

Variability of extreme weather events and its impact on crop yield in Bundelkhand Agroclimatic zone of Madhya Pradesh

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(Received 27 March 2019, Accepted 27 December 2019)

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सार – हाल ही के दशकों में मध्य प्रदेश के बूंदेलखंड के कृषि जलवायविक क्षेत्र ने मौसम की अनेक चरम घटनाओं, जैसे अत्यधिक गर्मी, शुष्कता, शीत तथा लगातार अनेक वर्षों तक सूखे की स्थितियों का सामना किया है। सूखा और जल की कमी इस क्षेत्र में संसाधनों को सीमित करने वाले मुख्य कारक हैं। पिछले दशक (2001-2010) में छतरपुर और दतिया जिलों में गर्मी के दिनों में भारी बढ़ोत्तरी हुई। पिछले दशक के दौरान टीकमगढ़ और छतरपुर जिलों में भारी वर्षा के दिनों में काफी कमी आई, जबकि दतिया में पाला पड़ने वाले दिनों में वृद्धि हुई। कालिक पैमाने पर सूखे की परिवर्तनशीलता की तुलना में सूक्ष्म स्तर की परिवर्तनशीलता काफी अधिक थी। हाल के दशक में सूक्ष्म स्तर पर सूखे की घटनाएँ काफी अधिक थीं। इस क्षेत्र में पिछले वर्षों में लगातार सूखा पड़ने से सोयाबीन और धान के उत्पादन की परिवर्तनशीलता में वृद्धि हुई। प्रस्तुत शोध पत्र में मौसम की चरम घटनाओं की परिवर्तनशीलता से धान तथा सोयाबीन के उत्पादन पर तथा ग्रामीण आजीविका पर इसके प्रभाव को प्रस्तुत करने का प्रयास किया गया है। भारी वर्षा के दिनों तथा वर्षा के दिनों से धान तथा सोयाबीन की फसलों पर सामान्य रूप से प्रभाव पड़ा। धान के सतत उत्पादन के लिए प्रतिवर्ष टीकमगढ़ में भारी वर्षा वाले 6 या अधिक दिन तथा छतरपुर में 7 दिन होने आवश्यक हैं। देखा गया है कि जिन जिलों में प्रति वर्ष, वर्षा के दिनों में कालिक परिवर्तनशीलता कम हुई, वहाँ सतत उत्पादन के लिए 5 से कम दिनों की वर्षा में कमी महत्वपूर्ण थी। जबकि जिन जिलों में वर्षा के दिनों में कालिक परिवर्तनशीलता कम पाई गई, वहाँ पर्याप्त उत्पादन के लिए भारी वर्षा के दिनों की संख्या विशेष रूप से अनिवार्य नहीं थी। दतिया और छतरपुर जिलों में अनेक दशकों से पशुओं में बैचैनी वाले दिनों की संख्या में वृद्धि हुई।

ABSTRACT. The Bundelkhand Agroclimatic Zone of Madhya Pradesh has witnessed many extreme weather events in recent decades like excessive hotness, dryness, coldness and number of consecutive drought years. Drought and water scarcity are the major resource limiting factors of this zone. There was sharp increase in numbers of hot days during last decade (2001-10) in Chhatarpur and Datia districts. The numbers of heavy rainfall days sharply decreased at Tikamgarh and Chhatarpur districts while frost days increased in Datia during last decade. The micro level variability of drought was much higher than the temporal scale variability. The occurrence of drought at micro level in the recent decade was much higher. The frequent occurrence of drought during recent past had increased the soybean and paddy yield variability in this zone. This paper attempts to present impact of variability of extreme weather events on paddy and soybean yield and also rural livelihood. The paddy and soybean yield were normally affected by number of heavy rainy days and number of rainy days. The number of heavy rainy days greater than equal to 6 days in Tikamgarh, 7 days in Chhatarpur per year were may be required for sustainable paddy production. It is observed that in those districts where the temporal variation in number of rainy days is decreasing, the decrease in number of rainy days below 5 days per year was crucial for sustainable yield. Whereas in the districts where little temporal variation in number of rainy days observed, a particular number of heavy rainy days is not necessary for adequate crop yield. In Datia and Chhatarpur district, the animal discomfort days increased over the decades.

Key words – Drought, High temperature, Heavy rainfall, Crop yield, Livelihood.

1. Introduction

Madhya Pradesh spreads over 30.8 million hectares of land and shares around 6.0 per cent of India's population. Around 71.3 per cent of the population lives in rural areas as compared to the national average of 68.8 per cent, making the state largely a rural economy. The state ranks second highest in the country in food grain production only after Uttar Pradesh. Agro-climatic diversity and topographical variations enable the state to

grow a wide range of cereals, pulses, oilseeds and cash crops, besides being home to varieties of plant species. Madhya Pradesh has a unique identity as the soya producing state of India. Around 25.4 per cent of gross cropped area and 55 per cent of oilseed area is devoted to soybean.

Bundelkhand in Madhya Pradesh is considered as one of most downtrodden and poverty-stricken regions in the country. The region comprises of seven districts of

Madhya Pradesh and all of them have their economy predominantly based on *rainfed* agriculture. The low productivity, undulated land areas, lack of irrigation facilities and unscientific cultivation has kept the agriculture at the verge of subsistence only. Though the Bundelkhand Agroclimatic Zone is not prone to big natural disasters such as earthquake, cyclone and flood but is affected by extreme weather events such as hot days, hailstorm, frost which ultimately upsets the farming in this zone frequently. The monsoon rains are quite crucial and for past several years, the region has received deficit rains leading to drought particularly for agriculture related activities. The pathetic part of these extreme weather events and drought is reflected in successive crop failures, lack of employment and migration of working youth (Anonymous, 2016).

Droughts and famines have occurred in India for centuries and have been traditionally mentioned. Drought ranks first among all the natural disasters in terms of extent of effect on crop production, livelihoods, environment, society and economy (Hewitt, 1997). Drought and floods are natural disasters, which have a direct impact on socio-economic aspects due to marked impact on food production (Vijayvergiya, 2004). The challenge of drought has been further compounded by lack of water resource development and management projects, negligence of the traditional water harvesting systems and inclination and adoption of water intensive commercial crops leading to an intense water-stressed environment in the region. Under such situations, creating awareness on the need for rational management of water resources is possible only by analyzing the temporal and spatial characteristics of drought and evaluating its potential impact on population livelihood.

A few studies on key aspects of the drought in Bundelkhand region at micro scales pertaining to a specific area have also been carried out by various researchers *viz.*, Pandey *et al.* (2010), Alam *et al.* (2014), Patel and Yadav (2015) and Kundu, (2018). Studies on impact of disaster and extreme weather events on crop yield on long term basis in Bundelkhand are very limited. Swaminathan and Rengalakshmi (2016) have reported the impact of extreme weather events on crop yield in India.

The districts under Bundelkhand Agroclimatic Zone namely Tikamgarh, Chhatarpur and Datia are chronic drought prone areas with high inter-annual rainfall variability. Thus, these three districts with different rainfall patterns have been selected for analyzing the extreme weather variability. The chronic droughts in last few decades have hit the Bundelkhand Agroclimatic Zone of Madhya Pradesh causing near disastrous situation,

particularly among the farming communities in rural belt. Reducing rains have created drinking water crisis and diminishing income and starvation-like situation in rural areas. In view of recurrence of droughts in the last decades, an adequate assessment of adverse impacts of drought is necessary to avoid its vulnerability on crop production and livelihood. The Impact of the spatio-temporal variations of meteorological drought on soybean and paddy production in the selected districts has been evaluated. The impacts of heavy rainfall, rainy days and drought on paddy and soybean crop yield were also presented. Additionally, the study also attempted to assess the major impacts of variability of extreme weather events on livelihood of the zone under study.

2. Study area and methodology

Madhya Pradesh has 5 crop zones, 4 soil types and 11 agro climatic zones. The Bundelkhand Agroclimatic Zone of Madhya Pradesh includes the districts of Datia, Chhatarpur and Tikamgarh (Fig. 1). The climate of this zone varied from semiarid to dry sub-humid and the soil type is classified as mixed red, black and alluvial with undulating surface varied from 1 to more than 10 per cent slope with low soil organic content.

District wise weather and crop data were collected and procured from India Meteorological Department (IMD), Pune and Madhya Pradesh (MP) state agriculture economics statistics department, Bhopal respectively. Daily temperatures (maximum and minimum) and rainfall data during the period 1971 - 2010 of these three districts were collected and screened for extreme weather events on decadal scale. Block wise daily rainfall data of the three districts were collected from IMD, Pune and used for study of micro scale drought identification. The district level extreme weather event days were calculated on decadal basis. The following criteria were adopted:

Hot day: when the daily maximum temperature $>45^{\circ}\text{C}$,

Frost day: when the daily minimum temperature $<2^{\circ}\text{C}$,

The cold days and frost days are different. However, the frost day, is defined based on the minimum temperature recorded in Stevenson's screen at a 1.2 meter above the ground surface. It has been observed and reported also that during winter season when the minimum temperature were recorded <2 or 2°C then the frosts were observed on the ground surface (Bureau of Meteorology, 2019), therefore, in the present study, less than 2° Celsius of minimum temperature considered as frost day.

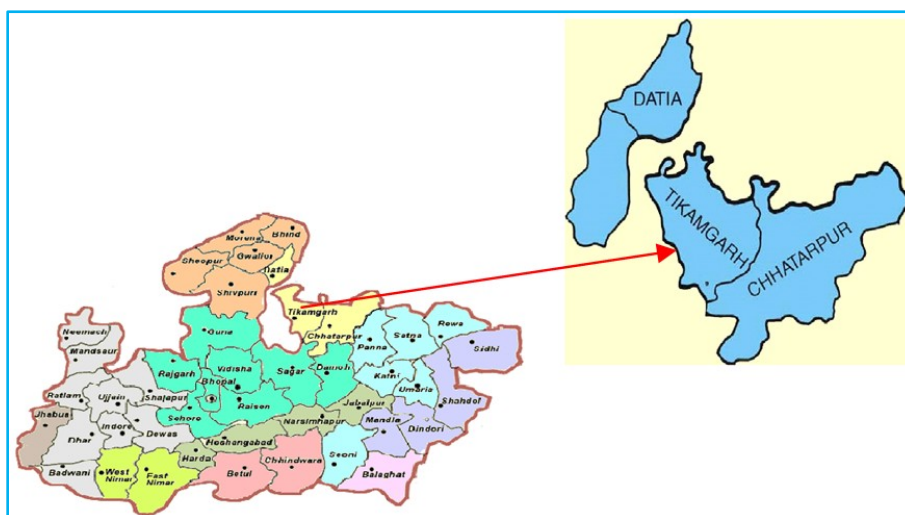


Fig. 1. Location map of Bundelkhand Agroclimatic Zone of Madhya Pradesh

Heavy rainy day : when the daily rainfall >50 mm

Rainy day : when the daily rainfall ≥ 2.5 mm

Animal discomfort day : when the daily maximum temperature $>39^{\circ}\text{C}$ and mean relative humidity $<30\%$ and (discomfort increases with higher RH as it reduces sweating)

Meteorological drought : When the annual rainfall is below 75% of normal rainfall of a particular place

The associations of extreme weather events with soybean and paddy yield were examined and analyzed. The critical extreme weather event limits were screened for sustainable yield in the respective districts. The predominant crops grown in all three districts during *kharif* season are soybean and paddy.

3. Results and discussion

3.1. Temporal variability

The analysis of the number of hot days, frost days, heavy rainfall days and rainy days has been carried out in this study to observe their variability in Bundelkhand Agroclimatic zone and presented in Tables 1-3. The frequency of heavy rainfall events has abruptly decreased in Tikamgarh district in the decade of 2001-10 (Table 1). Datia district also recorded a considerable decrease in

number of heavy rainfall days (Table 3). The number of heavy rainfall days has decreased from 47 days to 19 days in Tikamgarh and from 43 days to 29 days in Datia. The number of decadal rainy days was almost constant in Datia but decreased in Tikamgarh (from 484 to 355 days). The number of rainy days in Tikamgarh and Chhatarpur recorded a difference of 142 and 50 days in two consecutive decades respectively (Tables 1&2). This is indicative of the fact that these districts of the Bundelkhand Agroclimatic Zone of Madhya Pradesh are facing regular water scarcity as compared to Datia. For droughts to be realized in an area, the most important factors, is the timing and duration of the rainfall. For example, it makes a big difference in soil water recharge and availability of water, when an overall increase in rainfall comes in the form of heavy rainfall, or more recurrent small rainfalls. Heavy rainfall may be more likely to saturate the soil and increase the recharging effect (in spite of increased runoff), as compared to recurrent but small rainfalls. It was observed that frost days have decreased in Tikamgarh and Chhatarpur districts over the decades (Tables 1&2). During the first two decades under study, no frost days were observed, however, during the two later decades, the occurrence of frost had been observed in Datia district (Table 3). It was observed that during the past two decades, the number of frost days was increased in Datia district too.

3.2. Spatial variability

A block-wise analysis of meteorological drought in Bundelkhand Agroclimatic Zone of Madhya Pradesh was carried out and presented in Table 4. The block wise normal rainfall in the zone varied from 667.9 to 1111.1 mm (Table 4).

TABLE 1

Decadal variability of extreme weather events at Tikamgarh

Decade	Number of hot days	Number of frost days	Number of heavy rainy days	Number of rainy days	Number of drought years
1971-80	33	13	47	484	01
1981-90	53	03	49	430	01
1991-2000	65	04	48	497	00
2001-10	40	00	19	355	03

TABLE 2

Decadal variability of extreme weather events at Chhatarpur

Decade	Number of hot days	Number of frost days	Number of heavy rainy days	Number of rainy days	Number of drought years
1971-80	66	07	58	495	3
1981-90	58	02	59	571	1
1991-2000	111	01	58	531	1
2001-10	112	02	51	481	4

TABLE 3

Decadal variability of extreme weather events at Datia

Decade	Number of hot days	Number of frost days	Number of heavy rainy days	Number of rainy days	Number of drought years
1971-80	39	00	34	450	2
1981-90	43	00	43	458	1
1991-2000	78	01	37	466	1
2001-10	137	03	29	454	3

3.2.1. Block level drought variability

Tikamgarh district : Before the year 2000, the frequency of meteorological drought at micro scale was low and some of the blocks (Tikamgarh, Niwari and Baldevgarh) were not affected by the drought even in the severely drought hit year of 1987. Out of seven blocks in Tikamgarh district, the Jatara block was maximally (seven out of ten years) hit by drought during the recent decade. The frequency of drought during recent decade increased very much and sometimes affected consecutively for two to three years (2005, 2006 and 2007) due to which the crop yields were severely affected. The occurrence of droughts in Palera block was the lowest in the district.

Chhatarpur district : Out of seven blocks in Chhatarpur district, the Baxwaha block was maximally hit by drought during the recent decade (2001-2010). In

Baxwaha, the frequency was even high during recent decade (2001, 2006, 2007 and 2009) due to which the crop yields as well as livelihood were severely affected.

Datia district : The Indergarh and Bhandar block of the Datia district were maximally affected by the drought. The variability of drought at block level in Datia district was lower than in Chhatarpur and Tikamgarh. Out of four blocks in Datia district, the three blocks namely Seondha, Bhandar and Indergarh were hit by the drought thrice during the recent decade. The meteorological drought sometimes affected in consecutively two to three years (2005, 2006, 2007) causing near ruinous situation of crop production.

The spatial-temporal variability of meteorological drought at block level is high. The Bundelkhand region has been attracting attention of scientists and policy

TABLE 4

Block wise distribution of meteorological drought in Bundelkhand Agroclimatic zone

Block Name	Data-base	Normal Rainfall (mm)	Drought year
Tikamgarh district			
Tikamgarh	1970-2010	952.2	1986, 1991, 2001, 2007, 2010
Jatara	1970-2010	815.0	1975, 1986, 1987, 1998, 2000, 2001, 2002, 2005, 2006, 2007, 2010
Niwari	1970-2010	842.0	1975, 1978, 1979, 1981, 1989, 1994, 2000, 2006, 2010
Baldevgarh	1981-2010	690.3	2005, 2006, 2007, 2010
Prithvipur	1982-2010	824.7	1983, 1987, 1989, 2000, 2004, 2005, 2006, 2007
Palera	1985-2010	782.9	1986, 1987, 1988, 2006
Orchha	1985-2010	749.8	1985, 1987, 1988, 2004, 2005, 2006, 2007
Chhatarpur district			
Chhatarpur	1970-2010	931.7	1973, 1974, 1988, 1995, 1998, 2000, 2007
Badamalhara (Loudi)	1976-2010	949.3	1979, 1986, 1997, 1998, 2006, 2007
Bijawar	1976-2010	1111.1	1979, 1986, 1989, 1990, 1992, 1996, 2001, 2007, 2008
Nowgoan	1976-2010	966.7	1976, 1981, 1986, 1989, 1993, 2005, 2007, 2010
Baxwaha	1982-2010	1061.0	1989, 1991, 1995, 2000, 2001, 2006, 2007, 2009
Rajnagar	1986-2010	916.6	1986, 1989, 1995, 1998, 2006, 2007
Gaurihar	1986-2010	837.3	1986, 2001, 2006, 2010
Datia district			
Datia	1970-2010	748.7	1972, 1979, 2005, 2006
Seondha	1986-2010	711.0	1987, 1989, 2002, 2005, 2006
Bhander	1998-2010	778.3	2005, 2006, 2007
Indergarh	1986-2010	667.9	1986, 1987, 1990, 2005, 2006, 2007

makers since last few decades. Although, the historical records depict that there have been only twelve drought years in Bundelkhand during the whole of 19th and 20th century, *i.e.*, once in 16 years but the recurrences of drought increased from one to three in every 16 years during 1968-1992 (Singh *et al.*, 2003). The recurrence of drought during 2000-2015 was 7 to 9 in Tikamgarh and Chhatarpur districts (Anonymous, 2016). These droughts have been accompanied with several manifestations like late arrival and early withdrawal of rains, long break in between, lack of sufficient water in reservoirs and drying up of wells that eventually led to crop failure.

3.3. Impact of extreme weather event on district level crop yield

The long term yield data of paddy and soybean along with number of rainy days and heavy rainfall days of three districts were analyzed and presented in Figs. 2&7.

3.3.1. Tikamgarh district

The paddy yield is associated with number of rainy days and heavy rainfall days both however; the

association with number of heavy rainfall days is much more than the rainy days. The paddy yield in many years increased when the number of heavy rainfall days is 6 days or above. Similarly, the paddy yield was lower whenever the rainy days were below 50 days. Paddy is water loving crop and prefers to have soil moisture throughout its growth period, which used to be traditionally supplemented through creating water logged condition in the bunding. It is also observed that with the technological advancement, the paddy yield above 700 kg per hectare in the Tikamgarh district was achieved whenever there was a heavy rainfall of 6 days per year (Fig. 2). As compared to paddy, the water requirement of soybean crop is almost less than half. The total water requirement of paddy crop ranges from 1100 to 1250 mm, whereas soybean merely requires 550-625 mm of water per year from planting through maturity. However, number of rainy days and heavy rainfall days are the determinants of soil moisture. The soybean yield was not much affected by number of heavy rainy days (Fig. 2). The soybean crop requires adequate water after full bloom and during the pod filling stage for maximum yields (Doss *et al.*, 1974). However; it is noted that when the number of heavy rainfall days reduced the yield of the crop

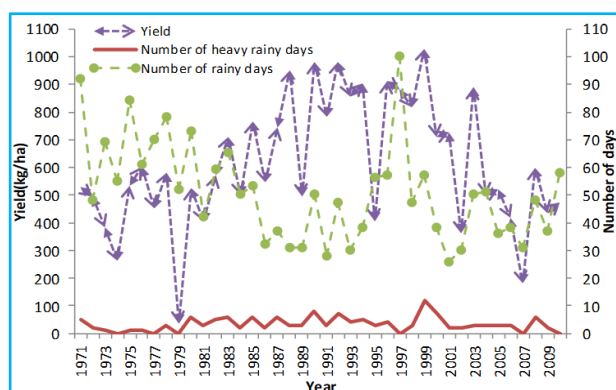


Fig. 2. Paddy yield variability and events of heavy rainfall and rainy days at Tikamagrh

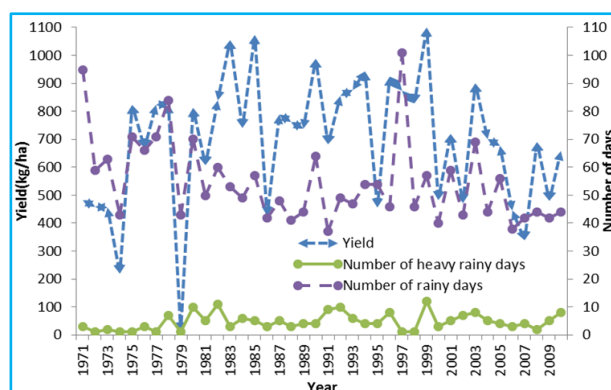


Fig. 4. Paddy yield variability and events of heavy rainfall and rainy days at Chhatarpur

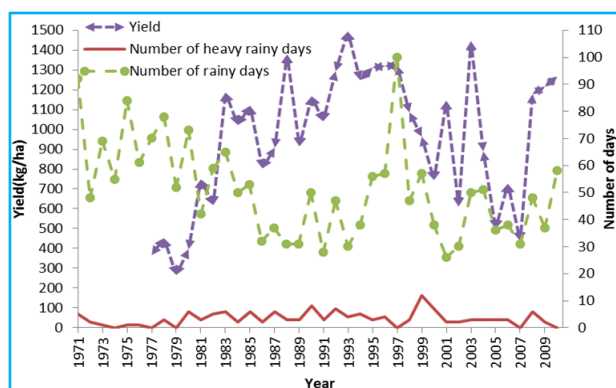


Fig. 3. Soybean yield variability and events of heavy rainfall and rainy days at Tikamagrh

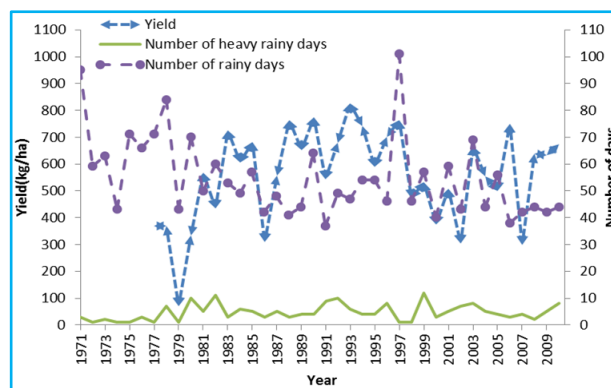


Fig. 5. Soybean yield variability and events of heavy rainfall and rainy days at Chhatarpur

from 1200 kg per hectare in the decade of 1991-2000 to 1000 kg per hectare in the decade of 2001-2010.

3.3.2. Chhatarpur district

The long-term yield data of paddy and soybean along with number of rainy days and heavy rainfall days in Chhatarpur were analyzed and presented in Figs. 4&5. It was noted that the fluctuations in paddy yield and heavy rainfall is related. Decline in paddy yield was observed when the heavy rainfall days less than 7 days per year at Chhatarpur. Occurrence of number of rainy (more than 50) days in a year resulted in higher paddy yield (more than 800 kg/hectare), as they might have provided continuous water supply, which is essential for the better growth of paddy crop (Fig. 4). Similarly, the paddy yield was lower whenever the rainy days were less than 50 days per year. Therefore, heavy rainy day of 7 days is essential to have sustainable paddy yield in the Chhatarpur district.

The soybean yield is positively associated with number of rainy days (Fig. 5). The number of heavy rainfall days had no sharp impact on soybean yield as they fell drastically below to 5 in the last decade but soybean

yield varied from 650 to 600 kg per hectare. Similar findings were reported by Kumari *et al.* (2004) where the study reported that the initial and conditional probabilities of the occurrence of dry and wet spells were associated with rice yield at six stations in Bihar.

3.3.3. Datia district

It was observed that paddy yield and heavy rainy days are not much related at Datia district (Fig. 6). Fig. 6 clearly shows that paddy yield was lower; whereas heavy rainfall days were greater than 5 days at Datia. The higher production of the paddy could be attributed due to increasing irrigation water for irrigated agriculture through construction of massive water bodies such as pond, dams, canals and other reservoirs etc.

Fig. 7 clearly depicts that the soybean yield is not positively associated with heavy rainy days at Datia. The decreased number of rainy days in the 2001-10 has not declined the soybean yield in Datia. The low yield might be associated with attack of other biotic stress such as spread of yellow mosaic and girdle beetle on the crop (Srivastava and Yadav, 2018).

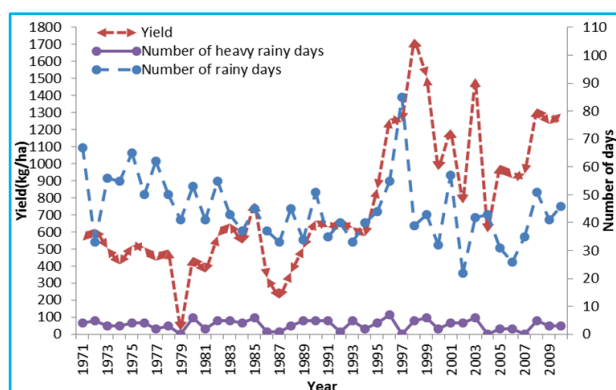


Fig. 6. Paddy yield variability and events of heavy rainfall and rainy days at Datia

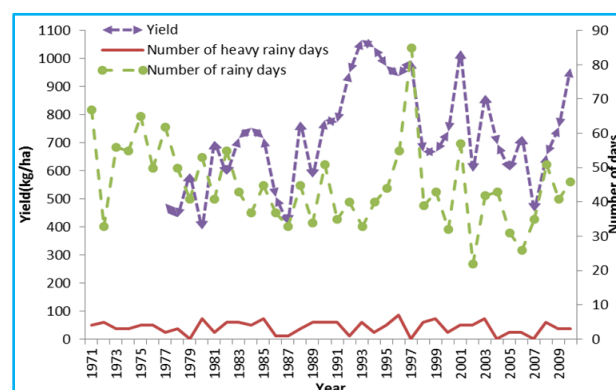


Fig. 7. Soybean yield variability and events of heavy rainfall and rainy days at Datia

The rainy days were decreasing at Tikamgarh and Chhatarpur districts, while at Datia district; it was mostly fluctuating between 40-60 days/year. It was observed that the districts where the rainy days were decreasing the days of heavy rainfall were crucial factor affecting paddy as well as soybean yield. At Tikamgarh district, rainy days decreased from 92 to 30 days per year and hence a critical heavy rainfall day greater than or equal to 6 may be required for sustainable paddy and soybean yield. The study of Kumari *et al.* (2004), Srivastava *et al.* (1996, 2000) also supported the requirement of moisture at critical phases of these crops for good yield under *rainfed* conditions. Thus, rainy days and heavy rainfall days are supplementary to each other to have a sustainable yield in *rainfed* condition. Shorter weather episodes can also affect yield by forcing changes in temperature, potential evapotranspiration and relative humidity availability but these factors are not considered in present study.

3.4. Impact of drought on district level crop yield

The cumulative build up of meteorological droughts led to hydrological as well as agricultural droughts, with a complex set of highly differentiated adverse impacts and

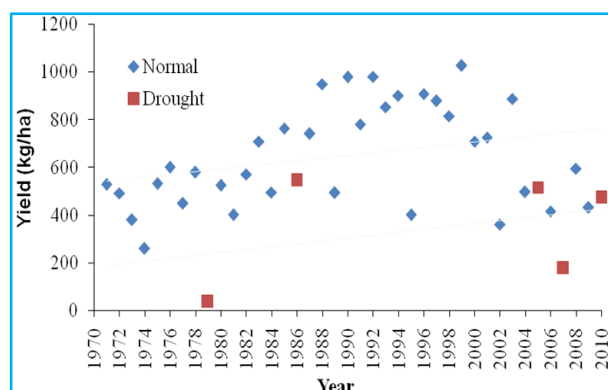


Fig. 8. Paddy yield in normal and drought years at Tikamgarh

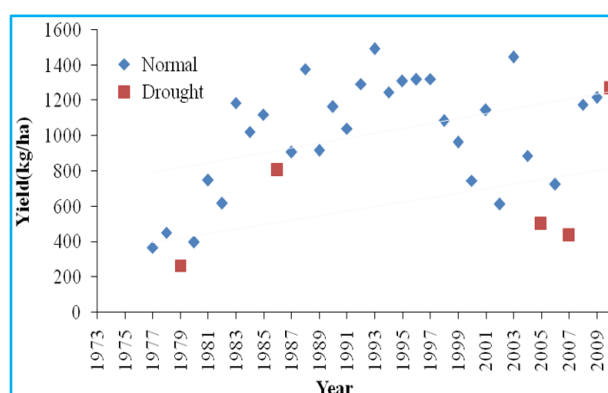


Fig. 9. Soybean yield in normal and drought years at Tikamgarh

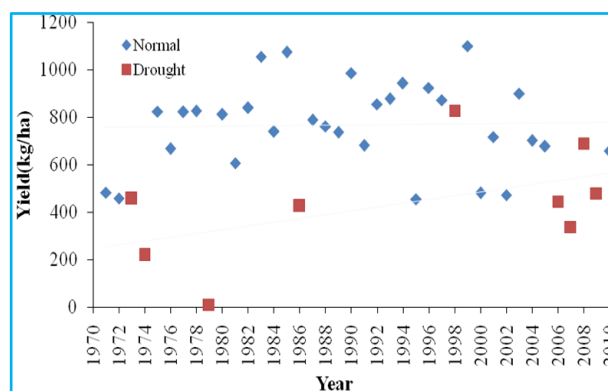


Fig. 10. Paddy yield in normal and drought years at Chhatarpur

tradeoffs. A district level analysis of drought and its impact on paddy and soybean crop was performed and presented in Figs. 8-13.

3.4.1. Tikamgarh

The paddy and soybean yield variability in the district was increased during the 2001-10, when the occurrence of drought was high (Figs. 8&9). It was observed from the analysis that drought decreased the paddy yield by 46 and soybean yield by 35 per cent at

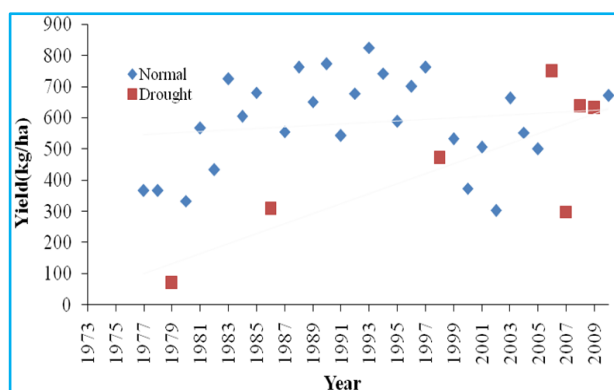


Fig. 11. Soybean yield in normal and drought years at Chhatarpur

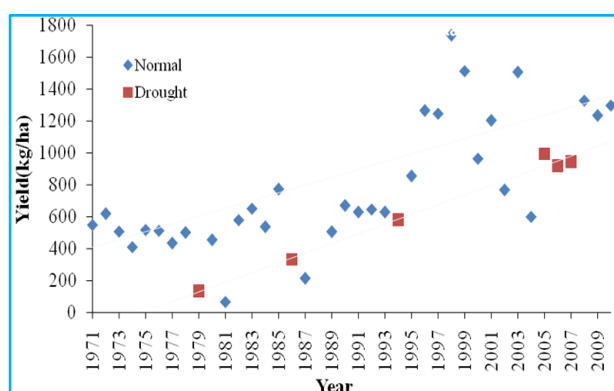


Fig. 12. Paddy yield in normal and drought years at Datia

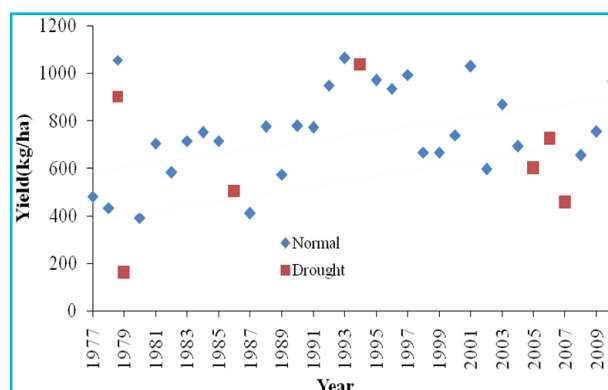


Fig. 13. Soybean yield in normal and drought years at Datia

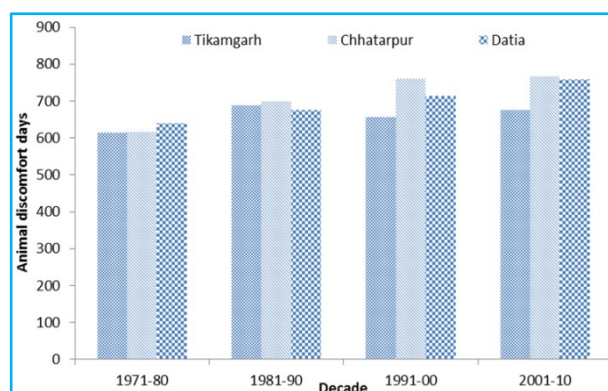


Fig. 14. Animal discomfort days variability in Bundelkhand Agroclimatic zone

Tikamgarh. The drought and paddy yield relationships are explained by other researchers too (Kumari *et al.*, 2004; Srivastava *et al.*, 2000) who reported that the rice yield was decreased by drought in Chhattisgarh and Bihar as well. The infrequent rainfall and consistent drought causes stress throughout flower induction and pod elongation stages in the crop that may have the greatest effects on final soybean yields. The effect of drought on soybean yield was also studied by Srivastava *et al.* (1996) confirming that the soybean productivity was decreased by drought in central India.

3.4.2. Chhatarpur

Figs. 10&11 depict the long-term yield data of paddy and soybean in normal and drought years at Chhatarpur. It was observed from the analysis that the drought decreased the paddy yield by 44 and the soybean yield by 22 per cent per cent at Chhatarpur.

3.4.3. Datia

The drought has reduced the paddy and soybean yield of the district. It was observed from the analysis that owing to the drought, paddy showed a 24 yield reduction

(Fig. 12), while soybean yield was decreased by 35 per cent (Fig. 13) at Datia. It was observed that the paddy yield during the normal rainfall years that is in 1981, 1987, 2004 was less than that of drought years. This might be because of outbreak of insect-pest infestation.

Drought and its impact on crop production had been reported earlier (Sastri and Patel, 1984; Sastri, 1985; Chaudhary *et al.*, 1989) in our country. The drought occurrence is associated with many negative impacts on food, fodder and ground water recharge as well as water resources. The primary necessity of food for human and fodder for animals largely depends on precipitation in *rainfed* area.

4. Weather extremes and livelihood

The Bundelkhand zone has been experiencing real and visible impacts of weather risks in the recent times. In the past two decades, there has been a steady increase in temperature, while water levels in entire Bundelkhand zone have dropped significantly (Anonymous, 2018) adversely affecting almost all sectors of the economy. Although the impacts of these weather risks are global, the most vulnerable are the poor and marginalized people;

who depend directly on the ecosystems for survival (Pandey *et al.*, 2010). These people have the least capacity to bear climatic risks.

More number of hot days will create discomfort not only for the human beings, but also animal husbandry, horticulture, livestock, fisheries, poultry and forest. The extreme weather events aggravate their integrated impacts on the crop production as well as livestock productivity in this zone. This type of situations are becoming more and more critical for the livelihood of the rural population as the basic income from the crop yield is at stake, leading to large scale (around 37 per cent) migration of rural population (Ratha Krishnan, 2008). Krishnamurthy (2012) reported that increased likelihood of climate-related disasters is expected to increase the vulnerability of exposed populations. He also reported the relationships between extreme weather events & migration and suggested for adequate planning and effective adaptation strategy.

4.1. Ground water level scenario

Rainfall has a direct impact on water resources, particularly in Central India where monsoon-rainfall is the only possible means for ground water recharge. Tikamgarh district, where wells being the main source of water for irrigation, records maximum number (76215) of dug wells leaving Chhatarpur behind in numbers, but significantly not far behind (Table 5). Unlike Tikamgarh and Chhatarpur districts, less than one third and half of the total numbers of dug wells, tube wells and tanks, are available in Datia. In all these districts, several water harvesting structures have been created in the recent past to ease the water situation. These water harvesting structures encompass the Bundela tanks, step wells, village ponds, haweli bundhies etc. however, many of these structures are currently in a state of public ignorance and are no longer able to harvest water for use during pre and post monsoon periods.

4.2. Animal discomfort

The incidences of extreme weather events certainly have profound impacts on health of livestock. The high temperatures in combination with low humidity during peak summer affect the milking potential of livestock while during rainy season with high humidity the animal discomfort increase as the sweating reduces. In Bundelkhand Agroclimatic Zone, livestock form an integral part of rural livelihood in addition to crop production. To study the impact of high temperature in combination with low humidity were analyzed to see their temporal changes. A long-term data of animal discomfort days in three districts of Bundelkhand Agroclimatic Zone is presented in Fig. 14. It is noticeable that in Chhatarpur

TABLE 5

Water/Irrigation resources of Bundelkhand Agroclimatic Zone

District	Tikamgarh	Chhatarpur	Datia
Dug wells	76215	66980	24679
Tube wells/Bore wells	1955	373	509
Tank/Ponds	276	143	2
Canals	175	45	3

(Source: Central ground water board district level reports)

and Datia districts, the animal discomfort days have radically increased. This sharp increase in discomfort days at Chhatarpur and Datia districts impacted the rural economy substantially. Several studies have also reported change in animal physiological behavior during exposure to environmental stress with the variations in the body temperature, respiratory rate, sweating rate and heart rate (Das *et al.*, 2016; Da Silva *et al.*, 2000). Kumar *et al.* (2018) studied the thermal humidity index on buffalo milk production in Tikamgarh district and reported that extended period of high ambient air temperature affects the ability of lactating buffaloes.

4.3. Agriculture management strategies

Advent of drought episodes during the growing periods or at critical development stages of the crop may hinder growth processes leading reduction in harvestable yield. However, a clear perceptive of the vulnerability of food crops as well as the agronomic impacts of drought is very necessary to take on adaptive approach for mitigating its negative effects. The conservation agriculture-based crop management technologies including zero tillage with residue recycling, direct seeding of paddy, raised bed planting and integrated approach for water, nutrient, pest-disease and weed management technologies may have potential to combat the extreme weather events and its variability impact in future. Diversification in cropping system and cultivation of more efficient C₄ crops like maize, sorghum, bajra and plantation of *mahua*, *anola*, *imli*, *jamun*, *karanj*, *ber*, *drumstick*, *kaitha*, *neem* and *sisham* in Bundelkhand Agroclimatic Zone may be adopted to minimize the ill effects of extreme weather events. Indigenous breeds of livestock such as *desi* Cows, Sheep, Goats etc. have potential to remain adjustable in extreme weathers and hence rearing these breeds would certainly equip farmers to cope up the weather risks.

5. Conclusions

Recurring drought and high frequency of hot days were observed in Bundelkhand Agroclimatic Zone. The

number of rainy days decreased sharply at Tikamgarh and Chhatarpur districts; while the hot days sharply increased in Chhatarpur and Datia districts. The meteorological drought variability was found to be high at block levels. It was found that in those districts where the temporal variation in number of rainy days is decreasing, a particular number of heavy rainy days are required for sustainable crop yield, whereas in the districts where little temporal variation in number of rainy days are observed, a particular number of heavy rainy days is not necessary for sustainable crop yield. In Datia and Chhatarpur district, the animal discomfort days have increased over the decades. Increase in hot days had negative impact the animal health and milk production in Chhatarpur and Datia districts. Drought has impact more on the paddy yield in Tikamgarh and Chhatarpur districts. The recurrent drought in the zone very apparently reflected in successive crop failures and lack of employment and has led to migration of working youth in large number.

Acknowledgements

Authors thank India Meteorological Department, Pune and State Department of Statistics and Economics, Bhopal for providing weather and crop yield data. The authors also expressed their heartfelt thanks to the anonymous referee for critical review and suggestions towards the improvement of the present study.

The contents and views expressed in this research paper/article are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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