Assessment of rainfall variations across different districts of Bundelkhand region.

ABSTRACT

The Bundelkhand region, one of the most vulnerable locations in central India, is prone to severe drought and crop failure attributed to annual rainfall fluctuation. In this study, basic statistics were utilized to determine the variances in rainfall across different districts in the Bundelkhand zone for 30 years (1987-2016) The average annual rainfall was found to be maximum for Damoh district (1169.24 mm) followed by Sagar district (1163.04 mm), Panna district (1118.79 mm), whereas it was minimum for Jalaun district (774.91 mm) followed by Datia district (841.61 mm), Hamirpur district (849.30 mm). In this study period in the year 2010 received low annual rainfall. The average seasonal rainfall was found to be maximum for Sagar district (1075.52 mm) followed by Damoh district (1073.40 mm), Panna district (1008.74 mm) whereas was minimum for Jalaun district (701.11 mm) followed by Datia district (769.1 mm). In this 30 year 1990 real received low seasonal rainfall. This research demonstrates the rainfall pattern over the study region and indicates susceptible locations that are more likely to face water stress as a result of rainfall variability.

Keyword- Bundelkhand region, vulnerable, rainfall, severe drought,

1. Introduction –

A region's deviation from normal rainfall has a huge impact on the availability of water resources for agriculture. Notwithstanding recent technological breakthroughs, weather and climate remain critical determinants in agricultural output. Variability in environmental elements such as precipitation and temperature, among others, impacts crop development phases and consequently agricultural production. Farmers are placed in danger throughout crop season due to variations in seasonal rainfall schedule in surmise to opt for the right time for sowing crop seeds and applying agricultural inputs.

The amount and temporal distribution of rainfall is generally the single most important determinant of inter annual fluctuations in national crop production levels (Mulat *et al.*, 2004). According to von Braun (1991), for instance, a 10% decrease in seasonal rainfall from the long-

term average generally translates into a 4.4% decrease in the country's food production. Rainfall in much of the country is, on the other hand, often erratic and unreliable; and rainfall variability and associated droughts have historically been major causes of food shortages and famines (Wood, 1977; Pankhurst and Johnson, 1988). Even though rainfall variability and drought are not new a phenomenon in Ethiopia, its frequency of occurrence has reportedly increased during the past a few decades (Ketema, 1999).

The incidence of drought is recurring phenomenon in India. It should be noted that drought is different from aridity and seasonal aridity since it is an irregularity of the climatic condition of the afflicted region. During 1871-2002, there were 22 major drought years, defined as years with All India Summer Monsoon Rainfall (AISMR) less than one standard deviation below the mean, i.e., anomaly below -10% (Department of Agriculture and Cooperation, 2009). Time after time the rate of incidence has varied but there is a stoic inevitability to its occurrence. According to the manual, the condition and recurrence rate of drought varies with different agro-climatic zones of the country. It is also observed that around 33% of the cropped area receives less than 750 mm of rainfall and rightly calls that percentage 'hotspot' of drought. One such hotspot which has been in the national as well as international news for its dire socio-economic condition is the geographical heartland of India, Bundelkhand. Since crop production, livestock rearing and seasonal out-migration provide more than 90% of rural income in Bundelkhand region (Samra, 2008), the effect of recurrent drought on this region is palpably devastating. **Gupta *et al*., (2014).**

Bundelkhand region has a long standing history of droughts and famines. The region witnessed "The Panic Famine" of 1873-74 (Loveday,1914, p.138). The Indian famine of 1896–1897 began in Bundelkhand early in 1895 and spread across many parts of the country, including the United Provinces, Central Provinces and Berar, Bihar, parts of the Bombay and Madras presidencies, and the Hissar district of Punjab, in addition to the princely states of Rajputana, Central India Agency and Hyderabad. The Bundelkhand district of Agra Province experienced drought in the autumn of 1895 as a result of poor summer-monsoon rains. When the winter monsoon also failed, the provincial government declared a famine early in 1896 (Imperial Gazetteer of India Vol. III 1907, p. 490-91). According to the report on drought mitigation strategies for UP and MP Bundelkhand by the Inter-ministerial Central Team

headed by Dr. J. S. Samra, the region experienced a major drought in every 16 years during the 18th and 19th centuries, which increased by three times during the period 1968 to 1992 (Samra, 2008). During 1905-06 Bombay and Bundelkhand provinces were affected by severe drought and cholera outbreak. However, drought associated mortality is unknown for Bundelkhand.

Drought is the combined effect of meteorological (reduced rainfall) and hydrological (reduced available water supply) factors. In the UP part of Bundelkhand, drought became evident in 2004-05 with a 25% short fall in monsoon rains. The rainfall deficit increased further to 43% in 2006-07 and 56% in 2007-08, leading to severe (metrological) drought conditions in Mahoba, Jhansi and Chitrakoot districts. Except Tikamgarh and Datia districts, drought in the Bundelkhand region of MP commenced from 2006-07.

2. Materials and Methods

2.1. General description of study area

The Bundelkhand region lies at the heart of India located below the Indo-Gangetic plain to the north with the undulating Vindhyan mountain range spread across the northwest to the south. The region span across thirteen districts: seven in Uttar Pradesh - Jhansi, Jalaun, Lalitpur, Hamirpur, Mahoba, Banda and Chitrakoot, and six in Madhya Pradesh - Datia, Tikamgarh, Chattarpur, Damoh, Sagar and Panna of total geographical area of 7.08 million hectares (mha). Therefore the present study was conducted in order to know the condition, pattern and frequency of drought in the bundelkhand region, so that different policies can be made in order to mitigate the impact of drought on agriculture as well as water resources. **Gupta, A. K., *et. al.* (2014).**

The latitude of study area of Bundelkhand lies between $23^0$20'N - $26^0$20'N and longitude lies between $78^0$20'E - $81^0$40'E.

2.2. Climate

Bundelkhand region experiences a hot and semi-humid climate. Usually the hottest days are in May and coldest days in December or January. The temperatures are much higher locally due to conditions such as lack of haze and radiation from rocky soils or outcrops. In summer there are local squalls of short intervals. This frequently results in a cloud of dust that can be so thick that it becomes murky during the daytime.

The average annual temperature is over 25°C. However, the mean monthly values vary considerably from the annual means and consequently the temperature range is high. In summer mean temperatures range around 30°C and can rise beyond 40°C in May - June. The monsoons from June to September bring down temperatures to around 22°C - 25°C with relative humidity varying between 70 to 80%. The mean annual precipitation varies from 75 cm in the north to 125 cm in the southeast. The average for the region can be considered around 100 cm and falls mainly in the monsoon months of June to September. Around 75% of rainfalls in these three months, and the total amount is highly variable and capricious. Some shallow westerly depressions cause winter rain which is highly beneficial to the Rabi crop. **(J. S. Sandhu, 2016).**

3.2.2. Agriculture

Bundelkhand (Uttar Pradesh) receives about 900 mm of rainfall. A little over 60% of the area is cultivated, but compared to other parts of Uttar Pradesh, the sub-region has less developed irrigation facilities. Only about 25%of the cultivated area is irrigated as against a State average of nearly 60%. Soil erosion is high and land productivity is low. Bundelkhand (Madhya Pradesh) proportion of wastelands is very high at about 37% in this sub-region. Only about 45% of the land is cultivated; a little over a third of the cultivated area is irrigated. The area receives relatively low rainfall of around 700 mm annually, the climate is dry, sub-humid and the soil type is classified as mixed red and black. **(J. S. Sandhu, 2016)**

3.2. Data sources and collections

3.2.1. Meteorological data:

To assess the meteorological drought, the monthly rainfall data series covering the period 1901-2016 for all 13 districts of bundelkhand region has been taken from Google Earth Pro (climate research unit) for the study 30 years (1987-2016) rainfall data has been downloaded.

3.3 Statistical Analysis

3.3.1 Mean rainfall

The amount of rainfall collected by a given rain gauge in 24 hours is known as daily rainfall (mm or cm) and the amount collected in one year is known as annual rainfall. The mean of the annual rainfall over of 30 years is known as mean annual rainfall (average annual rainfall or normal annual rainfall).

$$\text{Mean Annual Rainfall} = \frac{\text{Total Rainfall}}{\text{Number of Years}}$$

3.3.2 Standard deviation

In statistics, the standard deviation is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A low standard deviation indicates that the data points tend to be close to the mean (also called the expected value) of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values. Norman *et al.* (2003).

$$SD(\sigma) = \sqrt{\frac{\sum(X-Y)2}{n-1}}$$

Where,

σ = Standard deviation

X = Rainfall

Y = Mean rainfall

n = number of years

3.3.3 Coefficient of variation

In probability theory and statistics the coefficient of variation, also known as relative standard deviation, is a standardized measure of dispersion of a probability distribution or frequency distribution. It is often expressed as a percentage, and is defined as the the ratio of the standard deviation to the mean.

$$CV\% = \frac{Standard\ Deviation}{Mean} \times 100$$

3.3.4 Correlation analysis

Correlation is a term that refers to the strength of a relationship between two variable. A strong or high correlation means that two or more variable have a strong relationship which each other, while a week or low correlation means that the variables are hardly related. Correlation

analysis is the process of studying the strength of the relationship with available statistical data. (Cohen *et al*. 2014)

$$r = \frac{\Sigma(x - \bar{x})(y - \bar{y})}{\sqrt{\Sigma(x - \bar{x})2\,\Sigma(y - \bar{y})2}}$$

r – the correlation coefficient of the linear relationship between the variables x and y

x – the values of the x-variable in a sample

$\bar{x}$ - the mean of the values of the x-variable

y - the values of the y-variable in a sample

$\bar{y}$ - the mean of the values of the y-variable

3.3.5 Regression analysis

In statistical modeling, regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables (or 'predictors'). More specifically, regression analysis helps one to understand how the typical value of the dependent variable (or 'criterion variable) changes when any one of the independent variable is varied, while the other independent variable are held fixed. Most commonly, regression analysis estimate the conditional expectation of the dependent variable given the independent variable that is the average value of the dependent variable when the independent variables are fixed.

$$Y = a + bX\text{i}$$

Where,

a=constant or intercept

b=slope for X

Y=dependent variable

X_1=independent variables

3.3.6 Co-efficient of determination (R^2)

The coefficient of the determination R^2 is defined as the squared value of the Pearson correlation coefficient. R^2 signifies the proportion of the variance in measured data explained by

the model, or can also be interpreted as the squared ratio between covariance and the multiplied standard deviations of the observations and predictions. It range from 0 to 1, with values close to 1 indicating a good agreement, and typically values greater than 0.5 are considered acceptable in watershed simulation. Co-efficient of determination (R^2) was used to show the relationships between two different variables i.e. between dependent and independent variables. In the present case the simulated yield was considered as dependent variable and observed as independent variable. An increasing trend for example, with high R^2 value implies that there exists better relationship between two variables. Coefficient of determination was calculated using Microsoft Office Excel 2007 between two variables situated in X and Y co-ordinates.

4.1 Results and Discussion

Study of rainfall variations across different districts of Bundelkhand region

Basic statistics like mean, standard deviation (SD) and co-efficient of variation for annual as well as seasonal rainfall over 30 years (1988-2017). It is one of the important statistical tools used to know the variability of rainfall. Further, rainfall classification based on IMD specifications was done. The results are presented under the following sub headings. The result reveals that the annual rainfall varied over a wide range across different districts.

The data on basic statistics, rainfall classification of annual as well as seasonal rainfall are present below. Year wise annual rainfall, seasonal rainfall and percent rainfall departure from normal for districts of Bundelkhand region was given in Appendix-I to Appendix- XIII.

Banda District

The mean annual rainfall of Banda district was 813.26 mm with a coefficient of variation (CV) of 23% and standard deviation (SD) is about 185.24. Out of 30 years, 5 years received excess of rainfall. Where, 7 years *viz.*, 2006, 2007, 2009, 2010, 2014, 2015 and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 743.44 mm with coefficient of variation 25% and standard deviation (SD) is about 187.19. Out of 30 years, 8 years received excess of rainfall. Where, 6 years received deficit of rainfall (2006, 2007, 2009, 2010, 2014 and 2015).

Chattarpur District

The mean annual rainfall of Banda district was 952.52 mm with a coefficient of variation (CV) of 26% and standard deviation (SD) is about 243.79. Out of 30 years, 6 years received

excess of rainfall. Where, 7 years *viz.*, 1989, 2006, 2007, 2010, 2014, and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 878.36 mm with coefficient of variation 28% and standard deviation (SD) is about 246.60. Out of 30 years, 7 years received excess of rainfall. Where, 7 years received deficit of rainfall (2006, 2007, 2009, 2010, 2014, 2015 and 2017).

Chitrakoot District

The mean annual rainfall of Banda district was 853.14 mm with a coefficient of variation (CV) of 22% and standard deviation (SD) is about 191.93. Out of 30 years, 5 years received excess of rainfall. Where, 6 years *viz.*, 1989, 2006, 2007, 2009, 2010, and 2015 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 776.22 mm with coefficient of variation 25% and standard deviation (SD) is about 191.84. Out of 30 years, 6 years received excess of rainfall. Where, 6 years received deficit of rainfall (1989, 2006, 2007, 2009, 2010 and 2014).

Damoh District

The mean annual rainfall of Banda district was 1116.53 mm with a coefficient of variation (CV) of 26% and standard deviation (SD) is about 294.03. Out of 30 years, 7 years received excess of rainfall. Where, 7 years *viz.*, 1989, 1998, 2000, 2006, 2007, 2014 and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 852.39 mm with coefficient of variation 31% and standard deviation (SD) is about 266.72. Out of 30 years, 7 years received excess of rainfall. Where, 11 years received deficit of rainfall (1989, 1993, 1998, 2002 2006, 2007, 2009, 2010, 2014, 2015 and 2017).

Datia District

The mean annual rainfall of Banda district was 721.34 mm with a coefficient of variation (CV) of 23% and standard deviation (SD) is about 164.23. Out of 30 years, 7 years received excess of rainfall. Where, 7 years *viz.*, 1989, 2000, 2002, 2005, 2006, 2007 and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 651.05 mm with coefficient of variation 24% and standard deviation (SD) is about 156.72. Out of 30 years, 8 years received excess of rainfall. Where, 8 years received deficit of rainfall (2002, 2005, 2006, 2007, 2008, 2014, 2015 and 2017).

Hamirpur District

The mean annual rainfall of Banda district was 727.65 mm with a coefficient of variation (CV) of 25% and standard deviation (SD) is about 181.59. Out of 30 years, 6 years received excess of rainfall. Where, 7 years *viz.*, 1997, 2006, 2007, 2012, 2014, 2015 and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 653.28 mm with coefficient of variation 28% and standard deviation (SD) is about 179.73. Out of 30 years, 6 years received excess of rainfall. Where, 7 years received deficit of rainfall (1997, 2006, 2007, 2009, 2014, 2015 and 2017).

Jalaun District

The mean annual rainfall of Banda district was 634.81 mm with a coefficient of variation (CV) of 30% and standard deviation (SD) is about 187.35. Out of 30 years, 8 years received excess of rainfall. Where, 7 years *viz.*, 2006, 2007, 2011, 2012, 2014, 2015, and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 566.6 mm with coefficient of variation 31% and standard deviation (SD) is about 175.43. Out of 30 years, 7 years received excess of rainfall. Where, 7 years received deficit of rainfall (1997, 2002, 2006, 2007, 2009, 2011, 2012, 2014, 2015 and 2017).

Jhansi District

The mean annual rainfall of Banda district was 785.33 mm with a coefficient of variation (CV) of 25% and standard deviation (SD) is about 198.89. Out of 30 years, 7 years received excess of rainfall. Where, 6 years *viz.*, 1989, 2006, 2007, 2012, 2015 and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 712.03 mm with coefficient of variation 27% and standard deviation (SD) is about 191.07. Out of 30 years, 7 years received excess of rainfall. Wheres, 6 years received deficit of rainfall (2006, 2007, 2009, 2014, 2015 and 2017).

Lalitpur District

The mean annual rainfall of Banda district was 918.63 mm with a coefficient of variation (CV) of 26% and standard deviation (SD) is about 238.39. Out of 30 years, 6 years received excess of rainfall. Where, 6 years *viz.*, 1989, 2002, 2006, 2007, 2015 and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 853.76 mm with coefficient of variation 27% and standard deviation (SD) is about 231.95. Out of 30 years, 7 years received excess of rainfall. Where, 7 years received deficit of rainfall (1989, 2002, 2006, 2007, 2009, 2014, 2015 and 2017).

Mahoba District

The mean annual rainfall of Banda district was 844.98 mm with a coefficient of variation (CV) of 25% and standard deviation (SD) is about 211.32. Out of 30 years, 6 years received excess of rainfall. Where, 7 years *viz.*, 2006, 2007, 2010, 2012, 2014, 2015 and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 767.17 mm with coefficient of variation 28% and standard deviation (SD) is about 215.92. Out of 30 years, 7 years received excess of rainfall. Where\, 7 years received deficit of rainfall (2006, 2007, 2009, 2010, 2014, 2015 and 2017).

Panna District

The mean annual rainfall of Banda district was 1005.83 mm with a coefficient of variation (CV) of 25% and standard deviation (SD) is about 247.35. Out of 30 years, 6 years received excess of rainfall. Where, 5 years *viz.*, 2006, 2007, 2010, 2014 and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 928.39 mm with coefficient of variation 27% and standard deviation (SD) is about 250.53. Out of 30 years, 7 years received excess of rainfall. Where, 7 years received deficit of rainfall (2006, 2007, 2009, 2010, 2014, 2015 and 2017).

Sagar District

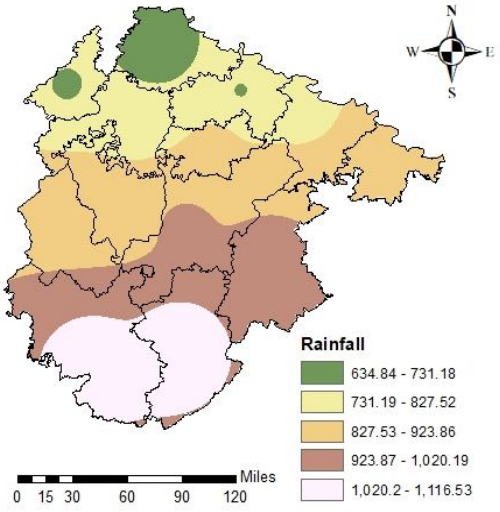
The mean annual rainfall of Banda district was 1094.59 mm with a coefficient of variation (CV) of 25% and standard deviation (SD) is about 274.17. Out of 30 years, 7 years received excess of rainfall. Where, 6 years *viz.*, 1989, 2002, 2006, 2007, 2010 and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 1016.13 mm with coefficient of variation 26% and standard deviation (SD) is about 264.32. Out of 30 years, 7 years received excess of rainfall. Where, 7 years received deficit of rainfall (1989, 2002, 2006, 2007, 2014, 2015 and 2017).

Tikamgarh District

The mean annual rainfall of Banda district was 872.45 mm with a coefficient of variation (CV) of 25% and standard deviation (SD) is about 220.81. Out of 30 years, 6 years received excess of rainfall. Where, 5 years *viz.*, 1989, 2006, 2007, 2015, and 2017 were deficit of rainfall. The mean seasonal rainfall for S-W monsoon was found to be 801.14 mm with coefficient of variation 27% and standard deviation (SD) is about 216.61. Out of 30 years, 6

years received excess of rainfall. Where, 7 years received deficit of rainfall (1989, 2006, 2007, 2009, 2014, 2015 and 2017)

Fig.1 Shows that Annual rainfall variation of Bundelkhand region is half of the area of Sagar and Damoh districts receives maximum rainfall and 50% area of the Panna, Sagar, Chattarpur, Damoh districts receives medium rainfall while Lalitpur, some parts of Panna, Damoh, Mahoba, Chattarpur districts receives normal rainfall. Hamirpur, Jhansi and half of Banda, Datia districts experiences minimum of rainfall and Jalaun, Datia district receives scarcity of rainfall.



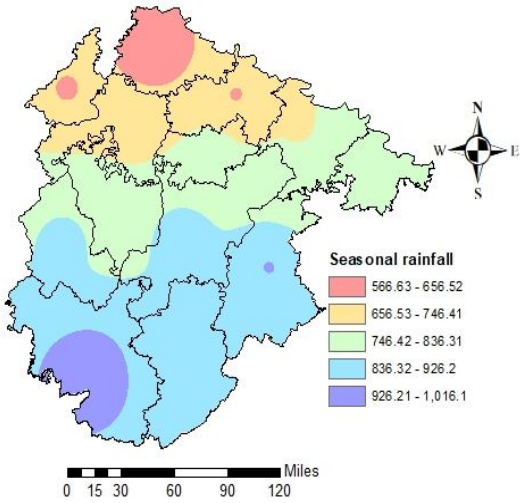


Fig.1 Annual Rainfall for Bundelkhand region **Fig. 2 Seasonal Rainfall for Bundelkhand region**

Fig. 2 Shows that Seasonal rainfall variation of Bundelkhand region is half of the area of Sagar and little area of Panna districts receives maximum rainfall and 50% of the Panna, Chattarpur, Lalitpur, Sagar, Damoh receives medium rainfall while parts of Tikamgarh, Chitrakoot, Damoh, Mahoba, receives normal rainfall. Some parts of Datia, Hamirpur, Jhansi experiences minimum of rainfall and Jalaun district receives scarcity of rainfall.

Table. 1 Seasonal rainfall classification for Bundelkhand region

DISTRICT NAME	Deficit rainfall
Banda	2006, 2007, 2009, 2010, 2014, 2015

Chattarpur	2006, 2007, 2009, 2010, 2014, 2015, 2017
Chitrakoot	1989, 2006, 2007, 2009, 2010, 2014
Damoh	1989, 1993, 1998, 2002 2006, 2007, 2009, 2010, 2014, 2015, 2017
Datia	2002, 2005, 2006, 2007, 2008, 2014, 2015, 2017
Hamirpur	1997, 2006, 2007, 2009, 2014, 2015, 2017
Jalaun	1997, 2002, 2006, 2007, 2009, 2011, 2012, 2014, 2015, 2017
Jhansi	2006, 2007, 2009, 2014, 2015, 2017
Lalitpur	1989, 2002, 2006, 2007, 2009, 2014, 2015, 2017
Mahoba	2006, 2007, 2009, 2010, 2014, 2015, 2017
Panna	2006, 2007, 2009, 2010, 2014, 2015, 2017
Sagar	1989, 2002, 2006, 2007, 2014, 2015, 2017
Tikamgarh	1989, 2006, 2007, 2009, 2014, 2015, 2017
Note: - According to IMD, rainfall classification based on rainfall departure are Excess rainfall (E) = (≥+20 %), Normal Rainfall (N) = (+19 to -19.9 %), Deficit rainfall (D) = (-20 to -59.9 %) and Scarcity rainfall (S) = (-60 to -99 %)	

CONCLUSIONS –

The main finding of the study are as followed the rainfall pattern have been analyzed for all 13 district of Bundelkhand Region for the period 1987 to 2016 from the studies it is cleared that rainfall pattern was not same over study it is slightly fluctuating in rainfall departure not only from year to year and place to place but also from month to month this clearly indicates that the uneven distribution of rainfall

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