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COMPARISON OF AGRICULTURAL DROUGHT INDICES FOR DIFFERENT DISTRICTS OF CHHATTISGARH

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ABSTRACT

The Indian economy, thus, has been described as a gamble monsoon. Aberrant weather is a part of agriculture in India affecting its production. Drought varies from place to place depending upon normal climatic conditions, available water resources, agricultural practices and the various socio-economic activities. This present research work was carried out during the study period agricultural drought pattern in different districts of Chhattisgarh. Based on the study it was found that Raipur had 6 mild, 3 moderate and 4 severe drought , Jagdalpur had 9 mild, 2 moderate and 2 disastrous droght and Ambikapur had 8mild, 2 moderate, 2 severe droughts in out of 24 years On the basis of SPI, While as per MAI Raipur had 5 mild,10 largeand 1 severe droughts Bilaspur had 9 mild, 2 largeand 3 severe droughtss Jagdalpur had 8 mild, 4 arge and Ambikapur had 9 mild, 7 large drought years.Ths based on agricultural drought analysis it was found that moisture adequacy index value for agricultural drought analysis seemed to be better as they are based on water balance computations which consider the rainfall distribution along with soil moisture availability for the crop growth period.

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INTRODUCTION

India, about 70% (228.3 million ha) of country's total land area (327.9 million ha) is classified as dry lands which are again divided into arid, semi-arid and dry subhumid zones (Meena *et al.,* 2016). The economy of the farmer is well influenced by weather and climate. It's also playing an important role in the economy of the State and even of the country (Pawar *et al.,* 2015). The Indian economy, thus, has been described as a gamble monsoon. India, receives the major quantum (74%) of its annual rainfall during southwest monsoon season (June to September). Aberrant weather is a part of agriculture in India affecting its production. Drought varies from place to place depending upon normal climatic conditions, available water resources, agricultural practices and the various socio-economic activities. Drought-related disasters in the 1980s killed over half a million people in Africa.(Kallis 2008). Drought in India has resulted in tens of millions of deaths over the course of the 18th, 19th, and 20th centuries. Indian agriculture is heavily dependent on the climate. A favorable southwest summer monsoon is critical in securing water for irrigating crops. In some parts of India, the failure of the monsoons result in water consequently in below-average crop yields. This is particularly true of major drought-prone regions such as southern and eastern Maharashtra, northern Karnataka, Andhra Pradesh, Odisha, Gujarat and Telangana Rajasthan's. In the past, droughts have periodically led to major Indian famines, including the Bengal famine of 1770, in which up to one third of the population in affected areas died; the 1876-1877 famine, over five million people died; and the 1899 famine, in which over 4.5 million died (Sun *et al*. and AMS, 2006).

Drought is characterized by three main aspects: intensity, duration, and spatial coverage (Allaby, 2002). Intensity is the degree of the precipitation, soil moisture, or water storage deficit; it may include consideration of the severity of the associated impacts. Drought typically lasts for several months to a few years, but extreme drought can persist for several years, or even decades for so called mega-drought.

Drought indices evaluate the departure of climate variables in a given time interval (month, season or year) from the "normal" conditions and are used as monitoring tools and operational indicators for water managers. In other words droughts indices are quantitative measures that characterize drought levels by assimilating data from one or several variables (indicators) such as precipitation and evapotranspiration into a single numerical value. Such an index is more readily useable than raw indicator data. The most commonly used indices are: Percent of Normal, Deciles, Standardized Precipitation Index (SPI), Palmer Drought Severity Index (PDSI), Crop Moisture Index (CMI) and Surface Water Supply Index (SWSI). Drought indices can be useful tools for providing information for decision-makers in business, government and to the public stakeholders. Keeping the above aspects in view, studies were carried out on comparison of agricultural drought indices for different districts of Chhattisgarh.

MATERIALS AND METHODS

For analysis daily and weekly long term weather data like maximum temperature,

minimum temperature, relative humidity, wind speed and rainfall of four districts has been considered. The data base for all four districts is not same.

Potential evapotranspiration

The monthly potential evapotranspiration for 4 districts for the period 2001-2010 was computed using the following formula of Thornthwaite modified equation. Thornthwaite and Mather's (1955) method of estimating PET is based solely on air temperature. PET estimates are based upon a 12-hour day (amount of daylight) and a 30-day month. Thornthwiate (1948) gave the following formula for computing monthly evapotranspiration:

E = 1.6 (10T/I) A

Where,

E = Unadjusted PET (cm)

T = Mean air temperature (ºC)

I = Annual or seasonal heat index. It is the summation of 12

Values of monthly heat indices i = (T/5) 1.514

A = 0.675 x10-6 x I-3 – 0.771x10-4 I2 + 1.79x10-2 I + 0.4924

For daily calculation the formula is modified as under.

$$PET = \frac{k \times e \times 10}{\text{Days in momth}} \text{ mm day}^{-1}$$

Where,

k = Adjustment factor

Agricultural drought analysis

Moisture adequacy index (Ima)

An index of moisture adequacy (Ima) has been calculated by computing the monthly water balance. The Imais the ratio of actual evapotranspiration to potential evapotranspiration, expressed as percentage.

$$\text{Index of moisture adequacy (Ima)} = \frac{AET}{PET} \times 100$$

The value of Ima = 100 indicates that the AET is equal to PET and that there is no moisture stress to the crop.

Standardized precipitation index (SPI)

The Standardized Precipitation Index (SPI) is one of the numerous indices that are being used to detect and monitor the drought across the world. It is developed by Mckee*et al* (1993) at Colorado State University, U.S.A. It is defined as the number of standard deviations that the observed cumulative rainfall at a given time scale would deviate from the long term means. Hayes *et al*. (2011) Standardized Precipitation Index (SPI) has been computed using the following equation

$$SPI = \frac{X_i - X_j}{\sigma_i}$$

where, X_i = Rainfall received during i^{th} period, X_j = Normal rainfall for j^{th} period,

σ_i = Standard deviation of rainfall during i^{th} period. In the present study, SPI has been computed on 1-month time scale (June, July, August, September, October) and 5 – month time scale (June-October) in order to correlate with district wise yield of rice and maize. In the case pigeon pea, SPI was worked out 1- month time scale (July to January) and 7 month scale (July-January).

RESULTS AND DISCUSSION

The agriculture drought intensity analyzed based on four months (*i*.e. June to September) data on SPI and Moisture Adequacy Index. The results are.

Raipur

Based on the SPI drought at Raipur there was mild drought during the years 1995, 1996,1997,1999,2001 and 2004 and moderate drought during the years 1991, 1992, 1998, 2000, 2002 and 2008, respectively. Based on MAI during the months June to September there was mild drought occurred on the years 1991, 1993, 2000, 2008 and 2011, respectively. In the years 1992, 1995, 1996, 1997, 1999, 2002, 2003, 2005, 2010 and 2014 there was large drought at Raipur. There was severe drought in 2009 based on moisture adequacy index values. Thus, it seems that moisture adequacy index captures better drought scenario than SPI values at Raipur (Table 1).

Bilaspur

At Bilaspur, there was mild drought during the years 1991,1992,1996,1997,1998, 2002, 2006,2008,2013 and 2014. There was moderate drought during the year 1999,2004 and 2009 based on SPI values. It was observed there was severe drought in the year 2000 at Bilaspur based on SPI value. Based on MAI values average of four months June to September, were mild drought in the year 1991, 1992, 1995, 1998, 1999, 2000, 2001, 2011 and 2014, respectively that was severe droughts during the year 2006 and 2010. Severe drought

Table 1: Drought condition in different year using SPI and MAI Raipur district

Year	SPI	MAI
1991	No drought	No drought
1992	Disatrous drought	Mild drought
1993	Mild drought	No drought
1994	Mild drought	Large drought
1995	Mild drought	Large drought
1996	Mild drought	Large drought
1997	Disatrous drought	Large drought
1998	Moderate drought	Mild drought
1999	No drought	No drought
2000	Mild drought	No drought
2001	No drought	Mild drought
2002	Moderate drought	Mild drought
2003	No drought	No drought
2004	No drought	No drought
2005	Mild drought	No drought
2006	No drought	Mild drought
2007	Mild drought	No drought
2008	No drought	No drought
2009	Mild drought	Mild drought
2010	No drought	No drought
2011	No drought	Mild drought
2012	No drought	No drought
2013	Mild drought	No drought
2014	No drought	Mild drought

Table 2: Drought condition in different year using SPI and MAI Bilaspur district

YEAR	SPI	MAI
1991	Mild Drought	Mild Drought
1992	Mild Drought	Large Drought
1993	No Drought	No Drought
1994	No Drought	No Drought
1995	No Drought	Mild Drought
1996	Mild Drought	Severe Drought
1997	Mild Drought	No Drought
1998	Mild Drought	Mild Drought
1999	Moderate Drought	Mild Drought
2000	Severe Drought	Mild Drought
2001	No Drought	Mild Drought
2002	Mild Drought	Severe Drought
2003	No Drought	No Drought
2004	Moderate Drought	No Drought
2005	No Drought	No Drought
2006	Mild Drought	Large Drought
2007	No Drought	No Drought
2008	Mild Drought	No Drought
2009	Moderate Drought	Severe Drought
2010	No Drought	Large Drought
2011	No Drought	Mild Drought
2012	No Drought	No Drought
2013	Mild Drought	No Drought
2014	Mild Drought	Mild Drought

Table 3: Drought condition in different year using SPI and MAI Jagdalpur district

Year	SPI	MAI
1991	No drought	No drough
1992	Disatrous drough	Mild drough
1993	Mild drough	No drough
1994	Mild drough	Large drough
1995	Mild drough	Large drough
1996	Mild drough	Large drough
1997	Disatrous drough	Large drough
1998	Moderate drough	Mild drough
1999	No drough	No drough
2000	Mild drough	No drough
2001	No drough	Mild drough
2002	Moderate drough	Mild drough
2003	No drough	No drough
2004	No drough	No drough
2005	Mild drough	No drough
2006	No drough	Mild drough
2007	Mild drough	No drough
2008	No drough	No drough
2009	Mild drough	Mild drough
2010	No drough	No drough
2011	No drough	Mild drough
2012	No drough	No drough
2013	Mild drough	No drough
2014	No drough	Mild drough

occurred during the year 1996, 2002 and 2009 at Bilaspur based on MAI values. Based on MAI values four continuously mild droughts occurred from1998 to 2001, at Bilaspur (Table 2).

Jagdalpur

At Jagdalpur, there were mild droughts based on SPI values during the years 1993,1994, 1995,1996,2000,2005,2007, 2009 and 2013, and there were moderate droughts during the years 1998 and 2002. However there were two disastrous droughts occurred during the year 1992 and 1997.based on SPI values. The drought intensities were computed by MAI values, average of four months (i.e. June to September) for Jagdalpur. There were mild droughts in the years 1992,1998,2001,2002,2006,2009,2011 and 2014. There were large droughts during the years 1994,1995, 1996, and 1997. It was interestingly to note that MAI values showed four continuously large agricultural droughts, but there was no severe drought at Jagdalpur (Table 3).

Table 4: Drought condition in different year using SPI and MAI Ambikapur district

Year	SPI	MAI
1991	No Drought	Mild Drought
1992	Mild Drought	Mild Drought
1993	Moderate Drought	No Drought
1994	No Drought	No Drought
1995	No Drought	Mild Drought
1996	Mild Drought	No Drought
1997	No Drought	No Drought
1998	No Drought	Mild Drought
1999	No Drought	No Drought
2000	No Drought	No Drought
2001	No Drought	No Drought
2002	No Drought	No Drought
2003	No Drought	Mild Drought
2004	Mild Drought	Large Drought
2005	Moderate Drought	Large Drought
2006	Mild Drought	Large Drought
2007	Mild Drought	Large Drought
2008	No Drought	No Drought
2009	Severe Drought	Large Drought
2010	Severe Drought	Large Drought
2011	Mild Drought	Large Drought
2012	No Drought	Mild Drought
2013	Mild Drought	Mild Drought
2014	Mild Drought	Mild Drought

Ambikapur

At Ambikapur there were mild droughts based on SPI values during the years 1992, 1996, 2004, 2006, 2007, 2011, 2013 and 2014 and there were moderate agriculture droughts during the year 1993 and 2005. It was found that there was two severe agriculture droughts during the year 2009 and 2010 at Ambikapur based on SPI values. Based on MAI value during the period June to September there was mild agricultural droughts during the years 1991,1992, 1993, 1995, 1998, 2003, 2012, 2013 and 2014. Last three years Ambikapur faced mild agricultural droughts from 2012 to 2014. There was large agricultural drought during the year, 2004, 2005, 2006, 2007, 2009, 2010 to 2011 (Table 4). It was interesting that Ambikapur faced seven large agricultural droughts out of eight years from 2004 to 2011 but there was no severe drought. Thus based on meteorological and agricultural drought analysis it was found that aridity index anomaly for drought analysis and moisture adequacy index values for agricultural drought analysis seemed to be better as they are based on water balance computations which consider the rainfall distribution along with soil moisture availability for the crop growth period.

Similarly, Das *et al.,* revealed that Out of 42 years from 1961 to 2003, drought occurred during 22 years or 52.4 % of the study period at some or other parts of Chhattisgarh. Villages of Mahasamund, Baster, Sarguja, Raipur and Durg districts phases 9 or 21%, 6 or 14%, 5 or 12% and 4 or 10% years drought, respectively. There were disastrous droughts of very high intensity ones in 16 years or in 38% of study years, severe in remaining 6 years or 14% of the study years. Bhelawe *et al*. were also experienced no severe and extreme droughts year in last 43 years at Raipur. However, there was 9 moderate drought (1974, 1979, 1987, 1988, 1991, 1992, 2000, 2002 and 2008) and 10 mild droughts (1972, 1976, 1978, 1982, 1995, 1996, 1998, 1999, 2001 and 2004).

Similarly, Hall and Brown compared monthly PDSI, Palmer-Z, and SPI for 1-, 3-, 6-, 12-, 24-, 36-, 48-, 60, and 72-month periods drought indices related to fire activity and potential in US and found that the 6- month SPI shows the better correlation in later of the season than earlier, the remaining SPI indices are spread relatively evenly throughout the season. PDSI correlates better with fire characteristics in the early part of the season, whereas the Palmer-Z shows better correlations in August and September month.

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