

**IMPACT OF RAINFALL ON PRODUCTION AND
PRODUCTIVITY OF HORTICULTURAL CROPS AND
VULNERABILITY ASSESSMENT IN DIFFERENT
DISTRICTS OF NORTHERN HILLS ZONE OF
CHHATTISGARH**

M.Sc. (Ag.) THESIS

by

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**DEPARTMENT OF AGROMETEOROLOGY
COLLEGE OF AGRICULTURE
FACULTY OF AGRICULTURE
INDIRA GANDHI KRISHI VISHWAVIDYALAYA
RAIPUR (Chhattisgarh)
2021**

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CHHATTISGARH**

Thesis

**Submitted to the
Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)**

**by
Sheetal Yadav**

**IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF**

**Master of Science
in**

**Agriculture
(Agrometeorology)**

Roll No. 20192346

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October, 2021

CERTIFICATE – I

This is to certify that the thesis entitled “**Impact of rainfall on production and productivity of horticultural crops and vulnerability assessment in different districts of Northern Hills zone of Chhattisgarh**” submitted in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Sheetal Yadav** under my guidance and supervision. The subject of the thesis has been approved by the student Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by her.

Uyom
23.12.21

Signature of Major Advisor

Dr. G.K. Das

Date:

THESIS APPROVED BY THE STUDENT ADVISORY COMMITTEE

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Member (Dr. R.R. Saxena)

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CERTIFICATE-II

This is to certify that the thesis entitled "**Impact of rainfall on production and productivity of horticultural crops and vulnerability assessment in different districts of Northern hills zone of Chhattisgarh**" Submitted by **Sheetal Yadav** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirement for the degree of Master of Science in Agriculture in the Department of Agrometeorology has been approved by the external examiner and students Advisory Committee after oral examination, under the chairmanship of the head of the Department/Dean.

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23.12.21

Signature of Head of the Department

Name

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Approved/Not approved

Director of Instructions

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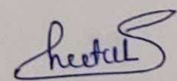

Sheetal Yadav

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LIST OF NOTATIONS/SYMBOLS

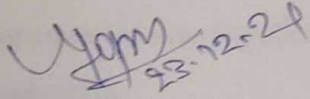
Notation/symbols	Full form
i.e.	: That is
-	Minus
y	Rainfall
Kg ha ⁻¹	: Kilogram per hectare
t ha ⁻¹	: tonnes per hectare
a	: Intercept
b	Slope
viz.	: Namely
etc.	: etcetera (other things)
Mm	: Millimeter
et al.	: and other
e.g.	: Example
%	: per cent
Ha.	: Hectare
F°	Fahrenheit
a/c	According to
°C	: degree Celsius
Fig.	: Figure
@	At the rate of
<	: Less than
+	: Plus

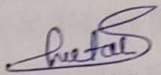
LIST OF ABBREVIATION

CG	:	Chhattisgarh
IGKV	:	Indira Gandhi Krishi Vishwavidyalaya
CAGR		Crop annual growth rate
APEDA		Agricultural and Processed Food Products Export Development Authority
IPCC	:	Intergovernmental Panel on Climate Change
CV	:	Coefficient of variation
NE		North-East
ACZ	:	Agro Climatic Zone
DRS	:	Directorate Of Research Station
CRIDA	:	Central Rice Research Institute For Dry-Land Agriculture
WMO	:	World Meteorological Organization
FAO		Food and Agriculture Organization
RF	:	Rainfall
NHB		National Horticulture Board
AMSL	:	Above Mean Sea Level

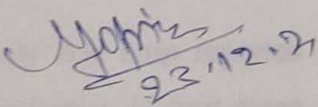
THESIS ABSTRACT

- a) Title of the Thesis : "Impact of rainfall on production and productivity of horticultural crops and vulnerability assessment in different districts of Northern hills zone of Chhattisgarh"
- b) Full Name of the Student : Sheetal Yadav
- c) Major Subject : Agrometeorology
- d) Name and Address of the Major Advisor : Dr. G.K. Das
Professor and HOD
Department of Agrometeorology college of Agriculture, Raipur
- e) Degree to be Awarded : M.Sc.(Ag.) Agrometeorology


Signature of Major Advisor


Signature of Student

Date.....


Signature of Head of the Department

ABSTRACT

The present studied entitled "**Impact of rainfall on production and productivity of horticultural crops and vulnerability assessment in different districts of Northern hills zone of Chhattisgarh**" was carried out at department of Agro-meteorology, COA, IGKV, Raipur to find out the trend of annual rainfall, area and production, correlation coefficient analysis of rainfall (annual and seasonal) with production and productivity of fruit and vegetable crops with different districts of Northern hills zone. Vulnerability assessment was also conduct. The crop data (2004-2020) and long term rainfall data (1991-2020) were used for present study. The rainfall data was collected form department of Agrometerology and crop data was collected from Directorate of Economics and Statistics. On all demographic, climatic, agricultural, occupational and geographic indicator, time series data was

indicator, time series data was collected for 16 years, from 2004-2020 from different source (Economics and Statistics). The rainfall trend analysis were computed with the help of linear trend graph method.

Trend analysis of annual rainfall in districts Surguja and Jashpur recorded non-significant decreasing trend whereas districts Koriya, Balrampur and Surajpur was found non-significant increasing trend. The maximum average annual rainfall was found in Surajpur district (1350.3 mm) and lowest average annual rainfall was found 1143 mm in Balrampur district.

In case of fruit crops five districts of Northern hills zone showed significant for both area and production but only district Surguja showed non-significant for most of the crops. Since all fruit crops showed increasing trend except for mango in Surguja district. In the same way most all vegetable crops showed significant increasing trend in Jashpur, Koriya and Balrampur districts while in district Surguja and Surajpur reported non-significant trend either increasing or decreasing both for area and production.

In correlation coefficient of rainfall with fruits only few crop reported significant correlation with production and productivity. Production of fruit crops was found significantly positive correlation with rainfall in district Surajpur for all crop except papaya. Mango and papaya production was reported significantly positive correlation with rainfall in Balrampur district. In Surguja district only papaya crop was found significantly negative correlation with rainfall and production of papaya cultivation.

When we see the result of productivity of fruit crop only the districts Koriya, Balrampur and Surajpur were found significantly positive or negative correlation with rainfall. In Koriya district only mango crop was recorded significantly positive correlation with rainfall whereas in Balrampur district only litchi and banana crop reported significantly negative correlation with rainfall and productivity. A significant positive correlation was found in district Surajpur for jackfruit and banana productivity.

In case of vegetable crops correlation was carried with seasonal rainfall (October, November, December and January). The results reported that all selected vegetables crops indicate non-significant positive or negative correlation on both production and productivity for all districts of Northern hills zone. Only in the district Jashpur reported significantly positive correlation with productivity of potato and seasonal rainfall.

The district Surajpur was found most vulnerable district as compare to other districts while Balrampur district showed least vulnerable. District Surguja, Jashpur and Koriya was moderate vulnerable with respect to climate change. To decrease vulnerability increase literacy rate, geographical area and increase area and production of crops.

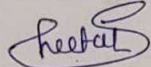
Keyword: trend analysis of rainfall, crop analysis, correlation, vulnerability assessment, climate change

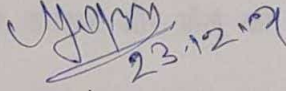
शोधसार

क) शोध का शीर्षक	छत्तीसगढ़ के उत्तरी पहाड़ी क्षेत्र में बागवानी फसलों के उत्पादन और उत्पादकता पर वर्षा का प्रभाव और विभिन्न जिलों में भेद्यता मूल्यांकन
इ) छात्रा का पूरा नाम	शीतल यादव
ग) प्रमुख विषय	कृषि मौसम विज्ञान
द) प्रमुख सलाहकार का नाम एवं पता	डॉ जी के दास प्राध्यापक और विभागाध्यक्ष कृषि मौसम विज्ञान विभाग कृषि महाविद्यालय, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर
ड.) प्रदान की जाने वाली उपाधि	कृषि स्नातकोत्तर (कृषि मौसम विज्ञान),

प्रमुख सलाहकार के
हस्ताक्षर

दिनांक.....


छात्रा के हस्ताक्षर


विभागाध्यक्ष के हस्ताक्षर

सारांश

वर्तमान अध्ययन शीर्षक "छत्तीसगढ़ के उत्तरी पहाड़ी क्षेत्र में बागवानी फसलों के उत्पादन और उत्पादकता पर वर्षा का प्रभाव और विभिन्न जिलों में भेद्यता मूल्यांकन" वार्षिक की प्रवृत्ति का पता लगाने के लिए कृषि-मौसम विज्ञान विभाग, कृषि महाविद्यालय आईजीकेवी, रायपुर में किया गया। उत्तरी पहाड़ी क्षेत्र के विभिन्न जिलों के साथ फल और सब्जी फसलों के उत्पादन और उत्पादकता के साथ वर्षा, क्षेत्र और उत्पादन, वर्षा (वार्षिक और मौसमी) का सहसंबंध गुणांक विश्लेषण किया गया। भेद्यता मूल्यांकन भी आयोजित किया गया था। वर्तमान अध्ययन के लिए फसल डेटा (2004-2020) और दीर्घकालिक वर्षा डेटा (1991-2020) का उपयोग किया गया। अर्थशास्त्र और सांख्यिकी निदेशालय से फसल डेटा और कृषि-मौसम विज्ञान विभाग से वर्षा के आंकड़े एकत्र किए गए। सभी जनसांख्यिकीय, जलवायु, कृषि, व्यावसायिक और भौगोलिक संकेतकों पर, विभिन्न स्रोतों (अर्थशास्त्र और सांख्यिकी) से 2004-2020 से 16 वर्षों के लिए समय श्रृंखला डेटा एकत्र किया गया था। वर्षा प्रवृत्ति विश्लेषण की गणना रैखिक प्रवृत्ति ग्राफ विधि की सहायता से की गई।

सरगुजा और जशपुर जिलों में वार्षिक वर्षा के रुझान विश्लेषण में गैर-महत्वपूर्ण कमी की प्रवृत्ति दर्ज की गई, जबकि कोरिया, बलरामपुर और सूरजपुर जिलों में गैर-महत्वपूर्ण वृद्धि की प्रवृत्ति पाई गई। अधिकतम औसत वार्षिक वर्षा सूरजपुर जिले में (1350.3 मिमी) और सबसे कम औसत वार्षिक वर्षा बलरामपुर जिले में 1143 मिमी पाई गई।

फल फसलों के मामले में उत्तरी पहाड़ी क्षेत्र के अधिकतम जिलों में क्षेत्र और उत्पादन दोनों के लिए महत्वपूर्ण प्रतिक्रिया दिखाया, लेकिन अधिकांश फसलों के लिए केवल जिला सरगुजा ने गैर-महत्वपूर्ण प्रतिक्रिया दिखाया। सरगुजा जिले में आम को छोड़कर सभी फलों की फसलों में वृद्धि का रुझान दिखा। इसी प्रकार अधिकांश सब्जियों की फसलों में जशपुर, कोरिया और बलरामपुर जिलों में उल्लेखनीय वृद्धि हुई है, जबकि जिले सरगुजा और सूरजपुर में गैर-महत्वपूर्ण प्रवृत्ति या तो क्षेत्र और उत्पादन दोनों के लिए बढ़ रही है या कम हो रही है।

वर्षा के सहसंबंध गुणांक में केवल कुछ ही फसलों ने उत्पादन और उत्पादकता के साथ महत्वपूर्ण सहसंबंध की सूचना दी। फल फसलों के उत्पादन में पपीता को छोड़कर सभी फसलों के लिए जिला सूरजपुर में वर्षा के साथ महत्वपूर्ण सकारात्मक सहसंबंध पाया गया। बलरामपुर जिले में वर्षा के साथ आम और पपीते के उत्पादन में महत्वपूर्ण सकारात्मक संबंध बताया गया। सरगुजा जिले में केवल पपीते की उत्पादन का वर्षा के साथ महत्वपूर्ण नकारात्मक सहसंबंध पाया गया।

जब हम फल फसल की उत्पादकता का परिणाम देखते हैं तो केवल कोरिया, बलरामपुर और सूरजपुर जिलों में वर्षा के साथ महत्वपूर्ण सकारात्मक या नकारात्मक सहसंबंध पाया गया। कोरिया जिले में केवल आम की फसल में वर्षा के साथ महत्वपूर्ण सकारात्मक सहसंबंध दर्ज किया गया, जबकि बलरामपुर जिले में केवल लीची और केले की फसल ने वर्षा और उत्पादकता के साथ महत्वपूर्ण नकारात्मक सहसंबंध दिखाया। जिला सूरजपुर में कटहल और केले की उत्पादकता के लिए एक महत्वपूर्ण सकारात्मक सहसंबंध पाया गया।

सब्जी फसलों के मामले में मौसमी वर्षा (अक्टूबर, नवंबर, दिसंबर और जनवरी) के साथ सहसंबंध किया गया था। परिणामों ने बताया कि सभी चयनित सब्जियों की फसलें उत्तरी पहाड़ी क्षेत्र के सभी जिलों के उत्पादन और उत्पादकता दोनों पर गैर-महत्वपूर्ण सकारात्मक या नकारात्मक सहसंबंध दर्शाती हैं। केवल जशपुर जिले में आलू की उत्पादकता और मौसमी वर्षा के साथ काफी सकारात्मक संबंध बताया गया है।

जलवायु परिवर्तन के प्रति समग्र संवेदनशीलता के परिणामों से पता चला कि सूरजपुर जिला अन्य जिलों की तुलना में सबसे अधिक संवेदनशील जिला पाया गया, जबकि बलरामपुर जिला सबसे कम संवेदनशील पाया गया। जलवायु परिवर्तन के संबंध में जिला सरगुजा, जशपुर और कोरिया मध्यम संवेदनशील हैं। भेद्यता को कम करने के लिए साक्षरता दर, भौगोलिक क्षेत्र में वृद्धि और क्षेत्र और फसलों के उत्पादन में वृद्धि करना आवश्यक है।

सूचक शब्द : वर्षा की प्रवृत्ति विश्लेषण, फसल विश्लेषण, सहसंबंध, भेद्यता मूल्यांकन, जलवायु परिवर्तन

CHAPTER-I INTRODUCTION

Climate is an important factor that needs serious attention as Indian agriculture is drastically affected by climate change in rainfed conditions. Rainfall is a single most important factor which determine success or failure of crop production. Due to the wide range of variation over a wide range of scales both in space and time, it is also one of the most complex and difficult factors of the hydrological cycle. Change in rainfall trend, variability, amount, and its spatial and seasonal distribution critically modify the river runoff pattern and regimes.(Gosain *et al.*, 2006), ground water reservoirs, frequency of extreme events, including floods and droughts, cropping pattern and agricultural productivity vegetation activity. As India is a monsoon reliant country the local hydrological, agricultural and economic activities heavily depend on micro-level rainfall. So it is necessary to analyze the occurrence and distribution of rainfall.

In India, for most parts of the country, 70-90% of the annual rainfall is received during the southwest monsoon season (June – September). In India, the average rainfall is 1250 mm. The south-west monsoon was responsible for 75% of total rainfall (June to September), the north-east monsoon for 13% (October to December), pre-monsoon cyclonic rainfall for 10% (mostly in April and May), and western disturbances for 2%. (December to February) (Chakraborty *et al.* 2013).

The global temperature has been rising for more than a century, and the effects of climate change are already visible in natural and human systems around the world (IPCC, 2014). The fifth assessment report of the Intergovernmental Panel on Climate Change, IPCC-AR5 (IPCC, 2014), defines the risk of climate change at the intersection of “hazard”, “exposure” and “vulnerability”. In this revised risk assessment framework, "vulnerability" is conceptualized as "internal attributes of the system." It represents the tendency or tendency of the system to be adversely affected and has nothing to do with hazards and exposures. The most imminent climate change is the increase in the level of greenhouse gases in the atmosphere leading to an increase in atmospheric temperature (IPCC, 2007). It is

manifested by frequent occurrences of droughts, floods, storms, melting glaciers, and rising sea levels.

These changes are already on the horizon, posing a significant danger to the nation's food security (Pathak *et al.*, 2012). Such uncertainties and hazards will become more prevalent in the future years. According to the Intergovernmental Panel on Climate Change assessment, global mean surface temperature will climb by 1.4-5.8 ° C. by 2100 (IPCC, 2001). The report projects that in the coming decades climate change will increase in all regions.

Globally, the mean earth temperature has changed by 0.74° C during 1996-2005 and is projected to increase in the range of 1-3.5° C by the year 2100. The Indian scenario of changing climate shows the same increasing trend of temperature with the warming of 0.4°C in last century and is projected to increase by 3-6° C by the end of the century (IPCC, 2007). For 1.5° C of global warming, there was increased heat waves, longer warm season and shorter cold season. At 2°C of global warming, heat extremes would more often reach critical tolerance thresholds for agricultural and health, the report shows. (a/c to sixth assessment report)

The Intergovernmental Panel on climate change (IPCC) has defined vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (McCarthy *et al.*, 2001). A vulnerability has been related or equated to concepts such as “resilience, marginality, susceptibility, adaptability, fragility, and risk” (Liverman, 1990). According to Adger and Kelly (1999), vulnerability refers to the degree to which a natural or social system is vulnerable to climate change damage.

Indicators of vulnerability assessment are used to measure and characterize a system's vulnerability. One of the most common methodologies in vulnerability research is indicator-based evaluation. In considering the prospect of a scenario of climate anomalies vulnerability may be regarded as a possibility of “future damage” (Wolf *et al.*, 2013). There is a wide consensus that vulnerability is a complex and dynamic phenomenon in which multiple aspects of a given social-ecological system interact to make individuals and regions more or less vulnerable

(Oppenheimer *et al.*, 2014). These qualities can be classified as exposure-related, sensitivity-related or adaptive-capacity related (Adger, 2006). Quantification of characteristics such as income, education, employment, gender, health status, mortality, physical aspects of the environment, institutional capacity, access to clean water, basic sanitation, and climatic scenarios have all been used in recent comparative assessments of climate change of vulnerability (Moss *et al.*, 2001). Decision makers and policy planners require information about climate change in order to prepare a strategy to address these issues. To efficiently distribute resources and mitigate the repercussions, a close assessment of the vulnerable is required.

The state of Chhattisgarh was born on November 1st, 2000 by separating 16 districts (currently 28) of the Madhya Pradesh region from the capital in Raipur. Chhattisgarh is located between latitude 17°46' to 24°06'N and longitude 80°15' to 84°20'E in the eastern central part of India with more than 20 million inhabitants. It is the 9th largest state in India, with an area of 137mha, with a population of 28.57 million as of 2020. Chhattisgarh has a tropical sub-humid climate because it is close to the Tropic of Cancer and depends on monsoon rains, making it hot and humid. The summer temperature in Chhattisgarh can reach 49° C (113° F). The average rainfall in Chhattisgarh is about 1,200 mm, which is received in about 65 rainy days, mainly due to the southwest monsoon receiving 85% of the rainfall from June to September and the remaining 15% from the northeast summer and winter. Rainfall contribution. Winter is from November to January. The winter is pleasant, with low temperatures and low humidity. The annual rainfall is the highest in the Baster Plateau (1396 mm), the lowest in the Chhattisgarh Plain (1103 mm), and the northern hilly area (1270 mm) is in the middle.

Fruits and vegetables account for nearly 90% of the country's total horticultural production. India is now the world's second largest producer of fruits and vegetables, leading in many horticultural crops such as mangoes, bananas, papaya, cashews, watermelon, apples, citrus, grapes, apples, coconuts, cowpea, peas, bitter gourd, potatoes, etc. Status, cabbage, cauliflower, eggplant, tomato, guava, onion and okra. However, the nature of horticultural crops is difficult to

assess its yield in India, the planting area of horticultural crops is 25.492 million hectares, and the total output is 313.85 million metric tons (third estimate for 2018-2019).

However, current attempts are being undertaken to create and compile statistical data by collecting data on horticulture crops in the state in a methodical manner. The main fruit crops grown in Chhattisgarh state are mango, guava, lime, litchi, cashew, sapota, etc. cultivated as both a cultivated as well as wild crop. The total area of fruit crop in the state is about 258630 ha along with the production of 2548930 Million Tonne in the year 2019-20. (a/c to Directorate Horticulture and Farm Forestry Chhattisgarh). From the perspective of agro-climate, mangoes can be successfully grown throughout the state, while the Sarguja and Jashpur areas in the northern mountainous areas are suitable for litchi production. Most vegetable crops, such as solanaceae, cucurbits, cabbage, cowpea, cauliflower, etc., grow well in the state. The total area of vegetable crops in the state is 525147 hectares. In 2109-20, the output was 7158.909 million tons. (A/c to Directorate Horticulture and Farm Forestry Chhattisgarh).

Chhattisgarh state is divided into three Agro-climatic zones such as Chhattisgarh Plains, Bastar-Plateau and Northern Hills zone. In the case of Northern hills, it comprises 21% of the geographical area of Chhattisgarh state and it includes five districts of the state such as Sarguja, Jashpur, Korea, Balrampur and Surajpur and Mango, Guava, Banana, Jackfruit, Litchi, potato, Tomato, Cabbage, Cauliflower, onion are main horticultural crops of the Northern hills zone. Litchi is one of the potential fruit crops in the area. Northern hills lie between the latitude ranging from 22⁰ to 24⁰ 11' North and longitude from 80⁰ to 84⁰ East. The normal annual rainfall is 1270 mm.

Climate change and its consequences are also a threat in Chhattisgarh. Climate change is likely to increase the frequency and intensity of climate-related natural hazards, according to available research. Early climate change research was to assess the regional climate change in Chhattisgarh State in central India and its impact on agriculture. It turns out that the size of the mutation is not the same across the state. In some places, rainfall has decreased by 30-35%, while in other

places, rainfall has only dropped from 0-5%. With changes in rainfall, overall climate change has affected the state's agriculture (Sastri, 2010).

The trend analysis of rainfall will help in future climate scenarios in Northern Hill zone and to understand the climate change. In this regard, a detailed study of monthly, seasonal and spatial variation of rainfall for the study area are need of present changing climate scenario.

Keeping these facts in view, the present study entitled “**Impact of rainfall on production and productivity of horticultural crops and vulnerability assessment in different districts of Northern Hills zone of Chhattisgarh**” was carried out with the following objectives:

1. To study the trend of rainfall, area and production of horticultural crops in different districts of Northern Hills zone of Chhattisgarh.

2. To study the impact of rainfall on production and productivity of horticultural crops in different districts of Chhattisgarh. (Mango, Litchi, Jackfruit, Papaya, Guava, Banana, Cauliflower, Cabbage, Brinjal, Tomato, Bhindi, Potato)

3. To assess and compare the districts wise vulnerability index of Chhattisgarh state of Northern Hills zone.

CHAPTER - II

REVIEW OF LITERATURE

In this chapter we discussed about the work done on the “**Impact of rainfall on production and productivity of horticultural crops and vulnerability assessment in different districts of Northern Hills zone of Chhattisgarh**” the work done in different district in Chhattisgarh, India and world has been reviewed and summarized below under given head.

2.1 Trend of rainfall, area and production of horticultural crops

2.1.1. Trend of rainfall

Panda and Sahu (2019) worked on trend analysis of seasonal rainfall pattern in Kalahandi, Bolangir and Koraput districts of Odisha, India. Rainfall data collected from period of 1980–2017 were analysed in this study. Mann–Kendall test and Sen's slope estimator were put to use in order to scrutinize and analyze the problems. The outcome of study indicates significant increasing trends are detected for rainfall limit during the period of 1980–2017. Rainfall is showing a quite good increasing trend (Sen's slope = 4.034) for JJAS season.

Kundu and Mondal (2019) showed that Maldah station documented maximum negative alteration in the size of yearly (–14%) and monsoon-season precipitation (–20.48%). South 24 Parganas precipitation post showed maximum constructive alteration in size of annual (+13.98%) and monsoon-season (+13.27%) precipitation. Precipitation after the monsoon season showed constructive alteration in size at 16 rainfall posts with maximum modification in Birbhum post (+40.07%). South 24 Parganas precipitation post showed uppermost constructive alteration in size of yearly (+13.98%) and monsoon-season (+13.27%) precipitation. Precipitation after the monsoon season showed constructive alteration in size at 16 precipitation sites with maximum alteration in Birbhum post (+40.07%).

Sevak *et al.* (2018) analysed the variability and trend analysis of rainfall for crop. The rainfall data of 37 year (1981-2017) of Sardarkrushinagar has been analyzed to find out fluctuations and presence of trend with historical time series.

The results revealed that the annual rainfall significantly increased at the rate of 13.9 mm/year. The long term annual mean of rainfall was 704.1 ± 420.1 mm with coefficient of variation of 59.7%. Decadal variability showed that the rainfall was found in decreasing trend during the decade of 1991-2000 while upward trend found during the decades of 1981-1990 and 2001-2010.

Sridhar and Raviraj (2017) the slope estimator method of MannKendall and Sen was used to analyze the yearly and periodic precipitation of 10 rain gauge posts in the Amaravathi Basin from 1982 to 2014. They stated atypical annual precipitation of 657.52 mm, of which the maximum yearly precipitation in 2005 was 1107.09 mm and the lowest for 2013 was 389.26 mm. Compared with other seasons.

Sharma *et al.* (2016) the long-standing rainfall figures (from 1965 to 2015) in the Agra region of Uttar Pradesh was studied. Linear regression testing is a parametric model, and it is one of the greatest common approaches for detecting trends in a figures sequences. The regular yearly rainfall (51 years) in the area is 671.6 mm, which is between 241.4 and 1235.1 mm. It is assessed that the yearly rainfall throughout the southwest monsoon season (June to September) accounts for about 86.6% of the annual rainfall. The average seasonal rainfall in Harif, Rabi, and summer are 576.4 mm (85.55%), 61.8 mm (91.16%) and 35.6 mm (5.29%), respectively.

Bari *et al.* (2016) investigated 50 years (1964-2013) of seasonal and annual rainfall trends and their fluctuation over time in Northern Bangladesh. The results showed that pre-monsoon and post-monsoon rainfall was increasing in most of the stations. The only decrement in pre-monsoon rainfall was found for hurdy (1.28 mm/year). Monsoon rainfall showed a decreasing trend in the majority of the area studied. Annual rainfall followed the monsoon rainfall trend. However, all of the positive and negative trends were found statistically non-significant at 95% confidence limit with the only exception for monsoon and annual rainfall at Rajshahi station.

Jana *et al.* (2016) worked upon the precipitation and drizzling-day figures in the Agra region of Uttar Pradesh from 1959 to 2010. These data was analysed

by way of Mann Kendall test, Spearman's rho test, Sen's test, regression analysis and change point analysis. The yearly monsoon and seasonal rainfall showed a significant downward trend, while May showed a significant upward trend. The yearly normal precipitation during monsoon, before monsoon and the winter season in Agra were found to be 697.10 mm, 532.90 mm, 89.30 mm and 29.06 mm, correspondingly. The rainfall after the monsoon season accounts for 76.45% of the yearly precipitation.

Mishra *et al.* (2016) found using parametric and non-parametric statistics-based tests, the trend of long-standing rainfall figures in the Tawa Command Zone of Madhya Pradesh was obtained. The average yearly rainfall in the area is 1174.8 mm, and the dependable rainfall (with a likelihood of 75%) is 989.6 mm, and the coefficient of variation is low (27.9%). There is a significant increase in rainfall during the period lying before the arrival of monsoon. The consequence of once-a-month rainfall tendency showed a declining tendency for the months of June and August, while growing tendency reflected in the months of July and September.

Jaswal *et al.* (2015) analysed the long-term precipitation data (1951-2005) for 37 stations in the western Himalayas. The findings presented that the yearly precipitation and the count of drizzling days both showed a significant downward trend, with a decrease of -4.58 mm and -0.13 days⁻¹, correspondingly. The three-dimensional pattern of monsoon precipitation and drizzling days shows that the southern and eastern regions of Himalayas have decreased significantly, especially in Shivalik, while the summer rainfall in the Central Himalayas has increased significantly, while the rainy days in Shivalik and Central Himalaya are consistent in space. The seasonal rainfall in Simla, Himachal Pradesh showed a significant increase in winter season (+1.47 mm year⁻¹) and summer season (+1.77 mm year⁻¹), and monsoon (3.71 mm year⁻¹) showed a significant increase. Decrease trend.

Khavse *et al.* (2015) analysed the trend of rainfall for Raipur. The long-duration alteration in precipitation has been evaluated by linear trend analysis method. Result showed the highest decrease in TMRF (Total Mean Rainfall) was realised in the month of August @ 1.4385 mm per year (data base 1971-2013) and

yearly TMRF amount was found to be amplified by 8.084 mm through the comparable duration. Yearly TMRF (Total Mean Rainfall) has shown significant increasing trend.

Bhuarya *et al.* (2015) calculated the periodic and yearly fluctuations in precipitation in varying areas of Chhattisgarh. The findings show the average yearly precipitation in the state is found to be 1167 ± 147 mm, of which winter, summer, southwest and monsoon stages contribute 20, 30, 1050 and 67 mm correspondingly. The Surajpur District, positioned in the Northern Hills Agricultural Climate Zone (ACZ), has the maximum yearly precipitation (1411 mm) and the southwest monsoon (1311 mm), while the Kabirdham District of the Chhattisgarh Plain ACZ has the lowermost yearly precipitation (885 mm), in the southwest Monsoon timeline (778 mm). The three-dimensional spreading of southwest monsoon precipitation in various areas shows that Kabirdham, Durg, Bemetara, Mungeli, Rajnandgaon and other areas have little precipitation and big inter-annual changeability. 80% of the arable land is planted with rice, which poses a high risk of crop failure. The event of monsoon rain failure.

Hasan *et al.* (2014) reported the yearly and periodic trends of rainfall in the South-East part of coastal Bangladesh over the period of (1980 to 2011) using non-parametric- Mann-Kendall and Sen.'s test. Result indicate that annual rainfall showed non-significant increasing trend in Bangladesh. The periodic investigation exposed least amount of rainfall occurring in winter season and how it was getting even drier. It is significant to point out that of all the seasons rainfall in pre-monsoon was growing pointedly (significant at $p= 0.05$ level) at the rate of 8.5 mm/year.

Patle and Libang (2014) worked on trend analysis of annual and seasonal rainfall to climate variability in North-East region of India. For this purpose temporal trends in annual and seasonal rainfall were detected using nonparametric Mann-Kendall test at 5% significance level. The daily time series rainfall data for the period 1971-2007 were analyzed statistically for each district separately. The result of annual rainfall was found decreasing trend in four districts of North-East region of India.

Chakraborty *et al.* (2013) worked on trend and variability analysis of rainfall series at Seonath River Basin, Chhattisgarh. In this paper, an attempt has been made to study the spatial and temporal variability of rainfall at Seonath sub basin in Chhattisgarh state (India) for 49 years (1960-2008). To detect correlation Lag-1 auto correlation coefficient was used. Mann Kendall (MK) or modified Mann-Kendall (MMK) (non-parametric) and Spearman's rho test (parametric) were applied to detect the trend. Result indicate that the decreasing trends of annual rainfall are mainly observed in the overall study area of Seonath River basin. The all-outnoteworthy reduced annual rainfall was noted for Bodala station (-13.8mm year⁻¹) and lowest for Simga station (0.1mm year⁻¹).

Singh and Dev (2012) analysed 50-year rainfall data analysis and future trend in Saharanpur region. The rainfall data analysis of Saharanpur area for a period of 50 years from 1959 to 2008 conveyed that declining tendency was found in annual rainfall. A negative trend was highlighted for the average annual rainfall for last 3 consecutive years.

Kumar *et al.* (2010) studied monthly, seasonal and annual trends of rainfall using monthly data series of 135 years (1871-2005) collected from 30 sub-division of India. Result showed that the half of the sub-division showed an increasing trend in annual rainfall, but it was significant in only three subdivision they are Haryana, Punjab, and Coastal Karnataka. Similarly, only one sub-division of Chhattisgarh indicated a significant decreasing trend out of the 15 sub-division. In India, the monsoon months of June to September account for more than 80% of the annual rainfall. During June and July, the number of sub-divisions showing increasing rainfall is almost equal to those showing decreasing rainfall. In August, the number of sub-divisions showing an increasing trend exceeds those showing a decreasing trend, whereas in September, the situation is the opposite for whole India. No noteworthy tendencies were noticed for yearly, periodic or monthly precipitation. Yearly and monsoon precipitation reduced, whereas precipitation occurring before, after and during winter months improved at the countrywide measure. Precipitation in the months of June, July and

September reduced, while in the month of August it amplified at the nationwide measure.

Das, P.J. (2009) reported that the southern part of Nagaon district in central Assam valley and adjoining parts of Karbi Anglong form a rain-shadow zone where annual rainfall is as low as 800-1200 mm. In this zone rainfall is decreasing slowly as found in Lumding where rainfall is on the decline at a rate of 2.15 mm per year. As a result water crisis might aggravate in this region in the coming years.

Naidu *et al.* (2009) studied that summer monsoon rainfall data from 30 meteorological sub-divisions of India were analysed during a 30-year period (1871-2005). The majority of the sub-divisions were found to have systematic increasing and decreasing tendencies in various segments of time series. Around the turn of the century, India was hit by a rainy monsoon. Rainfall is connected with the wakening of the southern oscillation and easing of the meridional temperature gradient across the Indian waters throughout the global warming era (1970-2005), according to 19 of the 30 meteorological subdivisions studied.

Yosef *et al.* (2009) studied that in order to discover potential patterns in rainfall extremity, researchers looked at the long-term trends of daily rainfall data in Israel as a function of intensity. Between 1950-51 and 2003-04, the rainy season, October-May, was investigated. Although there was an increase in trend across Israel, particularly in the central and southern regions, the conclusion was non-significant. The daily rainfall intensity indicated non-significant patterns of increased heavy rainfall in the centre and south and decreased heavy rainfall in the north. The north had an increase in light to moderate rainfall, while the centre and south saw a reduction. In Israel, there have been positive tendencies toward greater rainfall, which are considerable significant in several specific locations.

Osbon *et al.* (2000) analyzed variability and trend of daily heavy rainfall events over Niger River Basin Development Authority Area which were carried out by using Standardized Anomaly Index and Sperman Rank Correlation Coefficient by using 70 years of daily rainfall collected from eight stations and observed significant temporal variability on inter-annual and decadal time-scales in

the frequency of heavy rainfall events and heavy rainfall amount. Both the amount of annual heavy rainfall and frequency of heavy rainfall events demonstrated no pronounced temporal decreasing or increasing trend.

2.1.2. Trend of area and production

Kumar *et al.* (2021) worked on estimate the compound growth rate of area, production, and productivity of papaya in Bilaspur district of Chhattisgarh. The trend in area, production and productivity of papaya was estimated by computing linear equation for the period of 2007-08 to 2016-17. Result indicates that the trend of area and production of papaya crop both are increasing trend in Bilaspur district of Chhattisgarh.

Sahni *et al.* (2020) reported status of litchi cultivation in India from during 1991-2017 for litchi crop. Trend of area and production of litchi crop was found significant increasing in India. The world scenario of litchi cultivation reveals that India is the second largest producer of litchi after china with a total acreage over 93300 ha and a yearly output of over 568200 tonnes in 2016-17.

Ishfaq Ahmad shah (2020) studied Trend Analysis of Area, Production and Productivity of Apple Fruit in Jammu and Kashmir. For the present Study, Secondary data on Area, Production and productivity of apple fruit in India and the State of Jammu and Kashmir as a whole for the period from 1991-92 to 2017-18 were collected from the Department of Horticulture and the international statistical data regarding apple was obtained from the APEDA and FAO websites for the period. The Area, Production and yield of Apple in India witnessed growth momentum of 1.71, 2.83 and 1.11 respectively during the overall period. In the state of Jammu and Kashmir, the CAGR of the area has increased from 2.33 to 3.16 and the production has increased only from 3.51 to 3.83 while, the yield has decreased from 1.15 to 0.64. The estimated linear growth model for J&K's apple cultivation area shows that the annual growth rate is 3.16%. This model estimated J&K's apple cultivation area to be at 177258 hectares for the year 2020.

Devi and Kumar (2020) studied patterns and volume of vegetable production in India. To observe the patterns of area and production of principal

vegetables has been accumulated from 2001-2018. To examine the performance of vegetables, productivity has been calculated. Amongst all the vegetables, potato, onion, tomato and brinjal made a contribution with maximum area and production. The results suggested that the pattern of area and production of vegetable crop was discovered to be of growing fashion in India.

Priyadarshini *et al.* (2020) analysed the growth tendencies in area production and productivity of overall Horticultural crops in India (Haryana and Odisha states). The secondary statistics associated with area, production and productivity of overall horticultural crops in India, Haryana and Odisha were taken from national horticulture board data base and respective state horticultural departments from 2005-06 to 2017-18. The CAGR (compound annual growth rate) in area, production and productivity of the total span of horticultural crops in India were discovered 2.39, 4.72 and 2.32 percent respectively. The CAGR in area, production and productivity for Haryana was observed as 5.08, 7.55 and 2.34. for Odisha the CAGR in area, production and productivity of overall horticultural crops were observed as 0.91, 1.66. 0.75 percent respectively. The percentage change in area and production of horticultural crops in 2017-18 over 2005-06 was observed to be higher for Haryana than that of India and Odisha.

Singh *et al.* (2018) presented the production performance of fresh Mango in India. The required time series records were accumulated for a duration of 25 years from 1987-88 to 2014-15. The outcomes found out that the area under mango cultivation has registered a statistical non-sizeable positive compound growth rate of 3.78 per cent per annum, as its production registered growth rate of 3.00 per cent for the duration of the same time period. The productivity (-9.6 % pa) of mango in India was found to be registered considerably negative. It means that yield of mango declined by a grade of 0.96 per cent per annum. The Andhra Pradesh ranks first in mean area (19.35 %) assigned for mango cultivation and production (25.39 %), the compound annual growth rate, in case of area (3.36%pa) and production (1.38% pa) was found to be significantly positive while Uttar Pradesh occupied the topmost position in case of mean productivity (10.65 Mt ha.⁻¹) observed by Karnataka and Bihar.

Meenakshi S. (2018) worked on trends of horticulture and banana cultivation in India.. In order to analyse the trend and growth of the area, production and yield of banana cultivation in India throughout a duration of time, proportion approaches, co-efficient of dissimilarities, linear tendency and composite progress degree were utilised. The secondary figures observed various source from 2000-01 to 2016-17 was used for study results reveals that the area, production and yield of banana cultivation in India have been increasing at a compounded growth rate of 3.76 per cent, 4.92 per cent and 1.38 per cent respectively. The trend coefficients are optimistic and significant at 5 per cent level indicating a positive trend in the area, production and yield of banana cultivation. The trend coefficient for area, production and yield of banana cultivation is 0.045, 0.081 and 0.072. The analysis shows that trend in the area, production and yield of banana cultivation are positive and significant and the growth is increasing at a compounded rate of 3.76 per cent, 4.92 per cent and 1.38 per cent respectively.

Ghimire *et al.* (2018) analysed the trend on expanse, production and harvest of chief vegetables of Nepal. The time series data from 1977-78 to 2016-17 (40 years) of vegetables production and 5 years data (2011-12 – 2015-16) of major vegetables were collected and analysis was done through Microsoft Excel. The results showed that the area under vegetables cultivation has jumped by 222.8% while production was increased by 728.21% and productivity was increased by 156.6% between 1977-78 & 2016-17. They also reported that during the period of 5 years (2011-12 – 2015-16), the area, production and yield of solanaceous and cruciferous vegetable reported increasing trend for the expanse under tilling of eggplant (deteriorated by 5.2%) and for Radish (degenerated by 6.0%) correspondingly whereas cucurbitaceous vegetables also conveyed growing tendency in expanse and production but an decreasing tendency in harvest excluding for the harvest of cucumber (improved by 15.8%). However, the tendency of other chief vegetables were changing through the years.

Murthy and Babu (2018) reported trend analysis of mango area, production and productivity in Andhra Pradesh, India for the period during 1992-2017 based

on linear and non-linear statistical model. The result reveal that there is decreasing trend on area and production of mango crop in Andhra Pradesh. Based on this trend forecast area and production of mango crop for next three years the forecasted area and production of mango crop for the year 2018-19 to be 138.940 ha and 2111.517 ('000 MT) respectively.

Chaudhari *et al.* (2018) focussed on tendencies and variability in area, production and productivity of vegetables in Gujarat, India. The secondary data pertain to area, production and productivity of total vegetable crops grown in Gujarat state was collected from the report of Directorate of Horticulture, Government of Gujarat for the period from 1996-97 to 2015-16 and divided into Period I, Period II and overall period and analyzed with simple statistical tools like mean and percentage. The productivity in Gujarat recorded lesser increase which was under 3 per cent per annum throughout the whole and II period. The values of coefficient of variation confirmed that there has been variability in area and production, while a decrease in variability recorded in productivity over the period of time.

Uddin *et al.* (2016) analyzed the trends, growth rates of area, production and yield of major fruits in Chittagong region of Bangladesh and identified factors contributing to output growth during 1993/94-2009/10 using secondary data. The study revealed that the area and production of all fruits increased over the period except banana. The growth rates of area for mango, jackfruit and litchi were increased impressively and significantly. The highest increase in area was recorded for guava (131.67%), while the lowest for jackfruit (6.4%). The highest increase in production was recorded for guava (754.53%) while the lowest for jackfruit (20.29%).

Dhakre and Bhattacharya (2013) worked on growth and instability evaluation of vegetables in West Bengal, India. The research is primarily dependent on secondary records of vegetables including diverse vegetables as in their entirety for the period of 1997-98 to 2010-11. It was observed that the increase of area, production and productivity for all vegetables registered are showing positive changes and statistically significant in West Bengal, India.

2.2. Impact of rainfall on production and productivity

Karienyee Macharia Joseph (2020) studied the influence of rainfall variability and trends on tomato production in the semi-arid region of central Kenya. With the objective to identify the rainfall variability and trends between with the help of rainfall data obtained from Kenya Meteorological Department in Nairobi (1981 to 2014) while tomato production data was obtained from the sub-County Agriculture Office at Narumoru. Pearson's Product Moment Correlation was put to use to find out the correlation among rainfall amounts, tomato yields and prices. Results established that rainfall characteristics over the thirty-four years under study varied both annually and seasonally. The study area experienced changes in annual rainfall during the years under study (1981 to 2014) as indicated by the trend line equation $y = 5.57778x + 563.8$. Pearson's Product Moment Correlation ($r = 0.429$) showed that there was a positive correlation between rainfall and tomato yield and a relatively weak positive correlation between rainfall and tomato income ($r = 0.334$).

Batool *et al.* (2019) studied the rainfall variability and dynamics of cropping pattern in Kashmir Himalayas. Mann-Kendall and Sen-slope analysis have been used to find out the altering tendencies in rainfall, while correlation coefficient was used to examine the impact of rainfall variability on crop yield and the altering cropping pattern. The effects suggest that rainfall has reflected a reducing tendency from the previous few decades and has caused modifications in the crop yield/production and cropping pattern in addition, it was discovered that crops within the area have reflected varying relations with rainfall, and as a result, the area assigned to a few crops has elevated even as for some particular other crops it has witnessed a contraction.

Mensah *et al.* (2019) studied on effect of rainfall variability on crop production in the Worobong Ecological location of Fantekwa District, Ghana. Statistics accrued from the Ghana Meteorological agency (GMet) for 30-12 month's duration and grouped into 3 decades of 10 years each was used. Chosen crop statistics for 1993-2014 were also acquired from the Ministry of Food and Agriculture's District office and analyzed for tendencies of crop yield over the duration and apparent interaction among the crop statistics and the rainfall statistics. The end results found out that rainfall variability in the principal seasons for three groupings were lesser in value than the minor seasons. It also confirmed that yields of 3 crops have declined over the specified duration

Abhinav *et al.* (2018) studied effects of rainfall on coconut productivity in Kozhikode and Malappuram Districts of Kerala. To find out the variability in coconut production on an account of secondary records primarily based on rainfall accrued for a period of time from 1991 to 2015 (25 years). Panel records evaluation found out that rainfall for the duration of 3rd (July-September) and 4th (October-December) quarters was discovered to have sizable negative effect on coconut production. The size of rainfall determined for the duration of 1st (January-March) and 2nd (April-June) quarters has high quality non-sizable effect on coconut production. The growth pattern of rainfall confirmed an improving pattern in Kozhikode district while Malappuram district had a declining pattern through the year.

Salau *et al.* (2016) focussed on results of modifications in temperature, rainfall and relative humidity on banana production in Ondo state, Nigeria. Therefore, the influences of adjustments in significant climatic variables like temperature, rainfall and relative humidity at the production of a first-rate food commodity known as banana was investigated making use of the facts of 1998-2012 accumulated from Ondo state, Nigeria. The effects recommended that heavy rainfall and extraordinarily extreme temperature can lessen banana productivity all at the same time as the production was also turning small as both rainfall and temperature are very low with decreasing humidity. On a mean level, the findings display that an average temperature of approximately 26 °C and mean rainfall of

about 1891 mm with relative humidity of approximately 77% will result in desirable annual banana production above 61,000 tons in Ondo state.

Kumari *et al.* (2015) analyzed the impacts of climate modifications on production and variability in the region, production and productivity of main vegetables in India. This research was specifically based on secondary records gathered from NHM database 2013 and information was analyzed with the use of correlation coefficient, Compound growth rate [CGR] and Markov evaluation. The results discovered that for onion, area, production and productivity (CGR) was found to be the highest during last ten years. Co-efficient of variation [CV] was found to be maximum for tomato for the case of area and production however for the case of productivity CV was found to be maximum for brinjal. Correlation coefficient of area, production and productivity with rainfall was found to be negative.

Patil *et al.* (2015) worked on impact of climate change on major fruits in India from during 2003-2013. The research is performed primarily based on secondary records taken from Metrological department, NHB in order to make an analysis of statistics through numerous state-of-the-art methods that were used in Markov chain evaluation, CGR, Correlation. Correlation between rainfall and area, production and productivity of major fruits was estimated. Rainfall is negatively correlated with production of mango, banana, papaya, litchi and guava crop. In case of productivity litchi (46.25%) are positively correlated with rainfall and other crop showed negative correlation with rainfall.

Ndamani and Watanabe (2015) analyzed annual and seasonal rainfall variability and their relationships with crop production. Month-to-month rainfall statistics of 33 years accessible in Babile weather station was used. Seasonal and annual rainfall variability and concentration were analyzed making use of the coefficient of variation and the precipitation concentration index respectively. Accessible records on annual production volumes of principal crops produced in the duration of year 1992 and 2012 were used. Correlation evaluation was implemented to evaluate the impacts of rainfall on crop production. The results discovered mild seasonal and erratic annual rainfall concentration. Correlation

between annual rainfall and crop production was found to be negative for all of the crops studied. At seasonal standpoint, just sorghum, millet and groundnut were found to be negatively correlated with rainfall. Therefore, it may be concluded that assessing and enforcing suitable adaptation strategies via impactful stakeholder collaboration is crucial to reinforce the production of sorghum, millet and groundnut.

Karanja *et al.* (2014) studies the impact of Rainfall Variability on Potato production in Kenya. The goal of the research was, to examine seasonal and annual rainfall traits and there correlation with potato yields in Oljoro-orok department. Secondary facts on rainfall and potato yields was accumulated from Nyahururu Meteorological Station and District Agriculture workplace respectively for the duration of 11 years. The results imply that annual rainfall and potato yield indicate an effectively rising pattern between the year 1999 and 2009. Rainfall has proven a reducing pattern in the course of the lengthy wet season and an effectively rising pattern for the duration of brief wet season. Rainfall variability is substantial in both seasonal and annual tendencies starting from +464.97 in 2007 to 239.63 in 2009 at the annual pattern, +624 in 2007 to -360 in 2008 at some stage in the lengthy rain season and +152 in 2006 to 171.6 in 2007 all through the quick rain season.

Singh *et al.* (2014) analysed Impact of rainfall variability on fruit production in Jhalawar district of Rajasthan for the period 2001-2010. Result indicate that the annual rainfall had highly significant positive correlation with fruit production except mango. Guava crop showed significant positive correlation with annual rainfall and production of Guava cultivation while papaya crop showed positive but non-significant correlation.

Kumar *et al.* (2009) worked on effect of weather alterations on Seed production of Cabbage in North Western Himalayas. A research was carried out with the main focus on modifications in long-term climate-based parameters of Kullu valley on the grounds of annual and month-to-month rainfall, highest and lowest temperatures recorded in the course of ad 1962 to 2004. It was located that the mean maximum value of temperature of the month of May rose by way of

1.58°C. The lowest values of temperatures for the months of April and August rose by way of 2.03 and 2.165°C, respectively. From 1981 to 2004, approximately 40% fall in seed production per unit area was observed. Correlation coefficients between average month-to-month rainfall for the duration of May and seed yield ($r = -0.49$), average highest temperature for the duration of April and seed yield (-0.36) and highest temperature in the course of May and seed yield (-0.39) shows that as temperature rises, it influences seed production of cabbage adversely. Additionally, if rainfall improves in the course of May, the seed yield is decreased. It was additionally discovered that the rainfall in the course of August reduced and in the course of September it improved which then resulted in overdue onset of autumn thereby suggesting that the planting of cabbage ought to additionally be behind schedule at least by a fortnight to keep away from occurrence of soft rot and elevated seed yield.

Singh *et al.* (2005) did his analysis on rainfall as one of the highly significant climatic elements that manipulate the crop production in rainfed regions. The day-by-day rainfall records for 28 years (1972-99) as recorded at agro meteorological observatory Sabour, Bhagalpur have been analyzed for annual, seasonal, month-to-month and weekly durations. The possibility of 10, 20, and 40 mm rainfall per week exceed 60% between 19th to 41st, 24th to 40th and 26th to 39th standard meteorological weeks respectively. The average annual rainfall was found to be 1185.3 mm out of which 954.0 mm, 105.2 mm and 126.2 mm have been obtained in Kharif, summer and Rabi season, (7.52 mm) in December. Approximately 87% of the overall annual rainfall was recorded respectively. The maximum amount of rainfall (320.5 mm) was recorded in July and the least spread through 22nd to 41st weeks.

Hundal and kaur (2002) tested annual and seasonal climatic variability at distinct locations in Punjab state. The rainfall variabilities have been analyzed from historical day by day meteorological facts for Amritsar (1970-98), Patiala (1970-98), Ludhiana (1970-99) and Bathinda (1977-98). It was discovered that the yearly and seasonal rainfall exhibited excessive standard deviation and coefficient of variations indicating huge variations in rainfall at all of the stations. The

5 annual shifting mean huge variations in rainfall confirmed an average increase of approximately, 120 mm at Amritsar, 150 mm at Ludhiana, 150 mm at Patiala and 140 mm at Bhatinda respectively.

2.3. Climatic vulnerability index

Kadiyala *et al.* (2021) worked on weather change and vulnerability in Indian state of Telangana. based totally on climatic vulnerability assessment they located that the quantity of inclined mandals (currently 28%) may be expanded to 45% throughout early century and to 59% through mid-century. As per the weather exposure index ratings, Jogulamba-Gadwal district was found to be most critical as compared to all the districts involved in the study. Vulnerability index rankings indicated that Adilabad, Nagarkurnool, Nalgonda, Peddapalli, Suryapet, Wanaparthy, and Yadadri districts had been extremely prone districts in the kingdom. The ranking of prone models in every district envisages the need for a holistic method for every version or a collection of versions to reduce their sensitivity although implementation of site-precise variation techniques to decrease climate-associated shocks not just in agriculture but instead in other sectors as well.

Aditya and Bhardwaj (2018) focussed on the connection of weather-related parameters with phonological levels of predominant fruit crops and evaluation of their respective vulnerability to climate dispersions for chosen altitudinal gradients in Himachal Pradesh. The overall maximum and minimum temperature confirmed a boom for the last thirty years at all primary fruit producing regions, while, annual rainfall discovered an erratic fashion for the same. The fruit producing regions at 1000-1200 m amsl (Above mean sea level) of Solan district received maximum rating (0.56) and were found to be maximum susceptible for stone fruit crops production whereas the ones at 1400-1600 m above mean sea level were found to be least susceptible among the chosen altitudes. To deal with climatic modifications farmers have followed numerous adaptation and mitigation techniques like better water conservation strategies, varietal shifts and crop diversification with different fruits like kiwi, pomegranate and vegetables found in that region.

Dhamija *et al.* (2020) focussed on Consistency in Vulnerability of Wheat production to climate dispersion. The research makes use of the Intergovernmental Panel on climate change (IPCC) framework of vulnerability whilst using composite indices of 27 signs to give an explanation for exposure, sensitivity, and adaptive capability. We used climate projections in accordance with the present (1975–2005) conditional factors and two upcoming (2021–2050) representation concentration pathways (RCPs), 4.5 and 8.5, to estimate exposure to climatic dangers. Outcomes of the vulnerability profile recommend excessive vulnerability of the wheat crop in northern and central India. Especially, the districts Unnao, Sirsa, Hardoi, and Bathinda confirmed excessive vulnerability and excessive consistency throughout present day and upcoming weather situations. In totality, 84% of the districts confirmed more than 75% consistency within the present-day climatic factors, and 83% and 68% of the districts confirmed greater than 75% consistency for RCP 4.5 and RCP 8.5 climatic conditions for the 3 weighting strategies, respectively.

Kumari and Bharti (2017) built a vulnerability index and evaluated various districts of Kosi area (Bihar), they used the principal issue of vulnerability index i.e., (i) exposure (ii) sensitivity and (iii) adaptive potential. The results found out that, the district of Supaul changed Kishanganj from the primary function with regards to average vulnerability to climate dispersion. Kishanganj was found in first place with regards to sensitivity aspect of vulnerability. The extent of vulnerability of Kishanganj district was once again positioned underneath enormously susceptible district; but the district of Supaul, Saharsa, Madhepura, Purnea and Khagaria were located underneath mild vulnerability and the district of Araria was taken into consideration as least prone district amongst all the chosen district throughout the study thus far.

Lakshmi Prasanna (2017) worked on “Analysis of vulnerability indices in various agro-climatic zones of Andhra Pradesh. The time series records were accumulated for 30 years from 1985 to 2014 on all of the demographic, climatic, agricultural and occupational indicators. The outcomes concerning universal vulnerability to climate change discovered that Anantapuram from Scarce rainfall zone endured to stay maximum prone district for the duration of observe the 3

durations below. S.P.S. Nellore district from Southern area changed into the least vulnerable district in the 12 months 1994 and this role become occupied by the East Godavari district all through the periods 2004 and 2014.

Varadan and Pramod (2015) worked on mapping agricultural vulnerability of Tamil Nadu, India to weather change. It chooses the growth and instability of certain performance indicators to capture the relative vulnerability positioning of the districts of Tamil Nadu. The weighted element signs are then aggregated into an unmarried index by means of merely adding them. The results reveal that the all districts in an agro climatic variation quarter does not fall underneath the identical class of vulnerability which exemplifies the want for the state to prioritize research and improvement troubles and powerful decision making via BLocation-overall performance-Vulnerability primarily based strategies. In doing so, one ought to recall the expertise of local community to weather exchange.

Reddy *et al.* (2015) worked on Vulnerability assessment to climate trade in Krishna river basin districts of Andhra Pradesh and Telangana States. Inside the present paper vulnerability index changed into constructed through considering exposure, sensitivity and adaptive capability. Main aspect evaluation become used in assessing the vulnerability index for the districts of Krishna River basin in Andhra Pradesh and Telangana. Greater than 60 percent of the vicinity turned into prone within the districts and Ananthapur district is incredibly prone with an ordinary index of five.15. Krishna district is less inclined within the basin with an index -3.61.

Gizachew and Shimelis (2014) climate trade risk and Vulnerability in Ethiopia's principal Rift Valley have been researched, analysed, and mapped. This research become done in sixteen districts across Ethiopia's central Rift Valley (CRV) to estimate the degree of weather danger and relative vulnerability of the districts to climate change, and for that reason identify critical hotspots. The districts of Selti, Dodotana-Sire, and Tiyo were the most sensitive to climate change, whereas Arsinegele, Adamitulu-Jido-Kombolcha, and Dugda-Bora had been the least inclined. The ultimate districts were truly susceptible to climate change. This study demonstrates the significance of vulnerability mapping in

figuring out the numerous degrees of vulnerability of various localities and producing information that could help researchers, policymakers, non-public and public institutions in developing site-particular adaptation techniques and prioritizing investments on adapting methods for the most prone hotspots.

Sridevi *et al.* (2014) analyzed the vulnerability to climate dispersions in varying districts of four south Indian states i.e. Andhra Pradesh, Karnataka, Tamil Nadu and Kerala. They have taken 5 drivers of vulnerability signs like socio-demographic, climatic, agricultural, occupational and common property resource vulnerabilities to compute the composite vulnerability index. The composite vulnerability index suggests that, Adilabad, Chamarajanagar, Thiruvarur and Kasaragod are the most susceptible districts of Andhra Pradesh, Karnataka, Tamil Nadu and Kerala respectively, while Hyderabad, Belgaum, Thoothukkudi, Kottayam are the least susceptible districts.

Chandrasekhar (2014) made a try to check vulnerability to cyclones and floods in Odisha, India. District-sensitive relative vulnerability indices to assign vulnerability rank to each district consistent with its vulnerability stage in regards to cyclones and floods have been calculated. The consequences indicates that Balasore, Bhadrak, Jajpur, Kendrapada, Malkangiri, Nabarangpur, Nuapada and Rayagada had been extra susceptible as componed to different districts of the kingdom. Balasore, Bhadrak and Kendrapada are the coastal districts, whilst the closing five districts are non-coastal districts.

Hiremath and Shiyani (2013) the report stated that variables related to agricultural vulnerability were the main contributors to the overall vulnerability to climate change during 1991 and 2008. It was found that the Amreli area (North Solastra agro-climatic area) is the most severely vulnerable area and Panchmahals area, which is least vulnerable to climate change this year 2008.

Das (2011) worked on micro-degree analysis of vulnerability by means of looking on the degree of vulnerability of village mendacity inside 10 km from the coast in Kendrapada of orrissa district one of the most inclined districts of India. The diploma of vulnerability turned into described because the chance of witnessing human deaths due to excessive cyclonesand associated typhoon surge dangers and a huge range of things were taken into consideration to derive those

possibilities for villages. Out of the 262 villages, 112 to 132 villages had been found least prone with much less than a ten consistent with cent danger of going through deaths, while 72 to eighty-two villages were reasonably determined vulnerable, 34 to 37 village inclined, and 21 to 34 village highly inclined requiring complete evacuations earlier than a calamity.

Ravindranath *et al.* (2011) worked on accepted index primarily based approach for assessing agricultural vulnerability at district level within the NE (North – East) vicinity of India, with the use of secondary statistics. The weights for more than one parameter had been derived via professional suggestions and the weights were assumed to be identical throughout indicators. Results indicates that overall, in the North-East region, higher agricultural vulnerability is observed in the northern parts and vulnerability declines towards the southern parts of N-E region.

Patnaik and Narayanan (2005) focussed on the impact of climate dispersions on agriculture, infrastructure and demographic characteristics in the Coastal Districts in the eastern part of India. They stated that the frequency of incidence of intense events in the districts of the Orissa and Andhra Pradesh states are rather critical than other states. The clusters of districts of sub-standard infrastructure and demographic development are also the drive of maximum vulnerability.

O'brien *et al.* (2004) studied on mapping vulnerability to multiple stressors: climate change and globalization in India. The results indicated that Jhalawar district in Rajasthan, Anantapur district in Andhra Pradesh, Chitradurga district in Karnataka, had been highly prone to both weather exchange and change liberalization. The consequences of these case research support the macro profiles, which indicated that weather vulnerability will overlap with vulnerability to economic adjustments. The case looks at outcomes further counseled that state level agricultural rules, which vary throughout India, may also play an essential function in increasing nearby adaptability to weather variability and change in the context of alternate liberalization. Sooner or later, the approach enables to become aware of those places in which policy intervention is maximum vital both

geographically (e.g., double exposed districts) and thematically (e.g., get entry to irrigation, credit, alternative plants).

Atkins *et al.* (1998) studied the technique to degree the vulnerability and creation of a suitable composite vulnerability index for growing international locations and island states. The composite vulnerability indices have been supplied for a pattern of one hundred ten developing nations. When in comparison to important states, the rating means that tiny states are specifically susceptible. Small states like Cape Verde and Trinidad and Tobago are taken into consideration to have low ranges of susceptibility, whereas the remainder of the states, including Tonga, are envisioned to have high levels of vulnerability, Antigua and Barbudas being more liable to external monetary and environmental factors.

CHAPTER-III

MATERIALS AND METHODS

This chapter include description of the study area, data sources and method adopted for the research work on **“Impact of rainfall on production and productivity of horticultural crops and vulnerability assessment in different districts of Northern Hills zone of Chhattisgarh”** are briefly presented under following head.

3.1 Description of study area

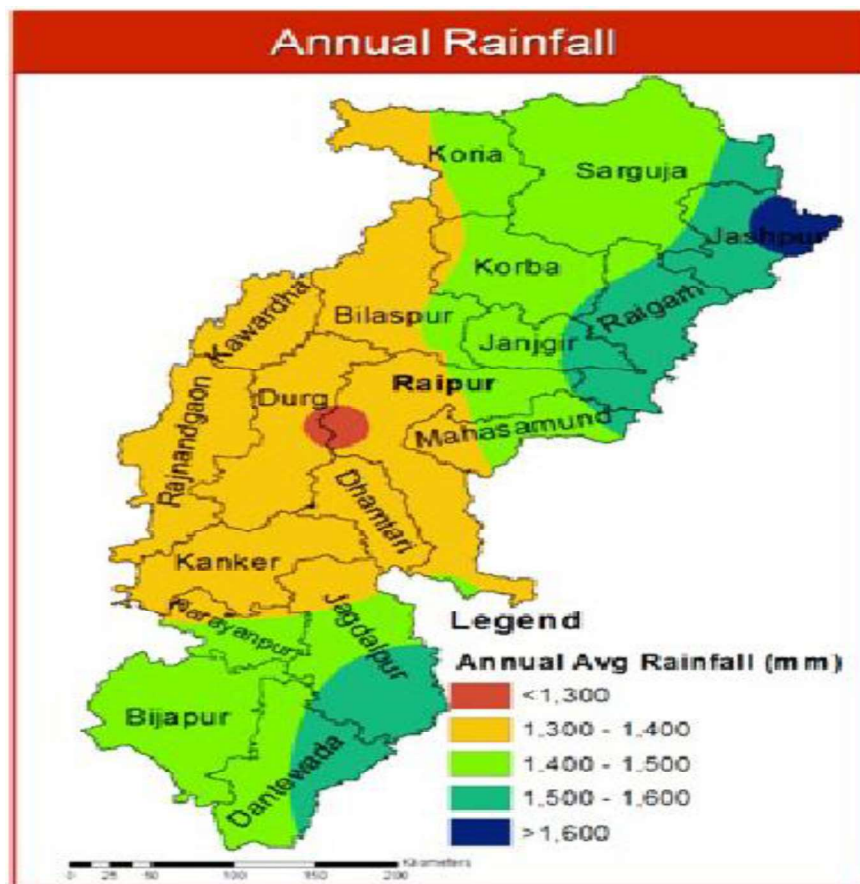
Chhattisgarh, carved out from Madhya Pradesh came into existence on 1 November 2000 as the 26th state of India. Chhattisgarh is located between latitude 17°46' to 24°06'N and longitude 80°15' to 84°20'E in the eastern central part of India. It is bordered on the north and east by Utter Pradesh and Jharkhand, on the east by Orissa, on the south by Telangana and Andhra Pradesh, and on the west by Madhya Pradesh and Maharashtra. 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 Millions hectors.

The Northern hills agro climatic zone included 5 districts. Total geographical area of northern hills zone are 28.47 lakh ha. and net sown area are 8.35 lakh ha. This is 21 % of the total geographical area of the state. The annual rainfall in the northern hill zone is around 1270 mm, with about 87 percent of the average rainfall falling between June and September. Irrigation intensity of northern hill zone is 11%. The soil in Northern hills zone is light to medium light (red-yellow), medium heavy to heavy (brown-black). The main horticultural crops grown in northern hills zone of Chhattisgarh fruit crops are Mango, Banana, Papaya, Guava, Lemon, Water Melon, Musk Melon, Ber, Aonla, Jack fruit, Litchi, Moringa etc. Some sub temperate fruit like pears. Some vegetables crops are Cauliflower, Cabbage, Brinjal, Tomato, Okra, Potato, Green pea, Leafy vegetables and Onion etc.

Table 3.1: Geographical locations of selected districts of Northern hills zone

Station	Latitude	Longitude	Altitude
Balrampur	23°11' N	83°19' E	528 meters
Jashpur	22°53' N	84°12' E	120 meter
Koriya	23°38' N	82°38' E	529 meter
Surajpur	22°94' N	83°16' E	528 meter
Surguja	23° 10'N	83°15' E	623 meter

Much of the information regarding a region's rainfall climatology is collected from daily rainfall data recorded in various districts and is based on weekly, monthly, seasonal, and annual rainfall data. The study was conducted in five districts of Chhattisgarh's Northern Hills Zone.

**Fig 3.1 Location of study area**

3.2 Data base

3.2.1 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 districts of Chhattisgarh was collected from the Department of Agrometeorology, College of Agriculture, Raipur. This study was conducted at Department of Agrometeorology by using weather cock software developed by CRIDA, Hyderabad (Rao *et al.*, 2011). Rainfall data collected for individual districts. Used for analysis purpose the data collected for long term periods are given below.

Table 3.2: rainfall data base for selected districts of Northern hills zone.

S.No.	STATION	DATABASE
1.	Balrampur	2003-2020
2.	Jashpur	1991-2020
3.	Surajpur	1991-2020
4.	Sarguja	1991-2020
5	Koriya	1991-2020

3.2.2 Area, production and productivity of Horticultural crops

Districts wise long term crop data (2004-2020) i.e. area, production & productivity of horticultural crops was collected from the report of Directorate of Economics and Statistics, Raipur (Chhattisgarh). Crop selection was based on more than 250 ha. area for fruit and vegetable crop in different districts of Northern hills zone of Chhattisgarh. The main horticultural crops grown in Northern hills zone are considered for study, they are Mango, Banana, Guava, Litchi, Jackfruit, Papaya, Cabbage, Cauliflower, Tomato, Potato, Brinjal, Bhindi.

3.2.3 Demographic, occupational and geographic data

Districts wise decadal demographic data i.e. population density and literacy rate, occupational data of agriculture workers and geographical data regarding first area for the period 1991, 2001 and 2011 was collected respective districts of Chhattisgarh from the Census report department of Madhya Pradesh and Chhattisgarh (2001).

3.2.4. Demographic, Climatic, and Agriculture Indices

Demographic, Climatic and Agricultural indices have been calculated as per standard procedure & formula given by **Patnaik and Narayanan (2005)** for different district of Northern hills zone of Chhattisgarh. Districts wise climatic vulnerability index was carried out with the help of following formula-

$$\text{Vulnerability Index} = \left[\sum_{i=1}^n (AI_i)^\alpha \right]^{1/\alpha} / n$$

Where,

AI = Average index

n = number of source of Vulnerability and $\alpha = n$

3.3 ANALYTICAL TECHNIQUES

3.3.1 Construction of Vulnerability Index

Construction of vulnerability index consists of several steps. First is the selection of study area which consists of 5 districts of Northern hills zone of Chhattisgarh. In each district a set of indicators were selected. All these indicators were grouped as demographic, climatic, agricultural, geographical and occupational sources of vulnerability. A list of selected indicators and their functional relationship identified with vulnerability were presented in Table 3.3.

Table 3.3 Functional relationship of indicators with vulnerability to climate change

S.No	Component	Indicator	Functional Relationship
1 (2)	Demographic	a. Population Density (person per sq. km)	↑
		b. Literacy rate (%)	↓
2 (2)	Climatic	a. Annual rainfall (mm)	↑
		b. Seasonal rainfall	↑
3 (3)	Agriculture	a. Area, production and productivity of selected crop	↓
		b. Cropping intensity (%)	↓
		c. Irrigation intensity (%)	↓
4 (4)	Occupational	a. Total main workers (no. per ha of net area sown)	↓
		b. Agricultural labourers (no. per ha of net area sown)	↓
		c. Non workers (no.per ha of net area sown)	↑
		d. Manufacturing laboureres	↓
5 (1)	Geographic	a. Forest area	↓

Steps for calculation of the Vulnerability Index

Here, we have used three types of indices to calculate climate 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.* increasing functional relationship and decreasing functional relationship. Dimension index scores should be between 0 and 1. The value 1 will correspond to that region with maximum value and 0 will correspond to the region with minimum value.

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

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

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 through 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 was misleading.

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

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

Where,

Indicator $_1$ = Geometric mean of Indicator $_1$

Indicator J = Geometric mean of Indicator J

J = number of indicators in each source of vulnerability

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:

$$\text{Vulnerability Index} = \left[\sum_{i=1}^n (AI_i)^\alpha \right]^{1/\alpha} / n$$

Where,

AI = Average index

n = number of source of Vulnerability and $\alpha = n$

In step iv, Garrett's Ranking Technique:

Outcome of step three was 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.

$$\text{Percentage position} = \frac{100(R_{ij} - 0.50)}{N_j}$$

Where,

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

N = Number of items ranked by the j individual.

1. To find out the most vulnerable districts based on vulnerability index

3.4 Software

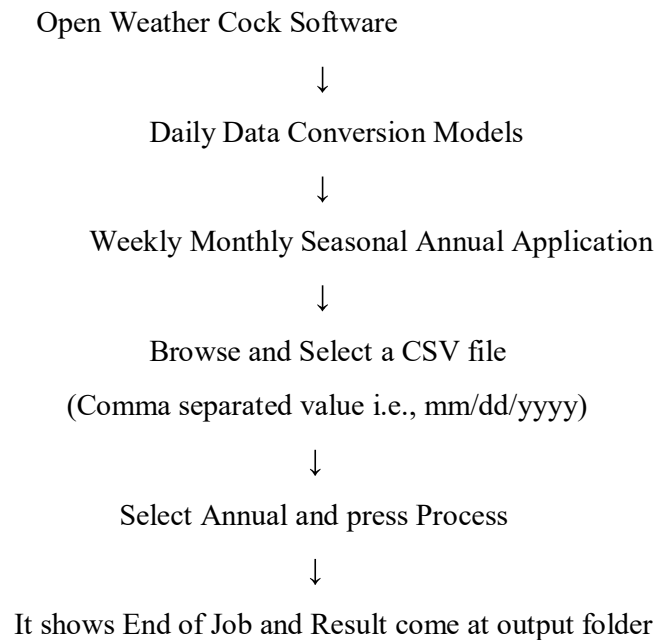
3.4.1 Weather cock

Weather cock with version 15 is a software developed by Rao *et al.* (2011) under All India Co-ordinate Research project CRIDA, Hyderabad. It contains various modules such as data management, data quality, daily data conversion,

rainfall analysis, temperature analysis, length of growing period and water balance. Application under rainfall analysis have been found viz., agricultural drought, meteorological drought, high rainfall events, incomplete gamma probability of dry and wet weeks, rainy days etc. some guideline to be followed for Weather Cock software given below

1. Weather cock folder name should never be renamed.
2. The entire file used in the software should be csv file of excel or created in notepad form.
3. Data should be in mm/dd/yyyy date structure
4. While analysing data with csv file, if any error occurs then open the csv file in notepad or excel and delete all the last commas in every data line.

Various steps in involve in conversion daily data to annual data are:



3.5 Correlation

To find out the relationship between rainfall, production and productivity of major horticulture crop in different districts of Northern hill zone. Correlation coefficient was calculated out by using following formula

$$r = \frac{cov(X,Y)}{\sigma_X \sigma_Y}$$

Where,

r = correlation coefficient

$cov(X, Y)$ = Co- variance of variable X and Y

σ_X = standard deviation of variable x

σ_Y = standard deviation of variable y

3.6 Trend analysis

A trend is a significant change over time exhibited by a random variable. Trend analysis is a technique for gathering data and attempting to discern a pattern or trend from it. This method is based on time series data, in which information (data) is plotted against time (over a long period of time) in order to find a general pattern of a link between time and information (factor).

3.6.1. Linear trend analysis

Linear regression is generally used to get an idea of the relationship between two variables. The slope of the observation is also estimated using the linear regression method. The linear regression line is derived using the following equation:

$$y = a + b x$$

where,

a = intercept

b = slope of the linear regression line.

x and y are the dependent and independent variables.

CHAPTER – IV

RESULT AND DISCUSSION

The present investigation entitled “Impact of rainfall on production and productivity of horticultural crops and vulnerability assessment in different districts of Northern hills zone of Chhattisgarh” was carried out to characterize the rainfall pattern, vulnerability assessment and according crop planning for different districts of the Northern hills zone. In this chapter results obtained during course of study are presented with the help of appropriate tables and figures as per need and discussed in the light of outcome of previous studies. The annual rainfall of five district of northern hills zone of Chhattisgarh namely Balrampur, Jashpur, Koriya, Surajpur and Surguja for different period was analyzed. The outcome of investigation are briefly presented and discussed under the following heads.

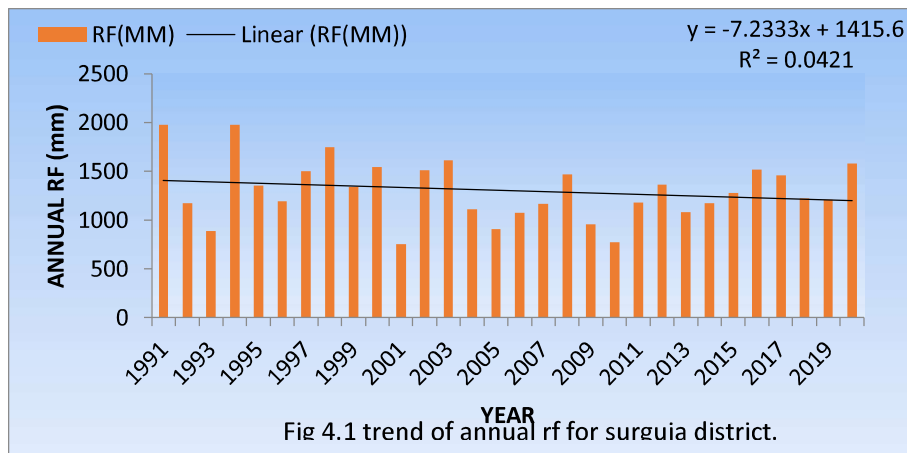
4.1 Trend analysis of rainfall, area and production

4.1.1 Trend analysis of annual rainfall

Daily rainfall data of 30 years (1991-2020) of 4 districts of Northern hill zone i.e. Jashpur, Surguja, Surajpur and Koriya and 17 years data (2003-2020) of district Balarampur were collected from the Department of Agrometeorology, Raipur and transformed into weekly, monthly, seasonal and annual rainfall data using weather cock software. The average annual rainfall data is subjected to statistical analysis with the help of linear regression and results are presented in Table 4.1

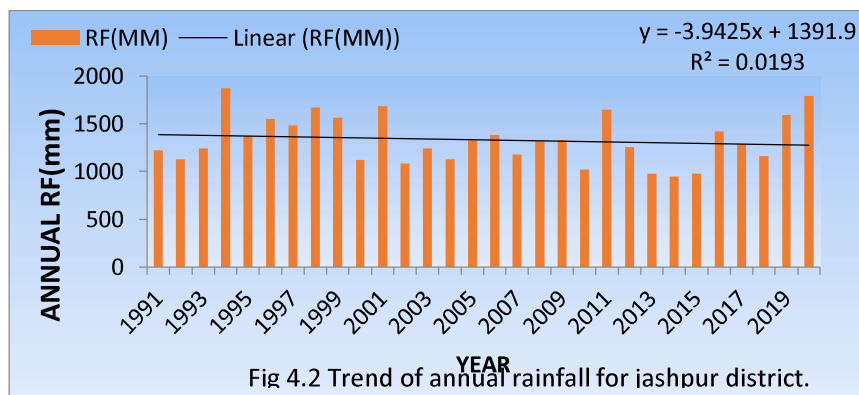
4.1.1.1 Trend analysis of annual rainfall for Surguja district

It is quite clear from the table that the district Surguja received highest rainfall of 1977.4 mm in the year 1994 and the lowest rainfall of 751.8 mm in the year 2001, whereas average annual rainfall of the district was 1238.4 mm. Results indicates that the there was non-significant decreasing trend of rainfall at the rate of 7.23 mm/year in district Surguja. Similar work has been done by Chakraborty et al. (2013) a decrease in rainfall might be due to global warming, increased pollution and some other factors.



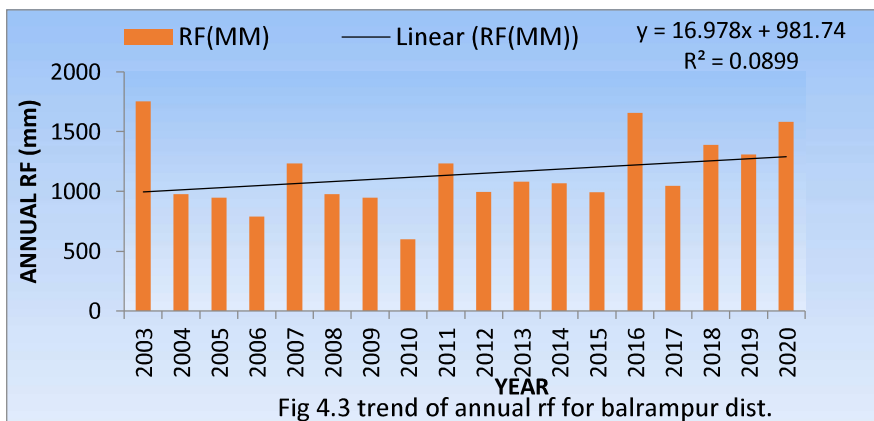
4.1.1.2 Trend analysis of annual rainfall for Jashpur district

Result indicate that the district Jashpur recorded maximum rainfall of 1871.4 mm in the year 1994 while the lowest rainfall of 945.4 mm was in the year 2014, with an average annual rainfall of 1330.8 mm was recorded during the period of 1991-2020. The outcome of analysis of linear trend graph showed non-significant decreasing trend of annual rainfall at the rate of 3.94 mm/year in the district Jashpur. A decrease in rainfall might be due to deforestation and some other factors. The proximate cause of a rainfall shortage might be due to one or more factor including an absence of available moisture in the atmosphere, large scale subsidence which suppresses convective activity, and the absence or non-arrival of rain-bearing system. Similar results has also been reported Patle et al. (2014) was also reported by Patle et al. (2014) conducted that there was decreasing trend in annual rainfall in Andhra Pradesh.



4.1.1.3 Trend analysis of annual rainfall for Balrampur district

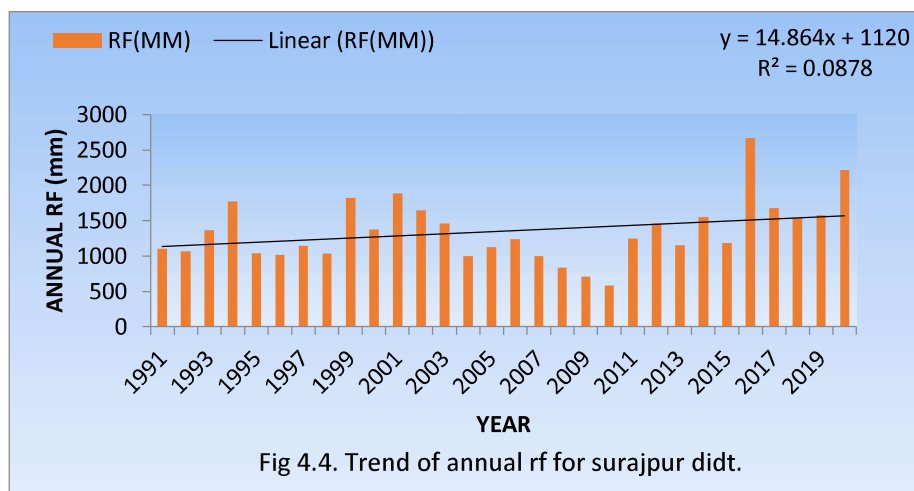
Fig 4.3 represents the highest annual rainfall of 1753.5 mm in district Balrampur which was noticed in the year 2003 while lowest rainfall of 598.2 mm was recorded in the year 2010. Long term average of annual rainfall was 1143 mm during last 17 years. The outcome of linear trend graph indicates non-significant increasing trend of rainfall at the rate of 16.97 mm/year in district Balrampur. Similar work has been done by Zaheed et al. (2014) who indicated that the amount of annual rainfall in South-East Bangladesh was increasing but it was non-significant. **Kumar et al. (2010)** also reported that the half of the sub-divisions of India showed an increasing trend in annual rainfall. Rainfall increase might be due to geological and man-made activities. Warmer oceans increase the amount of water that evaporates into the air. When more moisture-laden air moves over land or converges into a storm system it can produce more intense precipitation.



4.1.1.4 Trend analysis of annual rainfall for Surajpur district

Result presented in fig 4.4 indicates that the highest rainfall of 2665.6 mm was observed in the year 2016 in the district Surajpur whereas the lowest amount of rainfall was recorded 584.7 mm in the year 2010. The average annual rainfall recorded during the period was 1350.3 mm. The outcome of linear trend graph analysis showed non-significant increasing trend of annual rainfall at the rate of 14.86 mm/year. Zaheed et al. (2014) also indicated that the amount of annual rainfall in South-East Bangladesh was increasing but it was non-significant. **Yosef et al. (2009)** reported that the annual rainfall, an increased trend was shown across

Isreal, especially in the central and southern regions, although it was non-significant. Rainfall increase might be due to climate change. Also warmer oceans increase the amount of water that evaporates into the air. When more moisture-laden air moves over land or converges into a storm system it can produce more intense precipitation.



4.1.1.5. Trend analysis of annual rainfall for koriya district

The outcome of trend analysis of rainfall of indicates that district Koriya recorded the highest annual rainfall of 1916.6 mm in the year 2014 and lowest rainfall of 757.6 mm in the year 2007. The average annual rainfall of the district was 1232.7 mm during the study period. Non-significantly increasing trend of annual rainfall was observed at the rate of 2.22 mm/year during study period in the district koriya. **Yosef et al. (2009)** also reported that the increasing trend of annual rainfall across Isreal, especially for the central and southern regions, although it was non-significant. **Kumar et al. (2010)** also reported that the annual trends of 135 years (1871-2005) rainfall data for 30 sub-division (sub-region) of India. Result showed that the half of the sub-division of India showed increasing trend in annual rainfall. Increases in rainfall might be due to the rise in the magnitude and intensity of the EL-Nino effect, change in land use and air pollution could be the reason behind extreme rainfall.

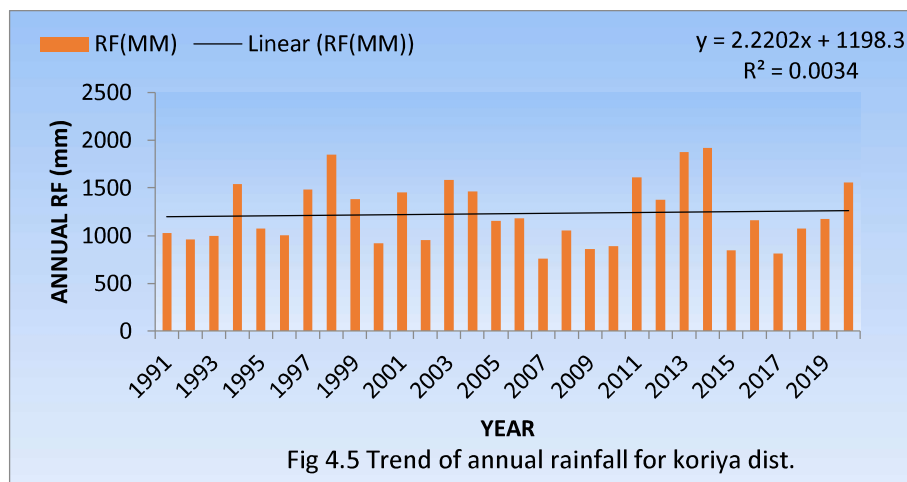


Table 4.1. District wise annual rainfall trend of Northern hills zone of Chhattisgarh

S.NO	District	Average	Equation	R ²	Liner trend result
1	Sarguja	1238.4	$y = -7.2333x + 1415.6$	0.0421	NS
2	Jashpur	1330.8	$y = -3.9425x + 1391.9$	0.0193	NS
3	Koriya	1232.7	$y = 2.2202x + 1198.3$	0.0034	NS
4	Balrampur	1143	$y = 16.978x + 981.74$	0.0899	NS
5	Surajpur	1350.3	$y = 14.864x + 1120$	0.0878	NS

4.1.2. Trend analysis of area and production of horticultural crops in Northern hills zone of Chhattisgarh

The present study included the trend analysis calculated with respect to area and production for five districts of Chhattisgarh located in Northern hills zone for a duration of 16 years (2004-2020). The study was based on the secondary data spread across 16 years (2004-2020). To carry out the trend analysis, linear regression method was used. The following table present the results carried out for major fruit and vegetable crops eventually grown in different districts of Northern hills zone.

Table 4.2 Trend of area and production of mango crop

District	Years	Area (ha)			Production (tonnes)		
		equation	R ²	r	equation	R ²	R
Surguja	2004-2020	y = -52.553x + 6701.7	0.040	0.200	y = 2358x + 24959	0.325	0.570*
Jashpur	2004-2020	y = 300.72x + 793.03	0.945	0.972**	y = 3741.6x - 8476.8	0.824	0.908*
Koriya	2004-2020	y = 142.89x + 980.17	0.901	0.949**	y = 1429.5x + 392.91	0.823	0.896*
Balrampur	2011-2020	y = 264.5x + 1930.3	0.972	0.986**	y = 2342x + 25766	0.940	0.969*
Surajpur	2011-2020	y = 205.72x + 3529.8	0.965	0.982**	y = 1563.9x + 14418	0.965	0.982*

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-2), r table value = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.1 Trend of area and production of mango crop in Northern hills zone

It is clear from the table 4.2 that in case of area of mango crop the trend of districts Jashpur, Koriya, Balrampur and Surajpur was significantly increasing at the rate of 300.72, 142.89, 264.5 and 205.72 ha/year respectively. Only one district i.e. Surguja showed non-significant decreasing trend of area of mango crop.

In case of production of mango crop the trend of all 5 districts showed significantly increasing trend in Northern hills zone at the rate of 2358, 3741.6, 1429.5, 2342 and 1563.9 tonnes/year respectively and it is clear from the table that

the production will increase as the area of mango crop increases in all the 4 districts of Northern hills zone the area of mango crop decreased but production was increased in the district Surguja. Increase in area and production of mango crop might be due to promotion of govt. policy and adoption new technologies in that district. Murthy and Babu (2018) analysed area, production and productivity trend of mango crop in Andhra Pradesh, India from the year 1992-2017 and reported that there is decreasing trend on area of mango crop.

Table 4.3 Trend of area and production of litchi crop

District	Years	Area (ha)			Production (tonnes)		
		Equation	R ²	r	equation	R ²	r
Surguja	2004-2020	y = 98.334x + 698.39	0.5635	0.750**	y = 1450.2x - 2003.8	0.701	0.8372**
Jashpur	2004-2020	y = 94.611x + 43.66	0.9448	0.9720**	y = 483.6x - 585.05	0.6935	0.8327**
Koriya	2004-2020	y = 57.64x - 106.88	0.9763	0.9880**	y = 396.32x - 1276	0.9238	0.9611**
Balrampur	2011-2020	y = 264.5x + 1930.3	0.9724	0.9861**	y = 227.95x + 3424.3	0.356	0.5966
Surajpur	2011-2020	y = 71.633x + 925.28	0.9809	0.9904**	y = 717.38x + 6515.6	0.9565	0.977**

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-2), r table value = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.2 Trend of area and production of litchi crop in Northern hills zone

It is quite clear from the table 4.3 the trend of area of litchi crop was found to be significantly increasing in all the 5 districts of Northern hills zone at the rate of 98.33, 94.61, 57.64, 264.5 and 71.63 ha/year respectively.

Similarly the production trend of litchi crop was found significantly increased in 4 districts of Northern hills zone i.e. Surguja, Jashpur, Koriya and Surajpur at the rate of 1450.2, 483.6, 396.32 and 717.38 tonnes/year while only district Balrampur was showed non-significant increasing trend. In nut shell we

can say that the area and production both of litchi crop are increasing in all the 5 districts of Northern hills zone. The increase in area and production for above districts might be due to favourable climatic parameters prevailing in the Northern hills zone and adoption new govt. scheme. Sahni et al. (2020) also worked on litchi cultivation in India. Result showed that the area and production trend was significantly increased in India.

Table 4.4 Trend of area and production of jackfruit crop

District	Years	Area (ha)			Production (tonnes)		
		Equation	R ²	r	equation	R ²	r
Surguja	2004-2020	y = 6.4577x +	0.026	0.1640	y = -	0.000	0.014
		552.01	9		8.5355x +	2	1
Jashpur	2004-2020	y = 23.79x +	0.458	0.676*	y =	0.792	0.882
		190.73		*	825.71x +		**
Koriya	2004-2020	y = 18.007x +	0.796	0.892*	y =	0.792	0.882
		243.03		*	573.59x +		**
Balrampur	2011-2020	y = 1.3x +	0.478	0.691*	y =	0.596	0.772
		280.83			15.467x +		**
Surajpur	2011-2020	y = 25.867x +	0.894	0.945*	y =	0.925	0.962
		329.44		*	271.75x +		**
							2752.2

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-2), r table value = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.3 Trend of area and production of jackfruit crop in Northern hills zone

From the above table 4.4 it is clear that trend of area of jackfruit crop increased significantly at the rate of 23.79, 18.007, 1.3 and 25.86 ha/year respectively while in in districts Jashpur, Koriya, Balrampur and Surajpur. In district Surguja reported non-significant increasing trend.

The trend of production of jackfruit crop in Jashpur, Koriya, Balrampur and Surajpur showed significantly increasing trend at the rate of 825.71, 573.59, 15.46 and 271.75 tonnes/year respectively in Northern hills zone but in district Surguja the production trend showed non-significant decreasing trend. Overall, it can be observed that the area and production of jackfruit are increasing significantly in all 4 districts of Northern hills zone but the area is increasing and production is decreasing in the Surguja district. Farmer of Surguja district are opting crop diversification might be possible reason.

Table 4.5 Trend of area and production of papaya crop

District	Years	Area (ha)			Production (tonnes)		
		Equation	R ²	r	equation	R ²	r
Surguja	2004-2020	Y = -33.041x + 1083.4	0.198	0.445	Y = -459.76x + 17359	0.051	0.226
Jashpur	2004-2020	Y = 7.5265x + 18.025	0.776	0.881*	Y = 206.58x - 103.54	0.837	0.915**
Koriya	2004-2020	Y = 34.057x + 215.85	0.926	0.962*	Y = 1253.5x - 456.04	0.8938	0.945**
Balrampur	2011-2020	Y = 111.87x + 376.33	0.973	0.971*	Y = 2126.9x + 7094.8	0.9721	0.985**
Surajpur	2011-2020	Y = -32.667x + 462.22	0.157	0.397	Y = -528.31x + 9184.7	0.0976	0.312

S**= 1% level of significant

Degree of freedom (n-2) = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.4. Trend of area and production of papaya crop in Northern hills zone

The outcome of results indicates that area under papaya cultivation in districts Koriya, Jashpur and Balrampur was increased significantly at the rate of 7.526, 34.05 and 111.87 ha/year respectively while districts Surguja and Surajpur were reported non-significant decreasing trend of area of papaya cultivation

The trend of papaya production indicates significantly increasing trend in districts Jashpur, Koriya and Balrampur at the rate of 206.58, 1253.5 and 2126.9 tonnes/year but in districts Surguja and Surajpur reported non-significant decreasing trend of papaya. Overall result showed that the area and production of papaya both crop are increasing in Koriya, Balrampur and Jashpur districts of Northern hills zone whereas the area and production both crop are decreasing in Surguja and Surajpur districts. This is in agreement with the finding of Kumar et al (2021) who also reported that the trend of area and production of papaya crop were increasing in Bilaspur district of Chhattisgarh

Table 4.6 Trend of area and production of guava crop

District	Years	Area (ha)			Production (tonnes)		
		equation	R ²	r	equation	R ²	r
Surguja	2004-2020	y = 31.901x + 595.1	0.342	0.585*	y = 410.5x + 3398.8	0.443	0.666**
Jashpur	2004-2020	y = 22.549x - 8.225	0.811	0.900**	y = 194.05x - 311.55	0.842	0.917**
Koriya	2004-2020	y = 53.669x + 175.73	0.955	0.977**	y = 631.69x - 520.25	0.963	0.981**
Balrampur	2011-2020	y = 46.017x + 463.03	0.940	0.969**	y = 225.16x + 2689	0.8226	0.895**
Surajpur	2011-2020	y = 49.567x + 501.72	0.974	0.986**	y = 468.27x + 3151.5	0.955	0.977**

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-2), r table value = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.5 Trend of area and production of guava crop in Northern hills zone

Result presented in table 4.6 result showed that the trend of area of guava crop was increased significantly at the rate of 31.90, 22.54, 53.66, 46.01 and 49.56 ha/year in all 5 districts of Northern hills zone.

The status of guava production results indicate that the all 5 districts of Northern hills zone showed significantly increasing trend at the rate of 410.5, 194.05, 631.69, 225.16 and 468.27 tonnes/year respectively. Overall, it is clear from the data that the production will increase as the area of guava crop increases in the all the 5 districts of Northern hills zone. The increase in area and production for above crop might be due to promotion of govt. policy and adoption of new technology and use of good seed/planting material.

Table 4.7 Trend of area and production of banana crop

District	Years	Area (ha)			Production (tonnes)		
		Equation	R ²	r	Equation	R ²	r
Surguja	2004-2020	y =	0.578	0.760*	y =	0.313	0.559*
		55.625x + 285.87			449.19x + 6809.7		
Jashpur	2004-2020	y =	0.909	0.953*	y =	0.897	0.772*
		32.971x - 50.875			791.03x - 1782		
Koriya	2004-2020	y =	0.897	0.947*	y =	0.835	0.914*
		71.959x - 9.025			1691.5x - 826.72		
Balrampur	2011-2020	y =	0.894	0.945*	y =	0.894	0.9456**
		278.68x + 392.47			3748.3x + 5279.8		
Surajpur	2011-2020	y =	0.913	0.955*	y =	0.907	0.952*
		170.12x + 492.97			2140.3x + 6815.4		

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-2), r table value = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.6 Trend of area and production of banana crop in Northern hills zone

Table 4.7 reveals that in case of area and production of banana crop the trend in 5 districts was increased significantly at the rate of 55.62, 32.97, 71.95, 278.68 and 170.12 ha/year respectively for area and 449.19, 791.03, 1691.5, 3748.3 and 2140.3 tonnes/year respectively for production in Northern hills zone. It can be said that the production will increase as the area of banana crop increases in the all 5 districts of Northern hills zone. The increase in area and production in above districts might be due promotion govt. policy, adoption of improved technology, favourable climate condition and proper market linkage. S. Meenakshi (2018) also worked on trends of banana cultivation in India with the help of long term data (2000-2001 to 2016-17). She reported trend in the area, production and yield of banana was positive and significantly increased in India.

Table 4.8 Trend of area and production of cauliflower crop

District	Years	Area (ha)			Production (tonnes)		
		equation	R ²	r	equation	R ²	r
Surguja	2004-2020	y = 2.0106x + 1099.3	0.000	0.03	y = 325.94x + 12946	0.065	0.255
Jahpur	2004-2020	y = 1.8662x + 238.58	0.008	0.089	y = 219.11x + 1696.8	0.533	0.730**
Koriya	2004-2020	y = 44.435x + 134.64	0.911	0.954**	y = 929.19x + 365.3	0.951	0.975**
Balrampur	2011-2020	y = 17.933x + 352.89	0.936	0.967**	y = 241.93x + 5990.8	0.8807	0.938**
Surajpur	2011-2020	y = 110.35x + 695.47	0.901	0.949**	y = 1802.6x + 10393	0.8256	0.908**

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-2), r table value = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.7 Trend of area and production of cauliflower crop in Northern hills zone

It is quite clear from the table 4.8 that the trend of area of cauliflower crop was increased significantly at the rate of 44.43, 17.93 and 110.35 ha/year in Koriya, Surajpur and Balrampur districts of Northern hills zone respectively whereas districts Surguja and Jashpur there was non-significant increasing trend.

Analysis of Production of cauliflower crop indicates that there was significantly increasing trend in districts Jashpur, Koriya, Surajpur and Balrampur but in district Surguja the trend analysis results showed non-significant increasing trend. Overall result showed that the area and production both are increasing in all 5 districts districts of Northern hills zone for cauliflower cultivation. The increase in area and production for above districts might be due to promotion of govt. policy, favourable climate and market linkage, improved soil fertility and cropping pattern. Ghimire *et al.* (2018) also reveals that during the period of 5 years (2011/12 - 2015/16), the area, production and productivity of solanaceous and cruciferous vegetables reported increasing trend in koriya, Balrampur and Surajpur districts. Dhakre and Bhattachary (2013) also observed that the growth of area, production and productivity of vegetables in the West Bengal registered positive and statistically significant.

Table 4.9 Trend of area and production of cabbage crop

District	Years	Area (ha)			Production (tonnes)		
		equation	R ²	r	equation	R ²	r
Surguja	2004-2020	y = 38.323x + 593.75	0.321	0.566*	y = 389.35x + 10503	0.096	0.31
Jashpur	2004-2020	y = -5.496x + 329.84	0.228	0.477	y = 128.33x + 3101.3	0.250	0.500*
Koriya	2004-2020	y = 34.546x + 134.82	0.959	0.979**	y = 773.11x + 142.03	0.805	0.897**
Balrampur	2011-2020	y = 15.05x + 375.53	0.954	0.976**	y = 70.63x + 6887.3	0.038	0.196
Surajpur	2011-2020	y = 67.25x + 526.53	0.929	0.964**	y = 1150.4x + 8863.7	0.936	0.967**

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-2), r table value = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.8 Trend of area and production of cabbage crop in Northern hills zone

The outcome of results presented in table 4.9 indicates that the districts Surguja, Koriya, Balrampur and surajpur reported significantly increasing trend in area of cabbage crop at the rate of 38.32, 34.54, 15.05 and 67.25 ha/year respectively. Whereas district Jashpur showed non-significant decreasing trend.

Critical analysis of table indicates that the districts Koriya, and Surajpur reported significantly increasing trend of production at the rate of 773.11 and 1150.4 tonnes/year respectively whereas districts Surguja, Jashpur and Balrampur showed non-significant increasing trend. In this table overall data of trend showed

production and area both are increasing in the Koriya, and Surajpur. It might be due to govt. policy, adoption of new technologies in cultivation and favourable market linkage in that district. Similar results also reported by Ghimire *et al.* (2018).

Table 4.10 Trend of area and production of brinjal crop

District	Years	Area (ha)			Production (tonnes)		
		Equation	R ²	r	equation	R ²	r
Surguj a	2004- 2020	y = - 60.373x + 2483.3	0.1434	0.3786	y = -120.71x + 26579	0.0027	0.051
Jashpu r	2004- 2020	y = - 24.158x + 621.27	0.5589	0.747**	y = -32.582x + 5652.9	0.0059	0.076
Koriya	2004- 2020	y = 38.276x + 237.85	0.9468	0.9730**	y = 1225.5x - 135.58	0.9894	0.994 **
Balram pur	2011- 2020	y = 46.333x + 785.22	0.8846	0.9405**	y = 763.97x + 13006	0.8843	0.940 3**
Surajp ur	2011- 2020	y = -92.6x + 1187.2	0.3945	0.6280	y = -1483.3x + 18785	0.3943	0.627 9

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-2), r table value = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.9 Trend of area and production of brinjal crop in Northern hills zone

It is quite clear from the table 4.10 the trend of area of brinjal crop was found significantly increasing in the district jashpur, Koriya and Balrampur of Northern hill zone at the rate of 24.15, 38.27 and 46.33 ha/year respectively but in districts Surguja and Surajpur there was non-significant increasing trend.

The production trend of brinjal crop is found significantly increasing in districts Koriya and Balrampur at the rate of 1225.5 and 763.97 tonnes/year

respectively whereas in the districts Surguja, Jashpur Surajpur showed non-significant decreasing trend of production of brinjal. Overall, it is clear from the data that the production will increase as the area of brinjal crop increase in the Koriya and Balrampur districts of Northern hills zone but the area and production was decreased in the Surguja, Jashpur and Surajpur districts. In Balrampur and Koriya is only districts showed increasing trend in area and production of brinjal crop. Devi et al. (2020) also worked on the trends of vegetable production in India, and reported that the trend of area and production of some crop like brinjal, tomato, potato and onion showed increasing trend.

4.11 Trend of area and production of tomato crop

District	Years	Area (ha)			Production (tonnes)		
		Equation	R ²	r	equation	R ²	r
Surguja	2004-2020	y = -55.053x + 3026.5	0.0939	0.306	y = 673.16x + 24466	0.0467	0.2161
Jashpur	2004-2020	y = 246.68x + 2092.2	0.9573	0.9784**	y = 5120.4x + 16412	0.8328	0.9125*
Koriya	2004-2020	y = 96.213x + 275.86	0.9004	0.9488**	y = 2004.2x - 198.66	0.9488	0.9740*
Balrampur	2011-2020	y = 97.55x + 1081.9	0.9222	0.9603**	y = 1404.8x + 17015	0.9238	0.961**
Surajpur	2011-2020	y = -37.217x + 1247.1	0.169	0.411	y = -524.87x + 19029	0.1438	0.379

S*** = 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-2), r table value = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.10 Trend of area and production of tomato crop in Northern hills zone

The outcome of results indicates that area under tomato cultivation in districts Jashpur, Koriya and Balrampur was increased significantly at the rate of 246.68, 96.21 and 97.55 ha/year respectively whereas the area of tomato crop reported non-significant decreasing trend in the districts Surguja and Surajpur.

The trend of tomato production indicates significantly increasing trend the districts Jashpur, Koriya and Balrampur at the rate of 5120.4, 2004.2 and 1404.8 tonnes/year respectively but in districts Surguja and Surajpur reported non-significant increasing and decreasing trend respectively of tomato production. It can be said that the production and area of tomato cultivation both are increasing in the Jashpur, Koriya, and Balrampur districts but the area is decreasing and production is increasing in the Surguja district. It might be due to promotion of govt. policy, adoption new technologies in cultivation and favourable market linkage in that district whereas in Surajpur district both area and production is decreasing. Similar results were also reported by Ghimire et al. (2018) and Devi et al. (2020).

4.12 Trend of area and production of okra crop

District	Years	Area (ha)			Production (tonnes)		
		equation	R ²	r	equation	R ²	r
Surguja	2004-2020	y = -38.717x + 2162.4	0.0588	0.242	y = 678.07x + 17356	0.0114	0.1067
Jashpur	2004-2020	y = -10.883x + 453.61	0.2931	0.5413*	y = -9.5537x + 3365.5	0.0028	0.0529
Koriya	2004-2020	y = 64.399x + 480.23	0.8732	0.9344*	y = 784.72x + 3436.2	0.9467	0.9729*
Balrampur	2011-2020	y = 138.37x + 393.94	0.6621	0.8136*	y = 1257.6x + 3712.4	0.4067	0.637*
Surajpur	2011-2020	y = -41.417x + 1101.4	0.2207	0.469	y = 222.17x + 11157	0.2041	0.4517

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-2), r table value = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.11 Trend of area and production of okra crop in Northern hills zone

It is closed observation of table 4.12 showed that the trend of area of okra crop was increased significantly in the district koriya and Balrampur while only district was Jashpur where the area of okra crop was decreased significantly

Production trend of okra crop indicates there was significantly increased trend of production in the districts Koriya and Balrampur at the rate of 784.72 and 1257.6 tonnes/year respectively but in districts Surguja, Jashpur and Surajpur results showed non-significant increasing and decreasing trend. Overall result showed that the area and production of okra crop both are increasing in Koriya and Balrampur districts of Northern hills zone but in Surguja and Surajpur districts area is decreasing and production is increasing. In case of Surguja and Surajpur district, though area has decreasing trend at the rate of 38.71 ha and 41.41 ha but still production has increased. It might be due to adoption new technologies in cultivation, favourable climatic condition for production and better market linkage.

4.13 Trend of area and production of potato crop

District	Years	Area (ha)		Production (tonnes)	
		equation	R ²	Equation	R ²
Surguja	2004-2020	y = -327.62x + 10948	R ² = 0.3618*	y = -3554.6x + 135949	R ² = 0.1106
Jashpur	2004-2020	y = 97.226x + 1557.6	R ² = 0.3118*	y = 2590.3x + 13713	R ² = 0.5962*
Koriya	2004-2020	y = 83.964x + 1300.1	R ² = 0.8199*	y = 1871.3x + 12940	R ² = 0.8769*
Balrampur	2011-2020	y = 343.63x + 1618.6	R ² = 0.8191*	y = 2889.5x + 32506	R ² = 0.3044
Surajpur	2011-2020	y = -271.27x + 4158.2	R ² = 0.381	y = -4142.1x + 66540	R ² = 0.3495

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-2), r table value = 14 (0.623, 0.497), 8 (0.765, 0.632)

4.1.2.12 Trend of area and production of potato crop in Northern hills zone

It can be seen from the table 4.13 that the trend of area of potato crop was increased significantly in the districts Jashpur, Koriya and Balrampur at the rate of 97.22, 83.96 and 343.63 ha/year respectively while the area of potato decreased significantly in the districts Surguja at the rate of 327.62 ha/year.

The production of potato crop was increased significantly in the districts Koriya and Jashpur at the rate of 2590.3 and 1871.3 tonnes/year respectively whereas the districts of Surguja, Surajpur and Balrampur showed non-significant increasing and decreasing trend. Overall it can be observed that the production and area of potato crop both are increasing in the Jashpur, Koriya, and Balrampur districts whereas the area and production both are decreasing in districts Surguja and Surajpur. Pandey *et al.* (2018) also reported that the growth of potato in terms of area, production and productivity, were significant increased trend in potato crop. Ghimire *et al.* (2018) also reported that Ghimire *et al.* (2018) also reported that area, production and yield of solaceous and cruciferous vegetable increased significantly in India.

4.2 Correlation between annual rainfall, production and productivity of fruit and vegetable crops

Correlation is a statistical term describing the degree to which two variable move in coordination with one another. If two variable move in the same direction then those variables are said to have a positive correlation. If they move in opposite directions then they have a negative correlation. It's a common tool for describing simple relationships without making a statement about cause and effect relationship. Correlation between annual rainfall, production and productivity of fruit and vegetable grown in different districts of Northern hill zones of Chhattisgarh are carried out to find out specific status and for future planning. Results indicates that as annual rainfall of districts seems to be affecting of production major horticultural crops in the table.

Table 4.14 Correlation coefficient value between annual rainfall, production and productivity of fruit crops from years 2004-20 and 2011-20

Crops		Districts				
		Surguja	Jashpur	Koriya	Balrampur	Surajpur
Mango	Production	-0.019	0.241	0.443	0.653*	0.697*
	productivity	0.126	0.272	0.496*	-0.533	0.480
Litchi	Production	0.305	0.030	0.233	-0.078	0.693*
	Productivity	0.189	-0.01	0.328	-0.679*	0.356
Jack fruit	production	-0.284	0.159	0.137	0.573	0.635*
	productivity	-0.37	0.17	0.12	0.56	0.781*
papaya	production	-0.516*	-0.025	0.331	0.646*	-0.111
	productivity	-0.338	-0.09	0.381	0.472	0.487
Guava	Production	0.154	0.007	0.268	0.426	0.718*
	Productivity	-0.098	-0.03	0.219	-0.51	0.46
Banana	Production	0.117	0.033	0.395	0.601	0.714*
	Productivity	-0.391	-0.07	0.346	-0.632*	-0.77**

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-1), r table value = 15(0.606, 0.482), 9(0.735, 0.602)

4.2.1 Impact of annual rainfall, production and productivity of fruits crop

A perusal of table 4.14 indicates that mango crop grown in different district of Northern hill zone, reported significantly positive correlation with rainfall and production i.e. Balrampur and Surajpur while district Surguja found non-significant negative correlation. The districts Jashpur and Koriya reported positive correlation but result was non-significant. The productivity of mango crop reported significantly positive correlation with rainfall in district Koriya. Other 3 districts i.e. Jashpur, Surguja, and Surajpur were found non-significant positive correlation and district Surajpur reported non-significant negative correlation with rainfall.

When we see the results of correlation workout for litchi crop, only one district i.e. Surajpur reported significantly positive correlation with rainfall and production of litchi crop, three districts i.e. Surguja, Jashpur and Koriya were found positive correlation but it was non-significant similarly the correlation was negative for district Balrampur that too was non-significant. Productivity of litchi crop was found significantly negative correlation in district Balrampur whereas other 3 districts i.e. Surguja, Koriya and Surajpur was found non-significant positive correlation and district Jashpur reported non-significant negative correlation with rainfall.

The results of correlation workout for jackfruit crop indicates that, only one district i.e. Surajpur was found significantly positive correlation with rainfall and production of jackfruit crop whereas districts i.e. Jashpur, Koriya and Balrampur reported non-significant positive correlation and district Surguja showed non-significant negative correlation with rainfall. The correlation of jackfruit productivity and rainfall was significantly positive in district Surajpur while all other 4 districts reported non-significant positive or negative correlation in jackfruit crop.

The correlation of papaya production and rainfall was significantly positive in district Balrampur and significantly negative in district Surguja. Rest three districts reported non-significant positive or negative correlation with rainfall and papaya production. The productivity of papaya crop in districts Koriya, Balrampur and Surajpur was found non-significant positive correlation with rainfall while

district Surguja and Jashpur reported non-significant negative correlation with rainfall and papaya production.

A perusal of table indicates that production of guava crop reported significantly positive correlation with rainfall and production in district Surajpur whereas other all 4 districts i.e. Jashpur, Surguja, Koriya and Balrampur were found non-significant positive correlation with rainfall in guava crop. The productivity of guava crop in district Surguja, Jashpur and Balrampur was found negative correlation with rainfall and productivity while district Koriya and Surajpur reported non-significant positive correlation with rainfall. All districts showed non-significant positive or negative correlation with rainfall and productivity.

The correlation of banana production and rainfall was significantly positive in district Surajpur. Rest all districts reported non-significant positive correlation with rainfall and banana production. Productivity of banana crop reported significantly negative correlation in districts Surajpur and Balrampur with rainfall whereas other three districts were found non-significant positive or negative correlation. Patil et al. (2015) also showed that the production of banana, mango, litchi, guava, papaya are negatively correlated with rainfall whereas productivity of litchi crops was positively correlated with rainfall. Singh et al. (2013) also analysed annual rainfall had highly significant positive correlation with fruit (guava, papaya) production whereas negative correlated with mango crop.

Table 4.15 Correlation coefficient value between seasonal rainfall, production and productivity of vegetable crops from years 2004-20 and 2011-20

Crops		Districts				
		Surguja	Jashpur	Koriya	Balrampur	Surajpur
Cauliflower	Production	0.128	-0.206	0.294	-0.143	-0.203
	Productivity	0.040	-0.205	0.246	0.082	-0.494
Cabbage	Production	0.045	0.041	0.00	-0.186	-0.050
	Productivity	-0.181	0.022	-0.35	-0.060	-0.250
Brinjal	production	0.141	-0.035	0.321	-0.281	0.308
	Productivity	0.086	0.083	0.269	0.299	-0.195
Tomato	production	0.117	0.024	0.341	-0.206	0.409
	Productivity	0.138	-0.016	0.335	0.335	-0.140
Okra	Production	-0.207	0.104	0.287	0.339	0.449
	Productivity	-0.237	-0.014	0.339	0.348	-0.267
Potato	Production	-0.123	0.047	0.289	-0.509	0.410
	Productivity	-0.126	0.489*	0.295	-0.324	0.403

S**= 1% level of significant, S* = 5% level of significant

Degree of freedom = (n-1), r table value = 15(0.606, 0.482), 9(0.735, 0.602)

4.2.2 Impact of seasonal rainfall, production and productivity of vegetable crops

The outcome of results presented in table 4.15 indicate that the all-vegetable crops reported non-significant correlation with rainfall, production and productivity except productivity of potato cultivation showed significantly positive

correlation in district Jashpur. The crops were non-significant for the duration of north-east monsoon season because the amount of rainfall during this season is much lesser as compared to that in the south-west monsoon season making the farmers are dependent on irrigation to produce crops, leading to a production not as high as it is during south-west monsoon season.

4.3 Vulnerability index for different district of Northern hills zone of Chhattisgarh

Vulnerability is often reflected in the condition of the economic system as well as the socio-economic characteristics of the population living in the system. It is hypothesised to be a function of its exposure (to the external stressor causing vulnerability), sensitivity of the entity's outcome to the external stressor, and its adaptive capacity in overcoming the adverse impact of the stressor on its outcome. In this section, we discuss about the results of vulnerability indices for individual districts of Northern hills zones of Chhattisgarh. The vulnerability index, mean we tried to capture a more comprehensive scale of vulnerability. This was done by including many indicators that served as proxies to look at different aspects of vulnerability.

The results showed that overall vulnerability to climate change for the year 2004-20. It is noticed that the ranks and relative magnitudes of the indices varied during these periods. In this section, the results of vulnerability indices workout for 5 districts of Northern hill zone viz. Balrampur, Jashpur, Korea, Surajpur and Surguja during different period summarized below

4.3.1 Average vulnerability index and ranking

Table 4.16 Indicator wise vulnerability index for five districts of Northern hills zone during years 2004-2020

Districts	Demographic index	Climatic index	Agriculture index	OI	GI
Surguja	0.33	0.49	0.77	0.41	0.50
Jashpur	0.70	0.58	0.17	0.28	0.65
Koriya	0.02	0.60	0.59	0.64	0.69
Balrampur	0.36	0.42	0.49	0.50	0
Surajpur	1.00	0.40	0.55	0.72	0.51

OI = Occupational index

GI = Geographical index

4.3.1.1 Contribution of different indicators to overall vulnerability to climate change

Table 4.16 revealed that on the basis of demographic index the district Surajpur ranked first followed by Jashpur (0.70) and Balrampur (0.36) with demographic index value of 1.00, whereas district koriya stand in last rank with the demographic index value of only 0.02. It means district Surajpur is more vulnerable and district Koriya is less vulnerable with respect to demographic vulnerability index. It means in that zone there is need to work to increase literacy rate.

In climatic index the district Koriya ranked first with climatic index value 0.60 followed by districts of Jashpur (0.58) and Surguja (0.49) and district Surajpur stand in last rank with the climatic index value of 0.40. It means district Koriya is more vulnerable whereas district Surajpur is less vulnerable with respect to climatic vulnerability index.

In agriculture index the district Surguja ranked first with agriculture index value 0.77 followed by Koriya (0.59) and Surajpur (0.55), whereas district Jashpur stand in last rank with the agriculture index value of only 0.17. It means district Surguja is more vulnerable and district Jashpur is less vulnerable with respect to

agriculture vulnerability index. It means in that zone there is need to work to increase area, production and productivity.

In district Surajpur showed first rank in occupational vulnerability index value of 0.72 followed by Koriya (0.64) and Balrampur (0.50) whereas district Jashpur showed last rank with respect to occupational index with value of 0.28. It means Surajpur is more vulnerable and Jashpur is less vulnerable with respect to occupational vulnerability index. This suggested that in that zone there is need to work to increase source of income to decrease vulnerability.

In geographic index the district Koriya ranked first with geographic index value 0.69 followed by Jashpur (0.65) and Surajpur (0.51), whereas district Balrampur stand in last rank with the geographic index value of only 0.00. It means district Koriya is more vulnerable and district Balrampur is less vulnerable with respect to geographic vulnerability index. It means in that zone there is need to work to increase forest area to decrease vulnerability in that zone. Laxmi Prasanna (2017) also worked on analysis of vulnerability indices in various agro-climatic zones of Andhra Pradesh from the data of the year 1985 to 2014. Result indicates that the in agricultural vulnerability Anantapuram district was the most vulnerable district.

Table 4.17. Average vulnerability index with rank for different district of Northern hills zone of Chhattisgarh

S.No.	Districts	AVI	Ranking	
1	Sarguja	0.50	3	
2	Jashpur	0.47	4	
3	Koriya	0.51	2	
4	Balrampur	0.36	5	Less vulnerable
5	Surajpur	0.64	1	More vulnerable

Table 4.3.1.2 Average vulnerability index and ranking

Average vulnerability index has workout by addition of all individual value of all index and average out by dividing 5, provides general status of vulnerability

of individual districts. The average value indicates that the district Surajpur reported highest average vulnerability of all indicator, (0.64) considered rank first and indicates more vulnerable as compared to other districts situated in Northern hills zone while district Koriya is found very less vulnerable with lowest average vulnerability of all indicator. Rest three districts fall in between this two category. Similar work was also done by Chandrasekhar (2014) result indicates that districts Balasore, Bhadrak, Jajpur, Kendrapada, Malkangiri, Nabarangpur, Nuapada and Rayagada were more vulnerable as compared to other districts of the state. Aditya and Bhardwaj (2020) also reported that the Solan district obtained highest score (0.56) and were most vulnerable for stone fruit crops production. Sridevi et al. (2014) worked on climate change in Agriculture sector. Result revealed that Adilabad, Chamarajanagar, Thiruvarur and Kasargod were the most vulnerable districts of Andhra Pradesh, Karnataka, Tamil nadu and Kerala respectively, whereas Hyderabad, Belgaum, Kottayam were the least vulnerable districts.

Table 4.18 Garretts ranking score of average vulnerability index for different districts of Northern hills zone of Chhattisgarh

S.NO.	Districts	Garretts ranking	Garretts ranking by G.R. conversion table
1	Sarguja	50	50
2	Jashpur	70	40
3	Koriya	30	61
4	Balrampur	90	25
5	Surajpur	10	76

4.3.1.3 Garretts ranking for different districts of Northern hills zone

The table 4.18 shows Garret's ranking along with their district and The Garret's ranking technique facilitates the preferential ordering of districts according to their vulnerability status which will in turn throw light on the decision-making perspectives by the people for that particular area. The technique

was used to rank the preference mentioned by the respondents on different factors and aspects of the cultivation process. It is used to find the most significant factor which had influenced the respondent in their practices. In garrets ranking average out the individual index value of indicator and then according ranked out. Table indicates that district Balrampur was less vulnerable among all other district where garretts ranking is 25 whereas Surajpur is more vulnerable among all other districts which garretts ranking value was 76 highest followed by Koriya (61) and Surguja (50).

After considering the vulnerability indices of the different district, any deviation in climatic variables such as rainfall, temperature should be assumed to increase vulnerability as such deviations necessitate adaptation of the economic activity to the emerging scenario. Sensitivity of crops to heat (temperature) stress is evident and irrigation is one of the key desired management responses. Therefore, we assumed that rising temperature and decreasing rainfall will have adverse impacts on agriculture. However, increase in extreme rainfall and temperature related events are assumed to be undesirable and hazardous.

It is clear from the table 4.18 that Surajpur was assigned rank one which was the most vulnerable districts among the other districts of Northern hills zone. This showed that the climate and weather of Surajpur was more susceptible to climate change and it will more affect the life of people living there. Surajpur district was more vulnerable because of increasing in population density. Agriculture and living of the people of Surajpur were affected mainly due to rainfall and temperature. Balrampur district was less vulnerable for climate change. The agriculture and other activities were not much affected by the climate change. Surguja, Koriya and Jashpur can be allocated as moderately vulnerable. Vulnerability index is important for policy making as it helps in taking precautions in most vulnerable areas. The adoption of precautionary measures also depends on the literacy and poverty of that area. The cropping pattern was decided on the basis of the climate and its vulnerability. The adaptive capacity of the people in these regions become less as for the past many seasons they have been vulnerable and this drains out their resources for adaptation at future time periods. Balrampur was less vulnerable areas as their climatic pattern, geographic and rainfall is not highly

variable. The less vulnerable districts will not be much affected by climate change mainly due to rainfall and temperature. There is less efforts are required in these districts as the agriculture is not much affected by climate change.

Similar work was also done by Hiremath and Shiyani (2013) they reported that the district of Amreli (north Saurashtra agro climatic zone) was found to the most vulnerable district and district of Panchmahals, the least vulnerable to climate change in the year 2008. Kumari and Bharti (2017) result also revealed that, the district of Supaul replaced Kishanganj from the first position with reference to overall vulnerability to climate change. Laxmi Prasanna (2017) worked on analysis of vulnerability indices in various agro-climatic zones of Andhra Pradesh from year 1985 to 2014. Result indicates that Anantapuram from scare rainfall zone continued to remain most vulnerable district during the three periods under study. Patnaik and Narayanan (2005) results also showed that in the districts of the Orissa and Andhra Pradesh states are highly vulnerable than the other states.

CHAPTER – V

SUMMARY AND CONCLUSION

The current research entitled “**Impact of rainfall on production and productivity of horticultural crops and vulnerability assessment in different districts of Northern hills zone of Chhattisgarh**” was conducted at IGKV, Raipur, Department of Agrometeorology, College of Agriculture (C.G) for 2004 to 2020. Rainfall plays an important role for livelihood and up-gradation of socioeconomic status of any state, hence the study was conducted to analyze the trends analysis of rainfall, area, and production of selected fruit and vegetable crops, correlation of selected fruit and vegetable crops with rainfall for the period from 2004-2020 and vulnerability assessment and ranking in Northern hill zone of Chhattisgarh state.

The outcome of weather characterization indicates that all 5 district showed non-significant trend. The districts Surguja and Jashpur showed non-significant decreasing trend in annual rainfall whereas districts Koriya, Balrampur and Surajpur reported non-significant increasing trend in annual rainfall.

Trend analysis of area and production of different fruit and vegetable crops shows the increasing or decreasing trend which is very important for crop planning. The trend analysis of area of mango crop showed significantly increasing in all 4 districts i.e. Jashpur, Koriya, Bakrampur and Suurajpur except in district Surguja, whereas trend of production showed significantly increasing trend in all 5 district. In litchi crop trend of area showed significantly increasing trend in all 5 districts of Northern hills zone while in case of production the districts Surguja, Jashpur, Koriya and Surajpur showed significantly increasing trend. In jackfruit crop significantly increasing trend showed in all 4 districts in area and production except the district Surguja, while area and production of papaya crop also showed significantly increasing trend in districts Koriya, Jashpur and Balrampur. The trend of area and production of guava and banana crops showed a significantly increasing trend in all 5 districts of Northern hill zone.

Trend analysis of area and production of vegetable crops indicates that all most of all vegetable crops reported significant trend in Northern hill zone. In cauliflower crop trend of area showed significantly increasing in districts Koriya, Balrampur and Surajpur whereas production trend reported increased significantly in the districts Jashpur, Koriya, balrampur and Surajpur. The trend of area of cabbage crop showed significantly increasing trend in the districts Surguja, Koriya, Balrampur and Surajpur while the production trend of cabbage was found significantly increasing in districts Jashpur, Koriya and Surajpur. When we see the area of brinjal crop the districts Jashpur, Koriya and Balrampur showed significantly increasing trend whereas trend of production of brinjal crop were found significantly increasing in districts Koriya and Balrampur. Trend of area and production of tomato crop was significant increasing in districts Jashpur, Koriya and Balrampur. In bhndi crop trend of area and production showed significantly increasing trend in districts Koriya and Balrampur whereas district Jashpur showed significant increasing trend in only area. The trend of area of potato crop showed significantly increasing in all 4 districts i.e. Surguja, Koriya, Balrampur and Jashpur while the production trend of potato was found significantly increasing in districts Jashpur and Koriya.

The correlation coefficient analysis of rainfall (annual) with production and productivity of fruit crops indicates that among all the fruit crops taken into consideration, production of mango crops was found significant positive in districts Balrampur and Koriya. The correlation of litchi and jackfruit production was found significantly positive with rainfall in district Surajpur. In papaya crop significantly negative or positive correlation were found in districts Surguja and Balrampur. Similarly in guava and banana crops showed significantly positive correlation in the district Surajpur.

Productivity of mango crop showed significantly positive in the districts Koriya and Surajpur whereas in litchi crop only district Balrampur found significantly positive with rainfall. The correlation coefficient in productivity of jackfruit crop showed significantly positive in the district Surajpur. Similarly in

banana crop the districts Balrampur and Surajpur showed significant positive correlation with rainfall and productivity.

In case of vegetable crops correlation between production and productivity with seasonal rainfall showed non-significant correlation for all selected vegetable crops in all districts of Northern hills zone except productivity of potato crop of district Jashpur.

Vulnerability is determined by the type, amount, and pace of climatic change and variation to which a system is subjected, as well as the sensitivity and adaptive capacity of the system. In Northern hills zone, district Surajpur was found to be most vulnerable as compared to other districts with respect to climate change whereas district Balrampur showed less vulnerable as compared to other districts in Northern hills zone. Districts Jashpur, Koriya and Surguja was found moderate vulnerable. Surajpur district is more vulnerable because of increasing in population density. Balrampur are less vulnerable areas as their climatic pattern, geographic and rainfall is not highly variable.

CONCLUSION

1. Rainfall showed non-significant trend in all 5 districts of Northern hills zone of Chhattisgarh. For area and production, all most of all districts of Northern hills zone showed significantly increasing trend for fruit and vegetable crops.
2. The correlation analysis of production and productivity of fruits with annual rainfall reported significant positive and negative correlation in districts Surajpur, Balrampur, Surguja and Koriya. The correlation of production and productivity of vegetable crops with seasonal rainfall was found non-significant positive or negative except in productivity of potato crop in Jashpur district indicates significantly positive correlation.
3. Based on overall vulnerability index and garrets ranking district Surajpur was found more vulnerable while district Balrampur was observed least vulnerable with respect to climate change in Northern hills zone of Chhattisgarh.

SUGGESTION

1. We have worked on out 5 districts of Northern hills zone, so it would be better to work on all 27 districts of C.G. at once, will give more better picture of the state with respect to climate change for future and the outcome can be used for better planning to fulfil future needs.

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APPENDIX – A

Table: Annual Rainfall (mm) of five districts (Jashpur, Surguja, Balrampur, Surajpur and Koriya of Northern hill zone from 1991 to 2020

District→	Jashpur	Surguja	Balrampur	Surajpur	Koriya
Year ↓	RF(mm)	RF(mm)	RF(mm)	RF(mm)	RF(mm)
1991	1222.9	1976.5	NA	1103	1027
1992	1125.4	1174.9	NA	1069.6	958.8
1993	1242.5	892.1	NA	1367	997
1994	1871.4	1977.4	NA	1770.2	1538
1995	1364.8	1352.4	NA	1039.5	1070
1996	1547.5	1193.6	NA	1019.2	1003.4
1997	1480.2	1501.9	NA	1143.5	1485.6
1998	1670.1	1748.9	NA	1032.4	1847.2
1999	1561.6	1342.6	NA	1827	1379.2
2000	1119	1543.9	NA	1376	923
2001	1680.8	751.8	NA	1884.2	1454.2
2002	1083.9	1511.1	NA	1646.4	952.2
2003	1242.1	1614.3	1753.5	1461.1	1584.1
2004	1126.5	1111.9	975.9	998.4	1464.5
2005	1324.7	907.2	945.8	1129.4	1157.4
2006	1381.3	1072.8	788.4	1236.2	1183
2007	1178.3	1167.1	1234	998.1	757.6
2008	1317	1469.5	975.9	840.1	1052.9
2009	1330.5	955.2	945.8	710.7	861
2010	1020.6	774.2	598.2	584.7	888.8
2011	1642.4	1178	1234	1245.8	1608.7

2012	1252.5	1364.1	995.4	1462.8	1378
2013	973.4	1081.1	1083.1	1151	1875.5
2014	945.4	1174	1065.4	1549.5	1916.6
2015	978.6	1276.5	993.4	1185.8	845.1
2016	1418.2	1517.5	1657.7	2665.6	1160.5
2017	1285.3	1456	1047.6	1683.9	813.2
2018	1159.5	1224.3	1388.6	1534.8	1070.4
2019	1588	1211.6	1309.9	1576.4	1172.7
2020	1790.6	1582	1582	2218	1556.2
Average	1330.8	1238.4	1143.033	1350.34	1232.727

Table: Demographic data

Districts	Population density		Literacy rate	
	2001	2011	2001	2011
Jashpur	127	132	63.8	63.8
Sarguja	125	162	54.8	54.8
Koriya	89	100	63.1	63.1
Balrampur	0	102	0	63.8
Surajpur	0	283	0	54.8

Table: agriculture data (cropping intensity)

Years	Districts				
	Surguja	Jashpur	Koriya	Balrampur	Surajpur
2004-05	115.67	106.31	111.97	0	0
2005-06	115.57	106.22	112.15	0	0
2006-07	115.64	106.24	111.45	0	0
2007-08	115.58	106.21	111.88	0	0
2008-09	115.26	106.23	111.49	0	0
2009-10	114.85	105.65	111.14	0	0
2010-11	114.91	105.85	110.25	0	0
2011-12	114.92	105.74	110.59	116.62	114.03

2012-13	114.91	105.46	111.07	116.86	114.31
2013-14	114.38	105.71	112.03	116.92	115.06
2014-15	114.73	105.67	112.03	116.66	114.68
2015-16	114.28	105.44	111.42	116.77	114.93
2016-17	118.19	105.26	111.83	114.99	114.24
2017-18	114.75	104.79	111.08	114.51	113.04

Table: agriculture data (irrigation intensity)

Years	Districts				
	Surguja	Jashpur	Koriya	Balrampur	Surajpur
2004-05	6.96	3.08	6.72	0	0
2005-06	7.18	3.13	7.22	0	0
2006-07	7.55	3.21	7.10	0	0
2007-08	7.39	3.25	6.83	0	0
2008-09	7.47	3.27	7.77	0	0
2009-10	7.60	3.80	7.53	0	0
2010-11	8.23	3.33	7.45	0	0
2011-12	8.99	3.65	7.94	7.38	9.50
2012-13	8.85	3.51	8.11	7.70	10.69
2013-14	8.94	3.62	7.68	9.38	11.96
2014-15	9.27	3.74	7.68	8.20	12.81
2015-16	9.26	3.67	7.52	7.76	11.18
2016-17	9.62	4.22	7.52	8.39	10.47
2017-18	10.52	3.66	7.48	8.19	10.65

Table: Occupational data (non-worker)

districts	2001	2011
Surguja	990053	425818
Jashpur	345262	364309
Koriya	306501	351846
Balrampur	0	370069
Surajpur	0	408192

Table: Occupational data (agricultural labour)

districts	2001	2011
Surguja	342593	167177
Jashpur	100070	197558
Koriya	61151	94648
Balrampur	0	187667
Surajpur	0	168512

Table: Occupational data (Total main worker)

districts	2001	2011
Surguja	605013	239367
Jashpur	261952	291349
Koriya	181837	173057
Balrampur	0	191396
Surajpur	0	191826

Table: Occupational data (Manufacturing labour)

districts	2001	2011
Surguja	16993	4528
Jashpur	10608	7553
Koriya	4086	4830
Balrampur	0	4404
Surajpur	0	3711

Table: total geographical data

districts	2001	2011
Surguja	731678.2	142933.1
Jashpur	275228.3	275228.3

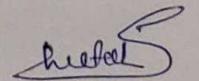
Koriya	490286.9	169504.4
Balrampur	0	333311.9
Surajpur	0	235514.5

RESUME

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Publications : No


Signature