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Impact of rainfall on production and productivity of horticultural crops and vulnerability assessment in different districts of Chhattisgarh Plain Zone (1)

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Abstract
The present research work entitled "Impact of rainfall on production and productivity of horticultural crops and vulnerability assessment in different districts of Chhattisgarh Plain Zone (1)" was carried out to find the trend of annual rainfall, area and production, correlation analysis in order to study the impact of annual and seasonal rainfall with production and productivity of fruits and vegetables respectively followed by vulnerability assessment with respect to climate change in eight districts of Chhattisgarh plain zone 1, i.e, Raipur, Mahasamund, Dhamtari, Durg, Rajnandgaon, Kanker, Balodabazar and Gariyaband. The time series data was collected for 16 years from 2004-2020 on all the demographic, climatic, agricultural, occupational and geographic indicators. Patnaik and Naraynan method was used for calculating the vulnerability index followed by Garret's ranking method in order to calculate the percentage vulnerability of the districts. Trend analysis was done using linear trend method and correlation analysis was carried out using MS Excel software. Also, Weather Cock software was used to calculate annual rainfall from 1991-2020.
As per the analysis of overall vulnerability index followed by Garret's ranking, district Mahasamund was found to be the most vulnerable while district Rajnandgaon was observed as least vulnerable for climate change among the eight districts of Chhattisgarh plain zone 1. Assessment of vulnerability index exemplifies the impact of climate change on vulnerability in terms of exposure, sensitivity and adaptability.

Keywords: Chhani, consumption, fuel-wood, households, Lanchaan

Introduction

India, located in the central part of South Asia at the north of the equator between 17°46' to 24°5' north latitude and 80°15' to 84°20' east longitude has total geographical area of 3, 28, 7240 square kilometers. India is mainly a sub-tropical country where agriculture is basically dependent on weather elements like rainfall, temperature, sunshine hours, relative humidity etc. Due to the dependency of monsoon, climate change and variability, most of the cropped area of our country is prone to biotic and abiotic stress.

Major portion of annual rainfall *i.e.* 75% (IMD, Chennai) was received by the southwest monsoon over most part of the country. India is divided into various agroclimatic and climatic zones hence resulting in wide scope of growing horticultural crops such as fruits, vegetables, root and tuber crops, medicinal & aromatic plants, spices, condiments, flowers, ornamentals & plantation crops which contributes significantly to the country's agricultural GDP.

The Chhattisgarh state separated from the Madhya Pradesh on November 1st ,2000 with 16 district (Presently 32) with capital city at Raipur. Geographically Chhattisgarh is located in between 17-23.7N latitude and 80.40-83.38E longitude in Central eastern part of India (Chhattisgarh at a glance, 2019) with about 2.56 crore population (Census, 2011) which makes it 16th largest state with respect to population. The total geographical area of the state is about 135,194 square kilometres (Chhattisgarh at a glance, 2019), which makes it the 10th largest state in India. South- west monsoon is the major source of precipitation in the state with average precipitation of about 1200 mm/year & major portion (85%) is received during southwest monsoon June–September. Chhattisgarh falls under the rice-agro-climatic zone. Rainfed farming are mostly practiced in the entire state as 89% of the cultivated area depends upon the monsoon (Meshram *et al*. 2017).

At global level climate change evidently became the toughest challenge faced by the world. By analyzing previous trends and current irregularity in weather elements it is evident that there will be critical situation for fruits and vegetable production in the state. The state already proves to be in precarious situation due to its high climate sensitivity and vulnerability, combined with low adaptive capacity (Vulnerability assessment of Chhattisgarh towards climate change, 2014). Vulnerability assessment is very important task to assess and for preparation of future climate risk, it will also further help in improvising the mitigation and adaptation strategy and management of present agricultural and climatic risk. Vulnerability assessment for agriculture and allied sectors with context to climate change is mandatory for developing & spreading climate-smart technologies. This valuable information are required by decision maker & planner for preparing strategies to address the adverse impact of climate change and for resource allocation alongwith prioritizing the vulnerable districts.

"Vulnerability to climate change is the degree to which an agricultural unit has the capacity to sustain with the damage caused due to climate change, including climate variability and extremes". Vulnerability assessment may be defined as the procedure to identify, quantify and prioritize the vulnerability in a system (IPCC 2004).

According to IPCC 2007, the vulnerability in context of climate change "the degree to which a system is susceptible to cope with, adverse effects of climate change, including climate variability & extreme". This framework includes a system which is highly sensitive towards the modest climate change whereas sensitivity includes the potential for substantial harmful effect and for which ability to adapt is severely constrained. A greater adaptive capacity is correlated with a lower vulnerability, while a greater impact is correlated with a higher vulnerability.

Vulnerability study or extent to which the people, agriculture & environment will affect requires three type of information: (1) "exposure, i.e. patterns of exposure to occurrences of hazards such as droughts and floods" (2) "sensitivity, i.e. the degree to which the system can experience damages due to a particular event"; and (3) adaptive capacity, i.e. the capacity of a system to recover from disaster and hazards. (IPCC Second Assessment Report ,1996) diverted the focus of vulnerability into two different factor *i.e.* sensitivity and adaptive capacity. Vulnerability may be defined as the degree to which the system can be adversely affected due to climate change in addition to this, sensitivity of the system is the capacity to adapt to new climatic condition also governs the vulnerability (Watson et al. 1996). Later, the combined function of exposure, sensitivity and adaptive capacity was termed as vulnerability (McCarthy et al. 2001). IPCC in its Third Assessment Report (TAR, 2001) defines vulnerability as the degree to which an agricultural system is susceptible or unable to cope up with adverse effects of climate change including climate variability and extremes. The Fourth Assessment Report (AR4, 2007) by IPCC stated the definition of vulnerability with close affirmity that of TAR (IPCC 2001). The Fifth Assessment Report (AR5, 2013) by IPCC summarizes that warming trends & increasing temperature extremes have been observed across most of the Asian region over the past century. The impacts of climate change on food production and food security in Asia will vary by region, with many regions experiences a decline in productivity. The Sixth Assessment Report for South Asia (SAS, 2021) concludes that heatwaves and humid heat stress will be more intense and frequent, alongwith the increase in both annual and summer monsoon precipitation with enhanced interannual variability during the 21st century.

The vulnerability of Indian agriculture has been determined at the district level using three core components: (i) exposure to hazards, (ii) sensitivity to climate change, i.e. the amount of damage expected to be caused by a particular event, and (iii) adaptive capacity to recover from stress. A novelty of this study is that it has considered climatic, physical and socio-economic factors together to arrive at vulnerability rating. In the absence of state level climate models and vulnerability studies, it will be difficult to manage it's as low community awareness and information, Chhattisgarh is potentially highly sensitive and vulnerable to climate change and its impacts.

Materials and Method

Study area

Chhattisgarh, formerly the part of Madhya Pradesh, came into existence on 1 November 2000 as the 26th state of union. Situated in the eastern India, Chhattisgarh lies between 17-23.7N latitude and 80.40-83.38E longitude. Surrounded in the west by M.P. and Maharashtra, in the north by M.P., in the east by Odisha and Jharkhand (the new state separated from Bihar) and in the south by Andhra Pradesh and Telangana ; the state has three agro-climatic zones, *viz*., Chhattisgarh plains, Baster plateau and Northern hills region spreading over a geographical area of about 13.60 million hectares.

Most of the information regarding the rainfall climatology of any region is mostly based on weekly, monthly, seasonal and annual rainfall data that are derived from daily rainfall recorded at individual station and on an average basis worked out for respective districts. The analysis was carried out within 8 districts.

Data for the study

Rainfall data base

The data required for the rainfall analysis was collected from Department of Agrometeorology IGKV Raipur. Long term rainfall data (1991-2020) for different stations of Chhattisgarh was collected from the Department of Agrometeorology, College of Agriculture, Raipur. This study was performed by using Weather Cock software developed by CRIDA, Hyderabad (Rao *et al*., 2011).

Demographic, Occupational and Geographic data

Decadal demographic data i.e. population density and literacy rate, occupational data of agricultural workers and geographical data regarding forest area for the period 2001 and 2011 respectively was collected from the Census department of Madhya Pradesh and Chhattisgarh for respective districts (Census India).

Demographic, Climatic, and Agriculture Indices

Demographic, Climatic and Agricultural indices will be calculated as per standard procedure & formula given by Patnaik and Narayanan (2005) [13] for different district of Chhattisgarh. Climatic vulnerability index for different districts will be carried out with the help of following formula-

Vulnerability Index = $[\sum_{i=1}^{n} (AI\ i)\ \alpha]_{1/\alpha}$ / n

Where

AI = Average index

n = number of source of Vulnerability and α = n

Method description

Construction of Vulnerability Index

The details of construction of Vulnerability Index are given below. First is the selection of study area which consists of eight districts of Chhattisgarh plain zone 1. For each district, set of five indicators were selected. All these indicators were grouped as demographic, climatic, agricultural, geographical and occupational parameters for vulnerability. Following is a list of selected indicators alongwith their functional relationship identified with vulnerability presented in Table 3.3.

Table 1: Functional relationship of indicators with vulnerability to climate change

S. No	Component	Indicator	Functional Relationship
1.	Demographic (2)	a. Population Density (person per sq. km)	↑
2.		b. Literacy rate (%)	↓
3.	Climatic (2)	a. Annual rainfall (mm)	↑
4.		b. Seasonal rainfall	↑
5.	Agriculture (3)	a. Area, production and productivity of selected crop	↑
6.		b. Cropping intensity (%)	↓
7.		c. Irrigation intensity (%)	↓

8.	Occupational (4)	a. Total main workers (no. per ha of net area sown)	↓
9.		b. Agricultural labourers (no. per ha of net area sown)	↓
10.		c. Non workers (no. per ha of net area sown)	↑
11.		d. Industrial labourers	↓
12.	Geographic (1)	a. Forest area	↓

Steps for calculation of the Vulnerability Index

Basically three types of indicators are used here to calculate climatic vulnerability.

In step i, we will calculate the geometric mean of demographic, climatic and agricultural indicators through the dimension index. Two type of functional relationship was possible *i.e.* ↑ functional relationship and ↓ functional relationship.

In this case we say that the variables have ↑ functional relationship with vulnerability and the normalization is done using the formula-

$$\text{Dimension index} = \frac{(\text{Actual } X_I - \text{Minimum } X_I)}{(\text{Maximum } X_I - \text{Minimum } X_I)} \quad (1)$$

Where

Actual X_I = Actual value of Current Year

Minimum X_I = Minimum value of Current Year

Maximum X_I = Maximum value of Current Year

All climatic indicators and one demographic indicator like population density both are calculated through this formula.

In this case we say that the variables have ↓ functional relationship with vulnerability and the normalization is done using the formula-

$$\text{Dimension index} = \frac{(\text{Actual } X_I - \text{Minimum } X_I)}{(\text{Maximum } X_I - \text{Minimum } X_I)} \quad ..(2)$$

Where

Actual X_I = Actual value of Current Year

Minimum X_I = Minimum value of Current Year

Maximum X_I = Maximum value of Current Year

All agricultural indicators and one demographic indicator like literacy rate both are calculated with the help of this formula.

This method of normalization that takes into account the functional relationship between the variable and vulnerability is important in the construction of the indices. If the functional relation is ignored and if the variables are normalized simply by applying formula (1), the resulting index will be misleading.

i. **In step ii**, the value of geometric mean of demographic, climatic and agricultural indicators obtained from step 1 will be calculate through the average index.

$$\text{Average Index i} = [\text{Indicator}_1 + \ldots\ldots\ldots + \text{Indicator}_J]/J$$

Where,

Indicator_1 = Geometric mean of Indicator_1

Indicator_J = Geometric mean of Indicator_J

J = number of indicators in each source of vulnerability

ii. In step iii, After calculation of average index (AI) for demographic, climatic and agricultural indicators, we have to work out climate vulnerability index is computed with the help of following formula:

$$\text{Vulnerability Index} = [\textstyle\sum_{i=1}^{n} (\text{AI i})\ \alpha]^{1/\alpha} / n$$

Where,

AI = Average index

n = number of source of Vulnerability and α = n

iii. **In step iv, Garrett's Ranking Technique:**

Outcome of step three will be ranked as per degree of vulnerability. The assigned rank was converted into percentage position which was subsequently transferred into Garrett score using Garrett's table. For each constraint, scores of individual respondents were added together and then divided by total number of respondents. Thus, mean score for each constraint was ranked by arranging them in descending order.

$$\text{Percentage position} = \frac{100\,(Rij - 0.50)}{Nj}$$

Where

R = Rank given for the i item by the j individual and

N = Number of items ranked by the j individual.

Result and Discussion

District wise vulnerability analysis for eight districts of Chhattisgarh plain zone 1 and status of degree of vulnerability from the year 2004-20

District wise vulnerability analysis has been carried out on the basis of five indicators (demographic, climatic, agricultural, occupational and geographic) has been carried out as per the vulnerability index methodology proposed by Patnaik and Narayanan (2005) [13] later used by Hiremanth and Shiyani (2013) [8]. The analysis is based on the secondary data taken as per the yearly basis for eight districts of Chhattisgarh plain zone 1. The findings of the analysis has been presented in the table given below.

Table 1: Indicator wise vulnerability index for eight districts of Chhattisgarh plain zone 1

District	Demographic vulnerability	Climatic vulnerability	Agricultural vulnerability	Occupational vulnerability	Geographic vulnerability
Raipur	0.59	0.52	0.40	0.31	0.67
Mahasamund	0.77	0.54	0.74	0.58	0.93
Dhamtari	0.26	0.48	0.45	0.61	0.87
Durg	0.71	0.33	0.19	0.47	1.00
Rajnandgaon	0.19	0.43	0.70	0.46	0.37
Kanker	0.30	0.47	0.81	0.71	0.49
Balodabazar	0.43	0.32	0.60	0.47	0.98
Gariyaband	0.50	0.41	0.84	0.67	0.97

Table 2: Average vulnerability Index with Rank for different districts of Chhattisgarh plain zone 1

S. No	District	Average vulnerability index (AVI)	Rank
1	Raipur	0.502	7
2	Mahasamund	0.714	1
3	Dhamtari	0.538	6
4	Durg	0.543	5
5	Rajnandgaon	0.431	8
6	Kanker	0.559	4
7	Balodabazar	0.564	3
8	Gariyaband	0.680	2

Table 3: Garret ranking score of average vulnerability index for different districts of Chhattisgarh plain zone 1

S. No	District	AVI Rank	Garret's percentage	Garret's Ranking
1	Raipur	7	81.25	32
2	Mahasamund	1	6.25	80
3	Dhamtari	6	68.75	41
4	Durg	5	56.25	47
5	Rajnandgaon	8	93.75	20
6	Kanker	4	43.75	53
7	Balodabazar	3	31.25	60
8	Gariyaband	2	18.75	68

Average vulnerability has been worked out adding the individual values of all indicator's average. As eight districts are taken for analysis, dividing by 8 provides general status of vulnerability of all the eight districts. The average of all values indicate that the district having highest garret ranking is the most vulnerable among all the districts taken into consideration. Hence, Mahasamund ranks first and is found to be the most vulnerable district among all situated in Chhattisgarh plain zone 1 while district Rajnandgaon is found to be the least vulnerable district with lowest average index of all indicatos as per the observation. Remaining districts fall in between these two categories.

Conclusion

As per the analysis of overall vulnerability index followed by Garret's ranking, district Mahasamund was found to be the most vulnerable while district Rajnandgaon was observed as least vulnerable for climate change among the eight districts of Chhattisgarh plain zone 1.

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