05.2023, the aforementioned annexure depicts the flood situation that transpired during the month of September in the year 2019 within Dhule District. This occurrence arose as a result of substantial rainfall within the catchment area of Lower Panzara Dam, coupled with precipitation in the unregulated catchment area of Dhule District.

v. I further submit that, in response to Annexure No. 4 as appended in the rejoinder dated 23.05.2023, that Annexure 4 depicts the flood situation that occurred during the month of September in the year 2022 within Dhule District. This event was triggered by precipitation in that area.

vi. I further submit that, in reply to Annexure No. 5 attached in the rejoinder dated 23.05.2023, that Annexure 5 reiterates the identical situation outlined in Annexure 3.

vii. Furthermore, the Applicant, in its rejoinder dated 23.05.2023, has additionally appended a set of Annexures under the headings of Annexure 6, Annexure 7, and Annexure 8. I submit that, Annexure- 6, enclosed with the Rejoinder dated 23.05.2023, primarily pertains to the flood situation in Nandurbar & Dhule District during the month of August in the year 2019.

viii. I further submit that, Annexure - 7, annexed to the Rejoinder dated 23.05.2023, illustrates the occurrence of pre-monsoon cloud bursting accompanied by sky lightning. This event took place in Taloda taluka of Nandurbar District during April 2023, which

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generally is a summer season, resulting in a moderate flood situation. However, such occurence is rare in nature.

ix. I say and submit that, Annexure No. 8 annexed to the rejoinder dated 23.05.2023 is a research paper of the study done by Indian Council of Agricultural Research (ICAR) & National Dairy Research Institute (NDRI) regarding Socio-Economic Vulnerability to climate change. The same is annexed herewith as Exhibit-A.

This said study was based on the socio-economic Vulnerability Assessment, which is based on many governing factors such as Rainfall, Drought, Agricultural production, Sustainability of Livelihoods etc. Hence, higher Socio-Economic Vulnerability Index at Nandurbar does not necessarily imply that, it is High Flood Prone Area. Nevertheless, taking into consideration current scenario of occurrence of flooding in Nandurbar district, some rivers have been taken up for Demaracation of Flood Lines.

2. I say and submit that, Annexure-9 annexed to the rejoinder dated 23.05.2023, pertains to Washim District which is geographically located on the common ridge of Tapi and Godavari River, and the tributaries originating from Washim District

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contribute to these rivers. It is important to note that there are no rivers flowing directly through the urban areas/ municipal area, and the small townships is classified as Gram Panchayats, situated along the banks of these aforementioned tributaries. The situation mentioned by the Petitioner at Annexure-9 of his Rejoinder dated 23.05.2023 has occurred due to moderate flooding which might have occurred due to occurrence of high-intensity rainfall for short time. However, this is a rare occurrence in this region. Given the minimal occurrence of flood-related loss of life and financial damages. There is no need of Demarcation of Blue line and Red line, in priority–I. However if in future, the need for flood line marking arises, then the same will be taken up.

3. I hereby assert and submit that, the details of Blue line and Red lines demarcation of Priority-I stretch of Konkan region was elaborated in earlier affidavit. The same is now marked & uploaded on website of Water Resources Department. Hence demarcation of flood lines along river length of 289.4 km of Konkan region which were in progress as mentioned in the earlier affidavit dated 08.02.2023 of this Respondent, have been now duly completed as shown in Exihibit-B.

4. It is further submitted that, considering occurrence of flash floods, cloud burst & heavy rainfall in recent

years between 2019 to 2022 in Dhule, Nandurbar & Jalgaon districts, the Respondent has already commenced the necessary procedures for marking the blue line and red line in these three ddistrict.

5. I say and submit that, the Water Resources Department, has completed demarcation of flood lines pertaining to priority –I rivers which flows through city/urban areas, as per the directions of this Hon'ble National Green Tribunal passed vide order dated 27.03.2015.

6. In view of the flood situation occurred in four Districts is studied in detailed and Water Resources Department has already identified the stretches of river which need to be demarcated, admittedly other than priority-I rivers. I say and submit that, Tapi Irrigation development Corporation, Jalgaon has already taken up the preliminary work required for demarcation of flood lines in the areas where recent flood situation has occurred and where there is possibility to occur thc flood in near future in the three districts, namely Dhule, Jalgaon and Nandurbar. Similarly, the Water Resources Department is duty bound to conduct immediate action plan pertaining to study of flood etc., throughout the Maharashtra State wherever such situation occurring in future.

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7. In the light of above submissions and immediate necessary actions taken by the Respondent, it may be concluded that this Respondent has already completed demarcation of flood lines along rivers, falling under Priority–I. I therefore, most respectfully pray to this Hon"ble National Green Tribunal to dispose of the present Execution Application.

Affiant / Deponent

(Sanjiv Arunkant Tatu)
Chief Engineer & Joint Secretary
Water Resources Department

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VERIFICATION

I, Sanjiv Arunkant Tatu, Chief Engineer & Joint Secretary, state that the contents of above affidavit are true and correct to the best of my knowledge, belief and information received from the Water Resources Department and in witness whereof I have signed this affidavit at Mumbai on the date mentioned herein under.

Deponent,

(Sanjiv Arunkant Tatu)

Chief Engineer & Joint Secretary
Water Resources Department

Mumbai.

Date: 12/09/2023

I know the affiant.

S.A Tatu.

S.A. Gaikwad.

(Sonal Anand Gaikwad)
Executive Engineer & Under Secretary
Water Resources Department

12/09/2023

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Exhibit A

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Socio-economic vulnerability to climate change – Index development and mapping for districts in Maharashtra, India

Chaitanya Ashok Adhav[1], Sendhil R[2] Chandel B S[1], Gunjan Bhandari[1], Ponnusamy K[1] and Hardev Ram[1]

[1] ICAR-National Dairy Research Institute, Karnal, Haryana, India.
[2] ICAR-Indian Institute of Wheat and Barley Research, Karnal, Haryana, India.

Highlights

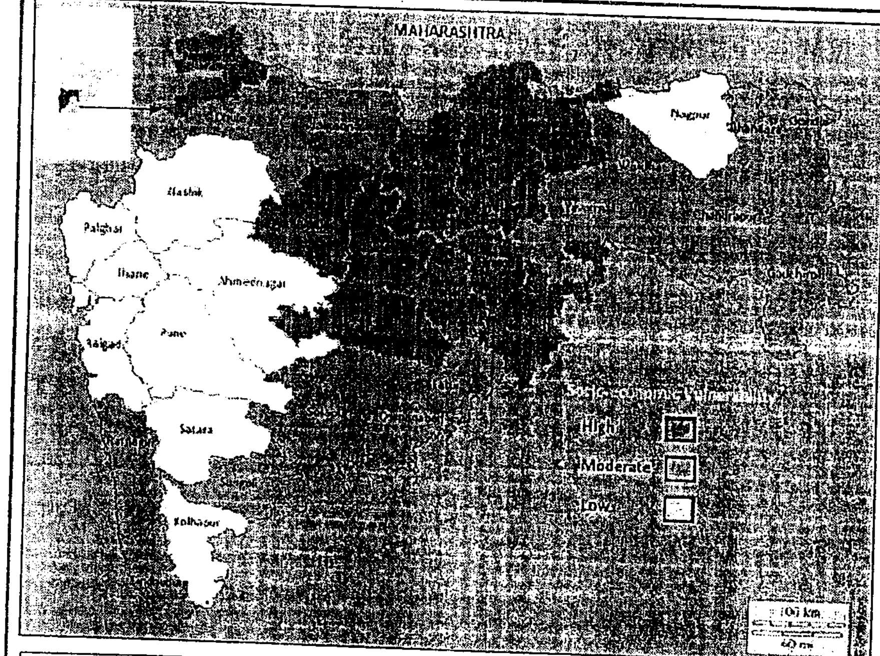
- Developed socio-economic vulnerability index (SeVI) to climate change in Maharashtra, India.
- SeVI constructed with 43 indicators (socio-economic, crop, and dairy) using the IPCC approach.
- 11 districts are highly vulnerable, followed by 14 and 9 under moderate and less category.
- Among the indicators, *kharif* temperature (PCA weight: 5.75) contributed more to the SeVI.
- Focus is on grassroots assessment and dissemination of climate change adaptation strategies.

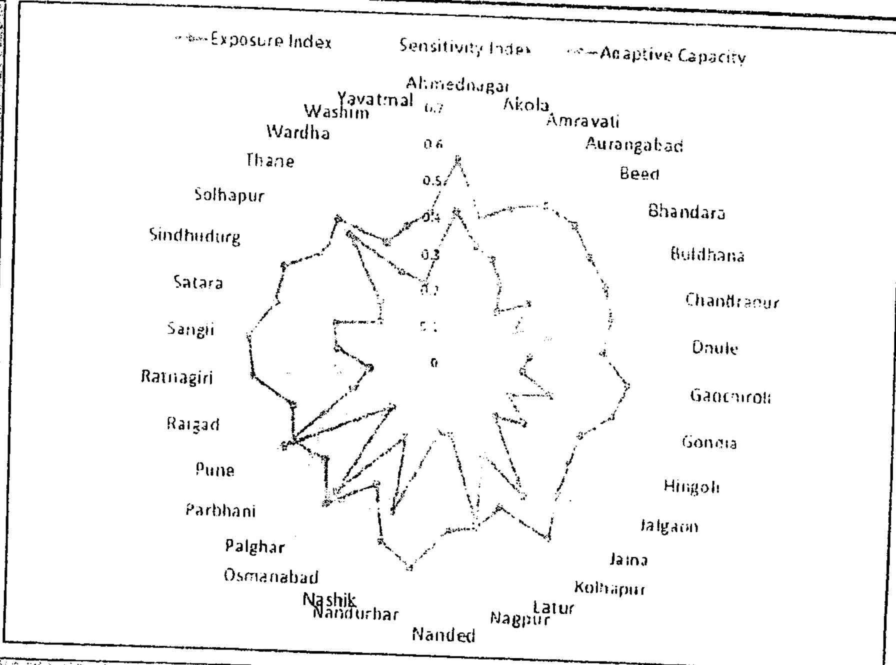
Abstract

Climate change is adversely affecting agrarian economy and farmers welfare in the Maharashtra state of India. An attempt has been made to develop climate change induced socio-economic vulnerability index (SeVI) comprising various socio-economic as well as crop and dairy indicators for 34 districts of Maharashtra. The SeVI was calculated using the Intergovernmental Panel on Climate Change (IPCC) approach using exposure, sensitivity and adaptive capacity components of vulnerability. Primary normalization of indicators was performed and weights were assigned to each indicator using the principal component analysis. Later, all districts were categorized as high, moderate and less vulnerable to climate change based on the magnitude of the index. Sangali has the highest exposure to socio-economic vulnerability (0.62) and the lowest was in Wardha (0.38). Sensitivity was found highest in Akola (0.68) and lowest in Sindhudurg (0.33). The highest adaptive capacity was identified in Pune (0.56) and the lowest was in Beed (0.19). Not a single district among all had higher adaptive capacity than exposure and sensitivity combined together. The SeVI was highest in Nandurbar (0.91) and lowest in Pune (0.41). Results indicated that out of 34 districts, 11 were categorized as highly vulnerable (39.94% cropped area), 14 as moderately vulnerable (36.85% cropped area), and nine as less vulnerable to climate change (23.21% cropped area). A majority of the highly vulnerable districts are from Central Maharashtra Plateau Zone. Moderately vulnerable districts are from Central and Eastern Vidarbha Zone. Less vulnerable districts are from North Konkan Coastal, Scarcity Zone and Western Maharashtra Zone. To cope with vulnerability to climate change, the focus should be on ground level adaptation and mitigation strategies. Major emphasis should be given in water scarcity zone and central zone of Maharashtra. Identifying the best fit strategies for adoption by assessing the locale respondent's perception is a task of utmost importance while dealing with climate change induced socio-economic vulnerability.

Keywords: Socio-economic vulnerability index (SeVI), principal component analysis, vulnerability mapping

Graphical Abstract





- For 34 districts in Maharashtra (India), a new composite socio-economic vulnerability index (SeVI) to climate change was developed.
- SeVI was constructed using 43 indicators (socio-economic, crop, and dairy) following the IPCC approach (Exposure, Sensitivity and Adaptive Capacity) approach.
- 11 districts are in high (39.94% cropped area) , 14 in moderate (36.85% cropped area), and 9 in less (23.21% cropped area) vulnerability category.
- Among the indicators, *Kharif* crop season daily temperature (PCA weight: 5.75) contributed more to the vulnerability in Maharashtra.
- Grassroots assessment and dissemination of region-specific climate change adaptation strategies is a pressing need to manage the socio-economic vulnerability.

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Socio-economic vulnerability to climate change – Index development and mapping for districts in Maharashtra, India

Chaitanya Ashok Adhav[1], Sendhil R[2] Chandel B S[1], Gunjan Bhandari[1], Ponnusamy K[1] and Hardev Ram[1]

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Abstract

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Keywords: Socio-economic vulnerability index (SeVI), principal component analysis, vulnerability mapping

1 Introduction

India's average temperature rose by 0.7°C between 1901 and 2018. It is projected to rise further by 4.4°C by the end of this century (Ministry of Earth Sciences GOI 2020[1]). Indian regions are characterized with a high populace mainly dependent on livelihoods sensitive to climate variations and witness to frequent fluctuations in agricultural production and therefore in incomes (Bizikova et al. 2015; Brown et al. 2018). High dependence on climate-sensitive sectors, limited infrastructure, volatile markets, poor socio-economic and low biophysical status of the habitat makes the rural poor most vulnerable to climate change (Banerjee 2014; Safriel and Adeel 2005; Singh et al. 2017). In India, vulnerability studies have focused mainly on how adaptation practices to climate change in agriculture were influenced by a wide range of social factors (Dhanya and Ramachandran 2016). Maharashtra is the third largest State in

[1] https://reliefweb.int/report/india/assessment-climate-change-over-indian-region-report-ministry-earth-sciences-moes

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India, accounting for 9.4% (3,07,731km^2) of the total geographical area of the country. Also, the second most populous State with a population of about 112 million (GOI Census 2011) including 244.22 lakh households. The predominance of rainfed regions, fluctuating climatic conditions, and acute underdevelopment in Vidarbha, Marathwada, and Konkan were the state's major development challenges. The maximum employment of 56 per cent was observed in agriculture and allied activities (Misra 2012). Except for sugarcane, little has been accomplished in the sector in comparison to other regions of the country over the last six decades (Sawant et al. 1999; World Bank 2003). The growth in the rainfall (113.4 per cent of usual rainfall) and the crop sector is projected to rise by 16.2 per cent, livestock by 4.4 per cent, and forestry by 5.7 per cent (Economic survey of Maharashtra 2019-20). Based on socio-political and other geographical considerations, the State is divided into five main regions: Vidarbha (north-eastern region), Marathwada (south-central region), Khandesh (north-western region), Northern Maharashtra and Western Maharashtra (Konkan). The state has been divided into 9 agro-climatic zones based on rainfall, soil type and the vegetation as Central Maharashtra Plateau Zone, Central Vidarbha, Eastern Vidarbha Zone, North Konkan Coastal Zone, South Konkan Coastal Zone, Scarcity Zone, Sub Montane Zone, Western Ghat Zone, Western Maharashtra Plain Zone (National Dairy Development Board 2015). Maharashtra occupies the western and central part of the country and has a long coastline stretching nearly 720 km along the Arabian Sea. The Western Ghats is not only the prominent biodiversity resource for the region and an important climatic divide (average elevation of 1200 meters), but also forms one of the three watersheds of the State from which originate several important rivers, including Godavari and Krishna. Climate shocks and stressors such as cyclones, floods, droughts, changing rainfall patterns and extreme temperatures are some examples of uncertainties faced by Maharashtra. Climate-related uncertainty refers to the inability to predict the scale, intensity and impact of climate change on human and natural environments (Curry and Webster 2011). Uncertainties in climate change projections are high and combined with the economic and political drivers of change makes local level effects difficult to predict (IPCC 2012). So, the present paper strives to assess climate change induced socio-economic vulnerability at regional level in Maharashtra.

2 Vulnerability assessment an overview

Abundant literature is available on assessment of climate change induced socio-economic vulnerability. Most of the studies have used the Intergovernmental Panel on Climate Change (IPCC) methodology for regional level climate change assessment. Brenkert and Malone (2005) in their study on modelling vulnerability and resilience to climate change used the Vulnerability-Resilience Indicator Prototype (VRIP). The model was adapted from the global/country version to account for Indian dietary practices and data availability regarding freshwater resources. Results (scaled to world values) showed that, nine Indian states were moderately resilient to climate change, principally because of low sulfur emissions and a relatively large percentage of unmanaged land. Das (2013) studied regional variation in potential vulnerability in Indian Agriculture to climate change. The Socio-Economic Vulnerability Index was calculated using indicators like irrigation strength, percentage of people living in poverty, percentage of agricultural workers among total workers, and literacy rate. Modified UNDP method has been used in constructing both biophysical vulnerability index and socio-economic vulnerability index. Results showed that most of the states with high vulnerability are located in India's central and north-central regions, according to research. Malakar and Mishra (2016) in their study on assessing socio-economic vulnerability to climate change focused on a city-level index-based approach. Various indicators of socio-economic vulnerability have been compiled and segregated into major components like infrastructure, technology, finance, social and space. Senapati and Gupta (2017) in their study on socio-

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economic vulnerability due to climate change on fishing communities in Mumbai, Maharashtra surveyed 200 fishermen from five fishing villages in Mumbai. The findings show that weakness persists in the fishing community due to physical and financial resource constraints. Due to their inability to use powerful mechanized boats and advanced technology, fishermen from *Madh* and *Worli* villages have been found to be more vulnerable and less adaptable. Ayanlade et al. (2018) studied rainfall variability and drought characteristics in two agro-climatic zones in Africa. In their study, inter-station and seasonality statistics reveals that there were less variable and wetter early growing seasons and late growing seasons in the rainforest zone, also more variable and drier growing seasons in other stations. The results show high spatial and temporal rainfall variability for the stations. Consequently, there are several anomalies in rainfall in recent years but much more in the locations around the Guinea Savanna. Rao (2019) worked on assessing differential vulnerability of communities in the agrarian context in two districts of Maharashtra. A community engaging vulnerability assessment tool was used to explore the climate risks and vulnerabilities of different social groups. Insights indicate that vulnerability is socially differentiated across farmer categories and social groups. Krishnan et al. (2019) in their study on vulnerability and spatial decision making for climate-change adaptation, formulated socio-economic vulnerability index (SEVI) as a function of sensitivity and adaptive capacity for planning grassroot-level interventions and adaptation strategies. The indicators were identified through a literature review, expert consultations, and an opinion survey. Also, statistical tests were used to validate them. Results showed that 92 villages (30%) in Sindhudurg were classified as highly vulnerable based on CVI values. Carpena (2019) studied impact of drought on household food consumption and nutritional intake. They found that dry shock has a statistically significant and negative effect on household nutrition. Singh (2020) worked on farmers' perception of climate change and adaptation decisions in Bundelkhand Region of India. In their study, multi-stage sampling technique was adopted to select study sites and respondents. Study findings revealed that variability in temperature and rainfall has affected adversely to the livelihoods of farmers. Balaganesh et al. (2020) worked on development of composite vulnerability index and district level mapping of climate change induced drought in Tamil Nadu, India. In their study Composite Drought Vulnerability Index (CDVI) was developed. Vulnerability mapping showed that most of the districts fall under north eastern and southern agro-climatic zones; a few districts in Cauvery delta and western zones which were prone to high vulnerability. Most of the districts in north western, western, and high rainfall zones were less vulnerable, whereas the remaining districts of Tamil Nadu were identified under moderate vulnerable to drought category. Swami and Parthasarathy (2021) studied dynamics of exposure, sensitivity, adaptive capacity and agricultural vulnerability at district scale for Maharashtra, India their findings show that a few districts are vulnerable despite being least exposed to climate variability signifying the contribution of sensitivity and adaptive capacity parameters towards their vulnerability. The results also highlight the intra-regional district level variability in resource distribution, exposure and sensitivity parameters indicating the significance of having a district-wise policy for Maharashtra, India. The present study focuses on real time assessment of regional vulnerability affecting the farm households using various socio-economical, crop and livestock indicators.

3 Materials and methods

3.1 Study area

Maharashtra state has been selected purposively for this study as the state is severely facing rainfall and temperature anomalies along with persistent droughts and many climatic factors impacting agriculture and allied activities. At present there are 36 districts in the state out of which two districts namely, Mumbai Central and Mumbai Suburban have been omitted in this study because of data unavailability related to farming and dairy components. Therefore, the remaining 34 districts of Maharashtra have been selected for the present study. Agriculture is the prime livelihood source for 51 per cent of the state population (State of India's Livelihoods Report 2019). Most of the rural population with small and marginal farmers and economically backward elements of the state rely on agriculture and allied activities for their livelihoods. Climate change is considered one of the most important challenges for Maharashtra. State is an agrarian economy despite being one of the most industrialised states in India. (Maharashtra State Presentation and Economy Growth Report 2020). Water scarcity during the *kharif* season (June to October) of 2018-19 in 26 districts affected 151 talukas (Economic survey of Maharashtra 2018-19). The area under *rabi* crops (November to February) was 50% less in 2018-19 compared to the previous year, mainly due to deficient rainfall in September and October 2018 (Economic survey of Maharashtra 2018-19)[2]. This signifies a key threat to communities that depend on agriculture for food and livelihoods. To combat this, climate induced socio-economic vulnerability assessment has been prioritized at regional level which helps to develop effective adaptation and mitigation strategies.

3.2 Data sources

For the development of district level SeVI, secondary data were collected on various climatic as well as socio-economic variables for the 34 districts of Maharashtra. All the variables were selected based on extensive literature enquiry and data availability. (Brenkert and Malone 2015; Malakar and Mishra 2016; Ayanlade et al. 2015; Rao 2019; Carpena 2019; Balaganesh et al. 2020). District level daily average rainfall, temperature and relative humidity data were collected for a period of 30 years (1991 to 2020) from the online web services of 'Solar Radiation Data (SoDa)[3] - Solar energy services for professionals' (web services, databases, algorithms, end-user applications). District level crop production statistics data, area under cultivation and operational holdings of small and marginal farmers were collected across Maharashtra, per cent sown area, per cent cropped area, total irrigated area and other farming related data for the past three agricultural years (2017-18 to 2018–19) were collected from various state government reports and Economic Survey of Maharashtra (2018-19, 2019-20). District level data on total bovine population, total milk production, per capita milk availability for the same period were obtained from advanced estimates and livestock census data published by the Department of Animal Husbandry, Government of Maharashtra, Livestock Census and other official reports.

3.3 Vulnerability estimation

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system. Exposure is the nature and degree to which a system is exposed to climate change. Sensitivity is the degree to which a system is adversely affected by climate change. Adaptive capacity is the capability of a production system or region to better adjust to climate change (IPCC 2007).

$$Vulnerability = (Exposure + Sensitivity) - Adaptive\ Capacity \quad (1)$$

In Eq. (1), the combined effect of exposure and sensitivity is called as 'potential impact', which is very much destructive, if the region or production system has a high magnitude of index.

[2] https://mahades.maharashtra.gov.in/files/publication/ESM_18_19_eng.pdf
[3] http://www.soda-pro.com/web-services/meteo-data/merra

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Hence, vulnerability level of a region is the extent of potential impact over adaptive capacity of that region or production system (Sendhil et al. 2018).

$$Vulnerability = Potential\,Impact - Adaptive\,Capacity \quad (2)$$

where,

$$Potential\,Impact = Exposure + Sensitivity \quad (3)$$

3.4 Steps in vulnerability assessment

The following steps have been used to assess the district level socio-economic- vulnerability index to climate change.

3..4.1 Identification of suitable indicators

Selection of indicators is of utmost importance for any study on vulnerability assessment. Hence, much care has been taken into consideration to finalize the variables under each indicator by thorough review of published literature and discussion with experts to give the *apriori* functional relationship (see Tables 2-4).

3.4.1.1 Indicators on exposure and functional relationship

Table 2 depicts the exposure indicator variables and their functional relationship. The explanation for selected indicator variables is given in the following section.

a) Trend analysis for climatic variables

For the trend analysis, non-parametric Mann-Kendall's test (Mann 1945; Kendall 1976) has been performed for climate variables. This test, as a robust statistical method, has been mostly used for studying the spatial variation and temporal trends of climatic time series (Yue and Wang 2004; Tabari et al. 2011; Mondal et al. 2012; Vijayasarathy 2013; Yadav et al. 2014). Coefficient of trend in daily average temperature, relative humidity and rainfall of *kharif* (July to October), *rabi* (November to February) and summer (March to June) seasons have been calculated for the 30 years period ranging from 1991 to 2020. Apparently, the climate indicators show positive functional relationship with the exposure (Sendhil et al. 2015; Sendhil et al. 2016; Sendhil et al. 2018). If the coefficients of selected variables increase, the exposure of the region to vulnerability increases.

b) Drought return periods for a certain precipitation deficit (compared to a normal situation)

Drought is the reduction of natural water resources due to deficiency of rainfall for prolonged period (Zhang et al. 2012). The IMD defines drought as a period of year or season when the deficiency of rainfall is more than 25% of the corresponding mean. Based on percentage departure from the mean, the seasonal drought can be classified as moderate, severe and extreme.

Table 1 Classification of drought based on the percentage departure of rainfall from mean.

Rainfall departure from mean (%)	Category of drought
< - 25 to - 45	Moderate
< - 45 to - 60	Severe
< - 60 or less	Extreme

*Source: Pandey et al.(2008)

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The average return period of drought is calculated by the following equation (Amrit et al. 2018).

$$R = \frac{N}{n} \quad (4)$$

Where,

R is the average return period of drought.

N is the total number of years data analyzed.

n is the total number of years with rainfall deficit of more than 25%.

Mathematically, the return period (R) is reciprocal of frequency (F).

i.e., $F = \frac{1}{R}$ (5)

Similarly, the return period of severe and extreme drought events has been calculated as the total number of years of rainfall record analysed divided by number of severe and extreme drought events respectively in each district (Amrit et al. 2018). For example, if the return period is of 5 years for a precipitation deficit of 20 % is means that here you can expect a precipitation deficit of 20 % every five years.

Table 2 Exposure indicators and their functional relationship.

S.No.	Exposure	Relationship with component
1	Trend in *kharif* rainfall (Coefficient of trend)	+
2	Trend in *rabi* rainfall (Coefficient of trend)	+
3	Trend in *summer* rainfall (Coefficient of trend)	+
4	Trend in *kharif* temperature (Coefficient of trend)	+
5	Trend in *rabi* temperature (Coefficient of trend)	+
6	Trend in *summer* temperature (Coefficient of trend)	+
7	Trend in *kharif* relative humidity (Coefficient of trend)	+
8	Trend in *rabi* relative humidity (Coefficient of trend)	+
9	Trend in *summer* relative humidity (Coefficient of trend)	+
10	Return period of moderate meteorological drought (No. of years)	-
11	Return period of sever meteorological drought (No. of years)	-
12	Return period of extreme meteorological drought (No. of years)	-
13	No. of consecutive two or more drought years (No. of years)	+
14	Return period of two years or more persistent droughts (No. of years)	-
15	No. of consecutive three or more drought years (No. of years)	+
16	Return period of three years or more persistent drought (No. of years)	-

Note. Selection of climatic variables (1-9): Ahsan *et al.* (2010); Sendhil *et al.* (2015); Sendhil *et al.* (2016); Sendhil *et al.* (2018); Ayanlade (2018); Balaganesh *et al.* (2020), Selection of drought related variables (10-16) Amrit *et al.* (2018)

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3.4.1.2 Indicators on sensitivity and functional relationship

Sensitivity indicator variables and their functional relationship have been explained in Table 3. Indicators like average size of operational holdings for small and marginal farmers; density of population; percentage of workers to the total population; per cent cropped area to the total area; per cent sown area to the total area; per cent area under nonagricultural use (Ahsan et al. 2010; Malakar et al. 2017; Balaganesh et al. 2020; Singh 2020) have positive functional relationship with sensitivity. If value of these variables increases, then sensitivity increases and ultimately socio-economic vulnerability increases. Also, indicators like per cent barren and uncultivable area; total irrigated area; total bovine population; ground water availability; farmers suicides (Brenkert and Malone 2005; Balaganesh et al. 2020; Singh, 2020) show negative functional relationship with sensitivity. If value of variables increases, sensitivity declines and finally vulnerability decreases. For district level farmers suicides, value two years data for the period 2018-19 have been considered. If the number of farmers suicides increases in a district, it increased the sensitivity.

a) Cropping intensity index

Cropping intensity index shows the number of crops being cultivated from the same part of land in an agricultural year. It is calculated by computing the ratio between gross cropped area and net sown area, expressed in percentage. This indicator has negative functional relationship with sensitivity. If the cropping intensity increases, sensitivity declines and finally vulnerability decreases. The formula for cropping intensity is as follows:

$$Cropping\ intenisty = \frac{Gross\ cropped\ area}{Net\ sown\ area} \times 100 \quad (6)$$

Table 3 Sensitivity indicators and their functional relationship.

S.No.	Sensitivity	Relationship with component
1	Average size of operational holdings for marginal farmers (%)	+
2	Average size of operational holdings for small farmers (%)	+
3	Density of population (Number)	+
4	Percentage of workers to the total population (%)	+
5	Per cent cropped area to the total area (%)	+
6	Per cent sown area to the total area (%)	+
7	Per cent area under nonagricultural use (%)	+
8	Per cent barren and uncultivable area (%)	-
9	Total irrigated area (Per ha.)	-
10	Total bovine population (Per ha.)	-
11	Ground water availability (max. mbgl)	-
12	Cropping intensity (%)	+
13	Farmers suicides (2018-2019) (Number)	+

Note: Selection of variables. 1-2: Ahsan *et al.* (2010). 3: Malakar *et al.* (2017). 5-9: Balaganesh *et al.* (2020); Singh (2020). 12: Balaganesh *et al.* (2020). 13: Brenkert and Malone (2005), and 4,10,11: Authors inclusion base on expert opinion.

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3.4.1.3 Indicators on adaptive capacity and functional relationship

a) Simpson index of crop diversification

Simpson Index of Diversification (SID) have been used for calculating district level crop diversification in Maharashtra (Shinde et al. 2013; Vardan and Kumar 2015; Mittal and Hariharan 2016). Principal crops grown in the state like rice, jowar, bajara, wheat, tur, mung, urad, gram and other pulses, oilseeds, groundnut, sunflower, soybean, cotton, sugarcane, turmeric and vegetables have been considered to calculate the index. If SID increases, adaptive capacity increases, hence socio-economic vulnerability decreases.

$$SID = 1 - \sum_j \left(\frac{a_j}{GCA}\right)^2 \quad (7)$$

where,

- a_j represents the area under the j th crop
- GCA represents the gross cropped area

Table 4 Adaptive capacity indicators and their functional relationship.

S.No.	Adaptive Capacity	Relationship with component
1	Per cent area under forest (%)	+
2	Per cent pasture and grazing land (%)	+
3	Literacy rate (%)	+
4	Total breedable bovine (Per ha.)	+
5	Human development index (Number)	+
6	Total milk production ('000 MT)	+
7	Per capita milk availability (grams/day)	+
8	Annual credit plan (crore)	+
9	*Antyodaya Anna Yojana* (AAY) food grain distribution (MT)	+
10	No. of fair price shops (Number)	+
11	Real gross domestic value added at constant prices (2011-12) crore	+
12	Percentage of households electrified per square km. (%)	+
13	District artificial insemination center (Number)	+
14	*Krishi Vigyan Kendra* (Number)	+
15	Simpson index of crop diversification (0 – 1)	+

Note: Selection of variables, 3: Brenkert and Malone (2015). 12. Ahsan. (2010),15: Shinde *et al.* (2013); Vardan and Kumar (2015); Mittal and Hariharan (2016) and 1,2,4-11,14: Authors inclusion base on expert opinion.

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b) Other indicators

Other indicators like per cent area under forest; per cent pasture and grazing land; literacy rate (Brenkert and Malone, 2015; Balaganesh et al. 2020); total breedable bovine; human development index; total milk production; per capita milk availability; Annual credit plan; *Antyodaya Anna Yojana* (AAY) food grain distribution; number of fair price shops; real gross domestic value added (RGDVA) at constant prices (2011-12); percentage of households electrified per square km (Ahsan 2010); number of district artificial insemination centers (Maiti et al. 2015); number of *Krishi Vigyan Kendra* have positive functional relationship with the adaptive capacity. If coefficient of the variables increases, adaptive capacity increases. Hence, vulnerability declines.

3.4.2 Normalization

Normalization of the indicators is an important step while computation of index in order to confirm that all the indicators are comparable owing to measurement on different scales for each indicator (Anand and Sen 1994; Vincent 2004; Varadan and Kumar 2015; Kale et al. 2016; Mahida and Sendhil 2017; Sendhil et al. 2018; Mamrutha et al. 2020; Balaganesh et al. 2020; Mohan et al. 2021).

If the indicators having positive functional relationship with their respective index, then the normalization has been done with the following formula,

$$Normalization = \frac{(Actual\ value - Minimum\ value)}{(Maximum\ value - Minimum\ value)} \qquad (8)$$

If negative functional relationship expected with the vulnerability, we used the following formula for normalization,

$$Normalization = \frac{(Maximum\ value - Actual\ value)}{(Maximum\ value - Minimum\ value)} \qquad (9)$$

3.4.3 Assigning weights to the indicators

After performing normalization of the indicators, respective weights were assigned based on their level of contribution to the vulnerability. Mostly assigning equal weights, inverse of variance, expert opinion and principal component analysis (PCA) are commonly used methods. Each method has its own benefits and drawbacks (Varadan and Kumar 2015; Sendhil et al. 2018; Balaganesh et al. 2020). PCA is the most widely used technique for weight assignment assuming existence of linear relationship among variables (Ayyoob et al. 2013; Kale et al. 2016; Sendhil et al. 2018; Balaganesh et al. 2020; Mamrutha et al. 2020). On that account, PCA tool has been used in the present study. The functional equation for the PCA is given as follows:

$$X_t = \Lambda_t F_t + e_t \qquad (10)$$

where,

- X_t indicates the N-dimensional vector of variables influencing vulnerability.
- Λ_t represents the $r \times 1$ common factor.
- F_t represents the factor loading.
- e_t represents the associated idiosyncratic error-term of order $N \times 1$.

The weights from the PCA were calculated with the following equation.

$$W_i = \sum |L_{ij}| E_j \tag{11}$$

where, W_i represents the weight of the i^{th} variable, E_j represents the Eigen value of the j^{th} factor, and L_{ij} represents the loading value of the i^{th} variable on j^{th} factor.

3.4.4 Socio-economic vulnerability index

Exposure, sensitivity and adaptive capacity indices were calculated separately by using their respective indicators along with their respective calculated weights in the following equation (Sendhil et al. 2018; Balaganesh et al. 2020).

$$Index_{District} = \frac{\sum_{i=1}^{n} X_i W_i}{\sum_{i=1}^{n} W_i} \tag{12}$$

where, X_i represents the normalized value of i^{th} variable, and W_i is the weight of i^{th} variable.

Finally, the socio-economic vulnerability index was calculated as per the IPCC approach, using Eq. (1).

$$SeVI = (Exposure + Sensitivity) - Adaptive\ Capacity \tag{13}$$

3.4.5 Categorization of districts

After computation of SeVI, 34 districts of Maharashtra were categorized as high, moderate and low using mean and standard deviation norm (Ayyoob et al. 2013; Kale et al. 2016; Sendhil et al. 2018; Balaganesh et al. 2020). The categorization is as follows:

- High = Index > (Mean + 0.5 SD)
- Moderate = (Mean – 0.5 SD) < Index < (Mean + 0.5 SD)
- Low = Index < (Mean – 0.5 SD)

4. Results and discussion

4.1 Exposure

Exposure index for 34 districts of Maharashtra (see Table 5) have been computed using climatic variables like average daily temperature, rainfall, relative humidity and drought return period. The highest exposure to climate change was observed in Sangali (0.62) and lowest was found in Wardha (0.38) with the mean index score of 0.50 and SD of 0.06. A less divergence (difference between maximum index value and minimum index value) of 0.24 has been observed in exposure among districts. Twelve districts namely Pune, Beed, Gadchiroli, Nashik, Palghar, Satara, Ahmednagar, Kolhapur, Sindhudurg, Nandurbar, Ratnagiri, Sangali were categorized under hight exposure; thirteen districts such as Amaravati, Parbhani, Nagpur, Nanded, Jalna, Solapur, Raigad, Chandrapur, Gondia, Bhandara, Buldhana, Aurangabad, Thane were categorized in moderate exposure; nine districts such as Wardha, Washim, Osmanabad, Akola, Yavatmal, Latur, Hingoli, Jalgaon, Dhule were found under low exposure to climate change. Eight districts are under high exposure are from Central Maharashtra Plateau Zone, only one district (Nandurbar) is under Western Maharashtra Plain Zone. This may be due to high concentric temperature and rainfall changes (Balaganesh et al. 2020) and lower number of drought return periods (Amrit et al. 2018) in the given zone. The highest weightage was observed for coefficient of trend in *kharif* daily average temperature (5.75), which is an important indicator for socio-economic vulnerability, also lowest was found in return period of two years or more persistent droughts (2.85), suggesting very less possibility of frequent drought occurrence and hence reduces socio-economic vulnerability.

Table 5 Exposure, sensitivity, adaptive capacity and composite socio-economic vulnerability indices for the districts of Maharashtra.

District	Exposure	Sensitivity	Adaptive Capacity	Composite SeVI
Ahmednagar	0.56^{H}	0.40^{L}	0.42^{H}	0.54^{L}
Akola	0.41^{L}	0.68^{H}	0.33^{M}	0.76^{H}
Amravati	0.47^{M}	0.61^{H}	0.31^{L}	0.76^{H}
Aurangabad	0.52^{M}	0.56^{H}	0.26^{M}	0.81^{H}
Beed	0.53^{H}	0.50^{M}	0.19^{L}	0.83^{H}
Bhandara	0.51^{M}	0.44^{M}	0.28^{M}	0.66^{M}
Buldhana	0.51^{M}	0.57^{H}	0.21^{L}	0.87^{H}
Chandrapur	0.50^{M}	0.45^{M}	0.30^{M}	0.65^{M}
Dhule	0.45^{L}	0.49^{M}	0.23^{L}	0.71^{M}
Gadchiroli	0.54^{H}	0.39^{L}	0.21^{L}	0.72^{M}
Gondia	0.51^{M}	0.43^{L}	0.31^{M}	0.62^{M}
Hingoli	0.44^{L}	0.57^{H}	0.20^{L}	0.81^{H}
Jalgaon	0.45^{L}	0.47^{M}	0.28^{M}	0.64^{M}
Jalna	0.48^{M}	0.54^{H}	0.20^{L}	0.83^{H}
Kolhapur	0.57^{H}	0.42^{L}	0.43^{H}	0.56^{L}
Latur	0.43^{L}	0.54^{H}	0.27^{M}	0.69^{M}
Nagpur	0.47^{M}	0.51^{M}	0.46^{H}	0.52^{L}
Nanded	0.47^{M}	0.50^{M}	0.20^{L}	0.77^{H}
Nandurbar	0.59^{H}	0.52^{M}	0.20^{L}	0.91^{H}
Nashik	0.55^{H}	0.41^{L}	0.45^{H}	0.50^{L}
Osmanabad	0.41^{L}	0.50^{M}	0.25^{L}	0.66^{M}
Palghar	0.55^{H}	0.52^{M}	0.50^{H}	0.57^{L}
Parbhani	0.47^{M}	0.55^{H}	0.22^{L}	0.80^{H}
Pune	0.53^{H}	0.44^{M}	0.56^{H}	0.41^{L}
Raigad	0.50^{M}	0.37^{L}	0.31^{M}	0.56^{L}
Ratnagiri	0.60^{H}	0.34^{L}	0.25^{L}	0.70^{M}
Sangli	0.62^{H}	0.41^{L}	0.35^{H}	0.68^{M}
Satara	0.56^{H}	0.35^{L}	0.37^{H}	0.54^{L}
Sindhudurg	0.58^{H}	0.33^{L}	0.24^{L}	0.66^{M}
Solhapur	0.49^{M}	0.48^{M}	0.27^{M}	0.70^{M}
Thane	0.52^{M}	0.48^{M}	0.47^{H}	0.54^{L}
Wardha	0.38^{L}	0.59^{H}	0.29^{M}	0.68^{M}
Washim	0.40^{L}	0.57^{H}	0.24^{L}	0.73^{H}
Yavatmal	0.42^{L}	0.61^{H}	0.31^{M}	0.72^{M}
Mean	**0.50**	0.49	0.31	**0.68**
SD	**0.06**	0.08	0.10	**0.11**

Note: H = High, M = Moderate and L = Low; SD = Standard Deviation

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4.2 Sensitivity

Sensitivity index for 34 districts of Maharashtra (see Table 5) showed highest sensitivity in Akola (0.68) and lowest was in Sindhudurg (0.33) with a mean index of 0.49 and SD of 0.08. A high divergence of 0.35 have been observed in sensitivity due to its varying range amongst all the districts. About twelve districts were categorized as highly sensitive, twelve districts as moderately sensitive and six districts as less sensitive. Sensitivity was observed high in eleven districts such as Latur, Jalna, Parbhani, Aurangabad, Buldhana, Hingoli, Washim, Wardha, Yavatmal, Amaravati, Akola (Central Maharashtra Plateau Zone, Eastern and Western Vidarbha. Moderate in thirteen districts like Bhandara, Pune, Chandrapur, Jalgaon, Thane, Solapur, Dhule, Nanded, Beed, Osmanabad, Nagpur, Nandurbar, Palghar (Scarcity Zone, South and North Konkan Coastal Zone). Lowest in ten districts such as Sindhudurg, Ratnagiri, Satara, Raigad, Gadchiroli, Ahmednagar, Nashik, Sangali, Kolhapur, Gondia (Scarcity Zone, Sub montane Zone). Higher sown area, higher percentage of small and marginal farmers to the total farmers, high sown area, low ground water level (Ahsan et al. 2010; Malakar et al. 2017; Balaganesh et al. 2020; Singh 2020) influenced positively to the sensitivity. Thought there was high irrigated area, high no. of total bovines, districts not escaped from sensitivity. Districts like Beed, Nagpur and Aurangabad were having higher no. of suicides (Brenkert and Malone 2005) which is the main reason of sensitivity in the mentioned districts. Hence comprehensive measure should be taken to mitigate socio-economic vulnerability. The highest sensitivity weightage was found in the case of per cent sown area (4.46) whereas, lowest was observed in ground water availability (2.69).

4.3 Adaptive capacity

Adaptive capacity index for 34 districts of Maharashtra is presented in Table 5. The highest adaptive capacity was found in Pune (0.56), while lowest was observed in Beed (0.19) with a mean index of 0.31 and SD of 0.10. Highest divergence value (0.37) has been observed in adaptive capacity. About nine districts were classified as highly adaptive to climate change, twelve districts as moderately adaptive and thirteen districts show low adaptive capacity. Highly adaptive districts are from Western Ghat Zone, Western Maharashtra Plain Zone, North Konkan Coastal Zone. The main reason for this may be high literacy rate, high rate of crop diversification, higher breedable population, higher milk yield, high no. of district artificial insemination centres (Shinde et al. 2013; Maiti et al. 2015; Vardan and Kumar 2015; Mittal and Hariharan 2016). Moderately and low adaptive districts are from Central Maharashtra Plateau Zone, Eastern and Western Vidarbha Zones because of low rate of crop diversification, low percentage of electrified households, low literacy rate, less milk production (Brenkert and Malone 2015; Balaganesh et al. 2020). The variable having highest weightage was total milk production (5.47), which leads to increase the adaptive capacity of the farmers as an important risk reducer component in farming, while lowest weightage was found in the case of share of SID (2.53).

4.4 Inter-index comparison of exposure, sensitivity and adaptive capacity

Adaptive capacity was lower for all the districts than exposure and sensitivity put together, except Pune that registered the highest adaptive capacity (0.58) (Fig. 1). District like Sangali have highest exposure, low sensitivity and high adaptive capacity. Hence categorized in moderate SeVI category. This implies that sensitivity and adaptive capacity play important role in reducing socio-economic vulnerability to climate change. Hingoli and Washim have low exposure index, high sensitivity index and low adaptive capacity index. Hence both the districts represent high SeVI. Buldhana and Parbhani have moderate exposure, high sensitivity and low adaptive capacity. Hence, these two districts represent high SeVI category.

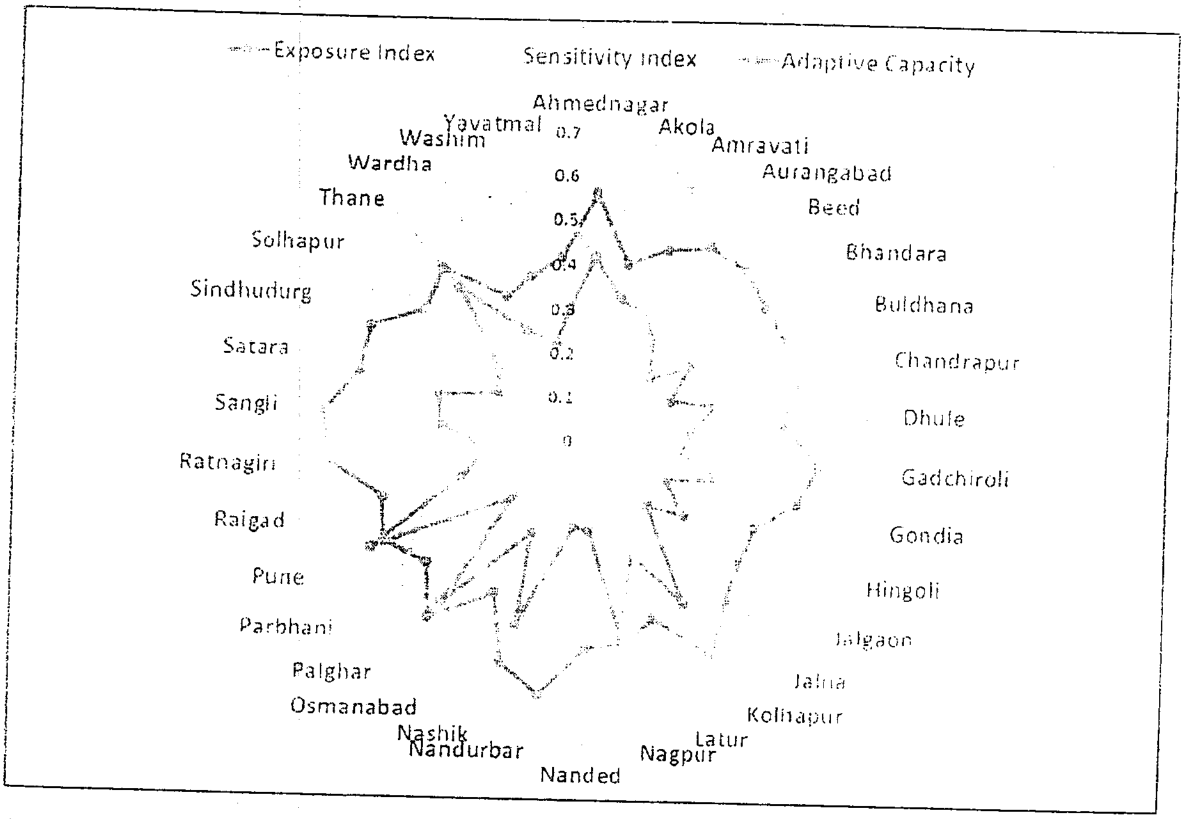

Fig. 1 Radar pictorial of exposure, sensitivity and adaptive capacity indices

Critical evaluation of inter-index comparison showed that all the districts have less adaptive capacity comprising more sensitivity and exposure implies that the study region is significantly vulnerable to climate change.

4.5 Socio-economic vulnerability index (SeVI)

The SeVI was computed using exposure, sensitivity and adaptive capacity indices (see Table 5). SeVI shows a wide divergence of 0.50 with a mean index of 0.68 and SD of 0.12. Socio-economic Vulnerability Index was highest in Nandurbar (0.91) and lowest in Pune (0.41). Results of district level vulnerability mapping showed that out of thirty-four districts, eleven districts were categorized as highly vulnerable, 14 as moderately vulnerable and nine as less vulnerable to climate change. Most of the highly vulnerable districts are from Central Maharashtra Plateau Zone. Moderately vulnerable districts are from Central and Eastern Vidarbha Zone. Less vulnerable districts are from North Konkan Coastal, Scarcity Zone and Western Maharashtra Zone. Potential impact for each district was calculated using sum of exposure and sensitivity (Eq.3.) shows mean score 0.98, SD 0.06 and low divergence value 0.24. The highest potential impact was observed in Nandurbar (0.59 + 0.52 = 1.11), followed by Buldhana (1.08), Palghar (1.07), Sangali, Jalna, Beed (1.03), Parbhani (1.02) and Hingoli (1.01). Possible reason behind this may be the high values of trend coefficients for climatic variables (For ex. Coefficient of trend in daily average *kharif* temperature and rainfall is 3.07 and 0.23 for Nandurbar) and persistent droughts prevailing in these districts. Lowest potential impact was found in Raigad (0.53+ 0.44 = 0.87). Reason behind this may be high drought return period causing less potential impact and lowering overall socio-economic vulnerability to climate change.

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4.6 Mapping of SeVI

Based on categorization of districts done in Table 5, the socio-economic vulnerability mapping was done for different districts accordingly (see Fig. 2). Table 6 shows the distribution of socio-economic parameters across vulnerability categories. For instance, combining the information from SeVI mapping and Table 6, it is explicit that out of 34 districts, 11 were categorized as highly vulnerable (having 39.94% cropped area), 14 as moderately vulnerable (36.85% cropped area), and nine as less vulnerable to climate change (23.21% cropped area). Further, farmers' suicide, a crucial indicator for SeVI, is more in the highly vulnerable region of Maharashtra registering 64.01 per cent.

Table 6 Distribution of socio-economic parameters across vulnerability categories.

Category	Total cropped area (hectare)	Total irrigated area (hectare)	Total bovine population (No.)	Average size of operational holdings for marginal farmers (acre)	Average size of operational holdings for small farmers (acre)	Farmers suicides (No.)
High	948.36 (39.94)	950200 (24.51)	5408865 (27.78)	6.83 (36.58)	15.46 (32.17)	891.00 (64.01)
Moderate	875.07 (36.85)	1405200 (36.24)	7455970 (38.30)	7.69 (41.19)	19.67 (40.94)	353.00 (25.36)
Low	551.17 (23.21)	1521800 (39.25)	6603529 (33.92)	4.15 (22.23)	12.92 (26.89)	148.00 (10.63)

Note: * Mumbai City and Mumbai Suburban districts are omitted from the analysis.
**For bovine population analysis, 20th Livestock Census-2019 data have been used.
Figures within parentheses indicate percentage share.

Maharashtra has been divided into nine agro-climatic zones based on rainfall, soil type and the vegetation as Central Maharashtra Plateau Zone, Central Vidarbha, Eastern Vidarbha Zone, North Konkan Coastal Zone, South Konkan Coastal Zone, Scarcity Zone, Sub Montane Zone, Western Ghat Zone, Western Maharashtra Plain Zone (Dairying in Maharashtra, A statistical profile, NDDB, 2015[4]). Fig.2. Fig. 3 and Table 7 gives a clear picture of vulnerability across the state comprising agro-climatic zones. Most of the highly vulnerable districts fall under the Central Maharashtra Plateau Zone with 26.81 per cent share of geographical area. Same zone covers 7.29 per cent area under moderately vulnerable category. Central Vidarbha Zone shares 6.58 per cent area, which falls under highly vulnerable category, 6.46 per cent area is moderately vulnerable and 3.21 per cent as less vulnerable to climate change. Eastern Vidarbha Zone shares 11.43 per cent geographical area under moderately vulnerable category. North Konkan Coastal Zone is having 5.43 per cent share of geographical area in less vulnerable category. South Konkan Coastal Zone covers two districts (Ratnagiri and Sindhudurg) having 4.36 per cent area under moderately vulnerable category. Scarcity Zone shares 7.57 per cent area, which falls under highly vulnerable category. In the same zone, 12.65 per cent area is moderately vulnerable and 8.94 per cent as less vulnerable to climate change. Sub Montane Zone shares 5.91 per cent of the total geographical area under moderately vulnerable category and 10.13 per cent area is less vulnerable. In the Western Ghat Zone, moderately vulnerable districts are having 7.55 per cent share to the total area. Western Maharashtra Plain Zone 1.49 per cent area falls under highly vulnerable category, 8.7 per cent area is moderately vulnerable and 10.13 per cent as less vulnerable to climate change. Results show that most of the highly vulnerable districts fall under Central Maharashtra Plateau, Central Vidarbha and Scarcity

[4] https://www.nddb.coop/sites/default/files/NDDB%20Maharashtra%20dairy%20Diggest.pdf

Zone. This is because these zones have high exposure and sensitivity compared to others and also low drought return periods causing threat to farming. Moderately vulnerable districts are found in every climatic zone except North Konkan Coastal Zone. This is because of North Konkan Zone have high sensitivity but low adaptive capacity implying scope for diversified farming in this area. There is not a single district found in Central Maharashtra and Eastern Vidarbha Zone under less vulnerable category. Mapping of districts show that there is an instant need for focused policy efforts in Central Maharashtra Plateau Zone, Scarcity Zone and Eastern Vidarbha Zone.

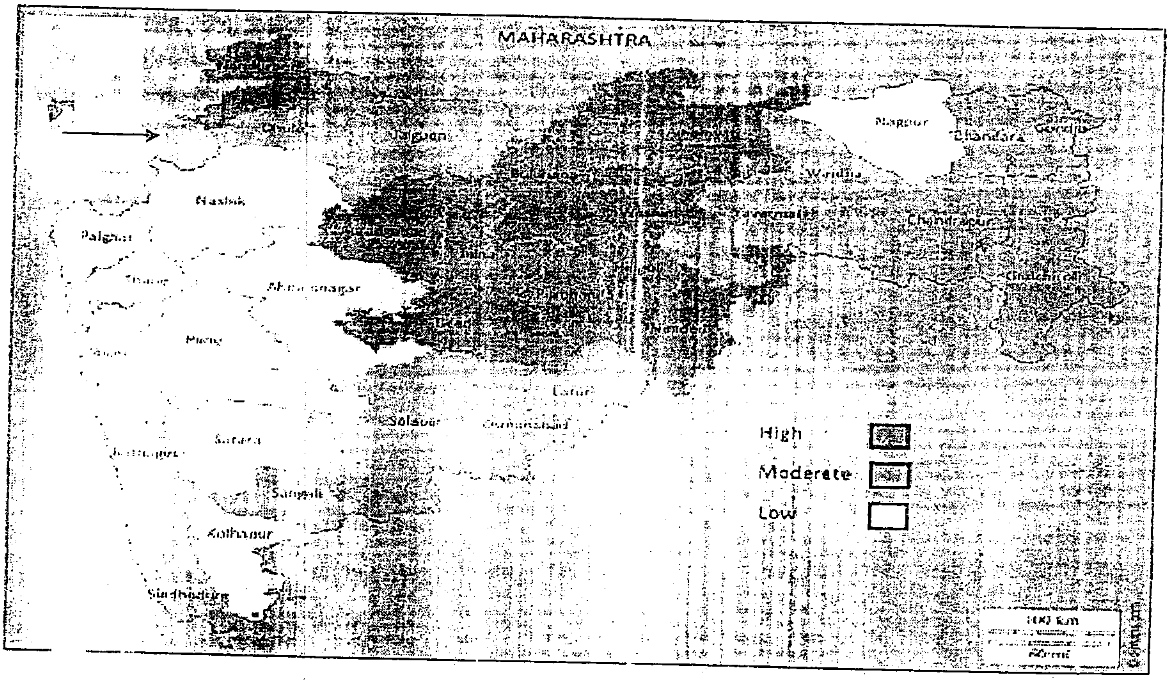
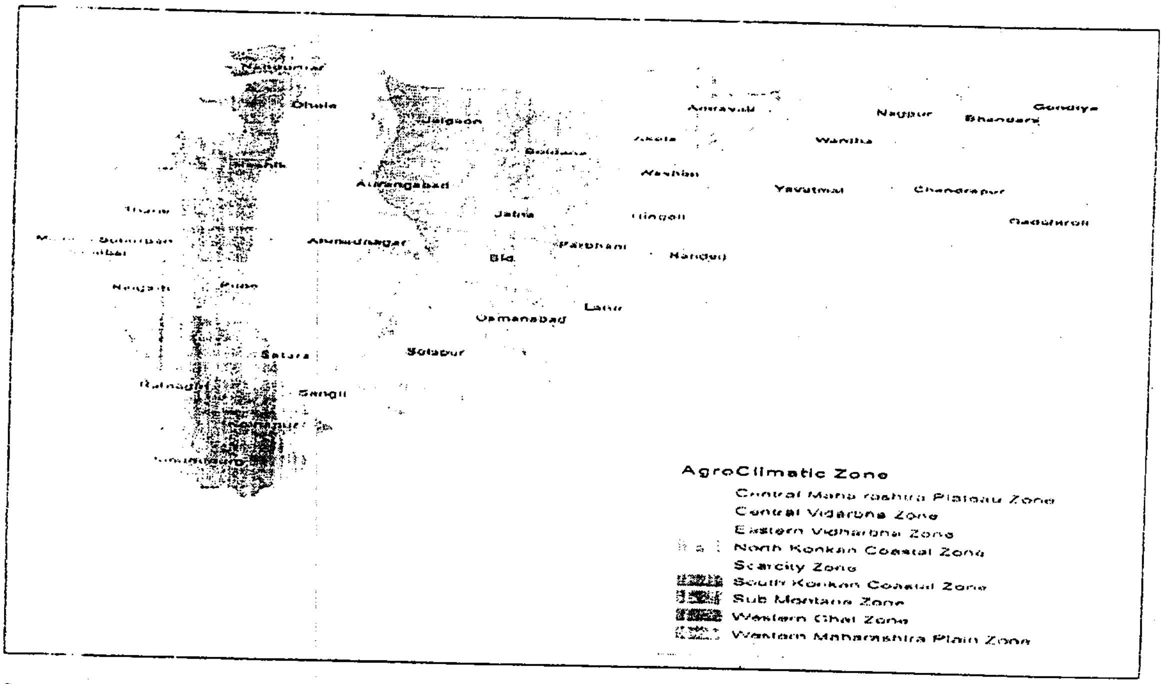


Fig. . lapping of socio-economic vulnerability in Maharashtra.



Source: Dairying in Maharashtra, A Statistical Profile, NDDB (2015)

Fig. 3 Agro-climatic zones in Maharashtra.

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Table 7 Agro-climatic zone wise classification of socio-economic vulnerability.

Agro-climatic zone	Categories of socio-economic vulnerability					
	High	% share of geographical area	Moderate	% share of geographical area	Low	% share of geographical area
Central Maharashtra Plateau Zone	Aurangabad, Buldhana, Jalna, Beed, Parbhani, Nanded, Hingoli, Washim, Akola, Amaravati	26.81	Jalgaon, Osmanabad and Latur	7.29	-	
Central Vidarbha	Part of Washim, Hingoli, Nanded	6.58	Wardha, Yavatmal	6.46	Nagpur	3.21
Eastern Vidarbha Zone	-		Bhandara, Gondia, Chandrapur, Gadchiroli	11.43	-	
North Konkan Coastal Zone	-		-		Palghar, Thane, Raigad	5.43
South Konkan Coastal Zone	-		Ratnagiri, Sindhudurg	4.36	-	
Scarcity Zone	Dhule, Part of Nandurbar and Aurangabad	7.57	Solapur Part of Nashik, Sangali	12.65	Ahmednagar, Satara	8.95
Sub Montane Zone	-		Part of Satara and Kolhapur	5.91	Part of Nashik and Pune	10.13
Western Ghat Zone	-		Part of Kolhapur, Nashik	7.55	Part of Palghar, Thane, Raigad, Pune, Satara, Nashik	18.97
Western Maharashtra Plain Zone	Part of Nandurbar	1.49	Part of Satara, Sangali, Kolhapur	8.7	Part of Nashik, Pune	10.13

Note: *Mumbai and Mumbai Suburban, two districts from North Konkan Coastal Zone are omitted due to unavailability of farming data.

5 Conclusion

Climate change has become a serious threat to global farming community. In Indian perspective, Maharashtra is consistently facing major temperature and rainfall anomalies day by day. This is affecting agriculture production and sustainability of livelihoods negatively. For this reason, the present study was conducted in 34 districts of Maharashtra. Inclusive Socio-economic vulnerability index (SeVI) comprising exposure, sensitivity and adaptive capacity variables effectively helps to identify vulnerability to climate change across selected region. The results show that the highest exposure to climate change was observed in Sangali (0.62) and lowest was found in Wardha (0.38) with the mean index score of 0.50 and SD of 0.06. Sensitivity was highest in Akola (0.68) and lowest was in Sindhudurg (0.33) with a mean index of 0.49 and SD of 0.08. The highest adaptive capacity was found in Pune (0.56), while lowest was observed in Beed (0.19) with a mean index of 0.31 and SD of 0.10. Overall, SeVI shows a wide divergence of 0.50 with a mean index of 0.68 and SD of 0.12. Socio-economic Vulnerability Index was highest in Nandurbar (0.91), lowest in Pune (0.41) and moderate in Yavatmal (0.72). Most of the highly vulnerable districts fall under Central Maharashtra Plateau, Central Vidarbha and Scarcity Zone. Moderately vulnerable districts are found in every climatic zone except North Konkan Coastal Zone. There is not a single district found in Central

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Maharashtra and Eastern Vidarbha Zone under less vulnerable category. To eliminate the ill effects of climate change induced socio-economic vulnerability, regional level adaptation and mitigation strategies should be developed and diffused in farming. Strategies like water harvesting and conservation, proper credit disbursement, early warning and forecasting of climate change, climate proof shelter for farm animals, proper vaccination and periodic health check-up and diversified farming should be adopted. Grassroots level evaluation and dissemination of sustainable coping strategies are important to counter the adverse effects of climate change.

Author contribution

Chaitanya Ashok Adhav: conceptualization, methodology, formal data analysis, investigation, data curation, writing - original draft, figures, visualization of data.

Sendhil R: conceptualization, resources, visualization, supervision, methodology, writing - review and editing.

Chandel B S: methodology, resources, validation, supervision.

Gunjan Bhandari: resources, visualization, writing - review and editing.

Ponnusamy K: validation, writing - review and editing.

Hardev Ram: writing - review and editing.

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Data availability

Available on request

Declaration

Conflict of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

[5] http://[illegible].pro.com/[illegible]services/meteo-data/[illegible]

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Exhibit-B

Sr. No.	District	Name of River not included in Previous Affidavit	Demarcation Details	Status
1.	Nasik	Kadwa River	41.40	Completed
		Parasha River	23.10	Completed
		Kolvan River	20.50	Completed
		Unanda (Ozer khad Dam To Kadawa River)	7.50	Completed
		Unanda (Pune goan dam to Ozer khad Dam.)	8.60	Completed
2.	Akola	Wan *	40.00	Completed
		Morna	12.00 (In progress)	Ground Survey is completed. Maps are prepared & in process of approval. The approval & subsequent uploading on the website is planned to be completed by the end of September-2023 by following due process.
		Vidrupa	8.00 (In progress)	
3.	Hingoli	Kaydhu River	45.00	Completed
4.	Jalna	Patharawala River	2.16	Completed
		Jogaladavi River	2.15	Completed
		Shaha River	2.11	Completed
		Ramasgav River	2.10	Completed
5	Palghar	Surya	48.00	Completed
		Wandri	10.00	Completed
		Deharji	34.00	Completed
		Gargai	22.00	Completed
		Pinjal	35.00	Completed
		Tansa	56.00	Completed
		Vaitarna	84.00	Completed
		Total	**504.02**	