Rainfall variability assessment over Bundelkhand region and its impact on rainfed agriculture

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Abstract

The present study is carried out over the Bundelkhand region, located in the central part of India which is susceptible to frequent drought and crop failure due to inter-annual rainfall variability. Gridded daily rainfall data resolution 0.25° × 0.25° for the period 1901–2013 has been analyzed to study the spatial variation of annual rainfall over Bundelkhand. A declining trend is observed in annual and monsoonal rainfall in most of this region which will be a challenge in mitigating the water requirements in *Kharif* as well as *Rabi* crops. Hence, arrangement for supplemental irrigation and intensification of water conservation measures is recommended for sustaining crop yield under this variable rainfall scenario.

1. Introduction

Normal rainfall deviation in a region has an enormous effect on the water availability for agriculture (Granados *et al*., 2017). Climatic variability in various parameters like precipitation and temperature etc. affects crop growth stages and thus, influences the crop yield. The frequency of natural hazards, particularly drought and flood events, has been amplified worldwide. Many a time, high-intensity rainfall events that occur in the offseason cause vast crop damage and put surgeon economic status of farmers. According to the Fifth Assessment Report of Intergovernmental Panel on Climate change (2014), there will be a worldwide increase in the number of monsoon break days and extreme rainfall events. A decline in the number of monsoon depressions and monsoon intensity and its frequency over India has been carried out extensively and some of them tried to link these parameters with climate variability (Vishnu *et al*., 2016). Various studies indicated the effect of rainfall variability on crop yield. Break days, spatiotemporal analysis of annual and seasonal rainfall and drought.

In this study, the continual spatial variation of annual and monsoonal rainfall and its trend over the Bundelkhand region has been studied based on fine-resolution gridded rainfall data, as well as its possible implications on rain, fed agriculture, and necessary advisories to mitigate the adverse effect of rainfall variability has been also discussed.

2. Materials and methods

2.1 Study area

Bundelkhand region, part of central India, comprises seven districts of Uttar Pradesh and six districts of Madhya Pradesh (figure 1).

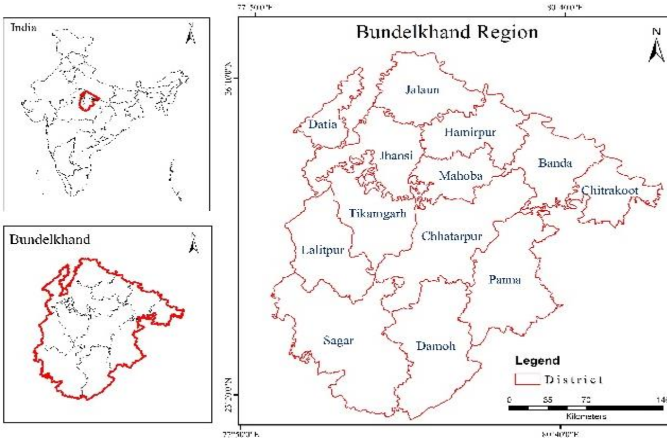

Figure 1: Location map of study area

The districts that belong to the state of Uttar Pradesh are Jhansi, Lalitpur, Mahoba, Chitrakoot, Banda, Hamirpur, and Jalaun while the districts Sagar, Damoh, Chhatarpur, Tikamgarh, Panna, and Datia come under Madhya Pradesh. The total geographical area of Bundelkhand is 7.16 million hectares. It is mostly an agrarian economy as about 82% of its population depends on agriculture.

2.2 Data used

Gridded daily rainfall data of resolution 0.25° × 0.25° for the period 1901–2013 acquired from the India Meteorological Department (IMD) is used in this study. Rainfall data of 156 grids spread evenly over Bundelkhand and its 30 km buffer area is studied.

2.3 Trend analysis

In this study, Modified Mann-Kendall (MMK) test (Hamed and Rao, 1998) along with the Theil-Sen estimator (Theil, H.,1992; Sen, P. K.,1968) is used for trend analysis of seasonal and annual taluk scale (a taluk is a subdivision of a district comprising of several villages) of Bundelkhand. A positive value of the MMK test statistic (Z) signifies a rising suggests a declining trend of the time trend whereas its negative value series variable. If a linear trend exists in

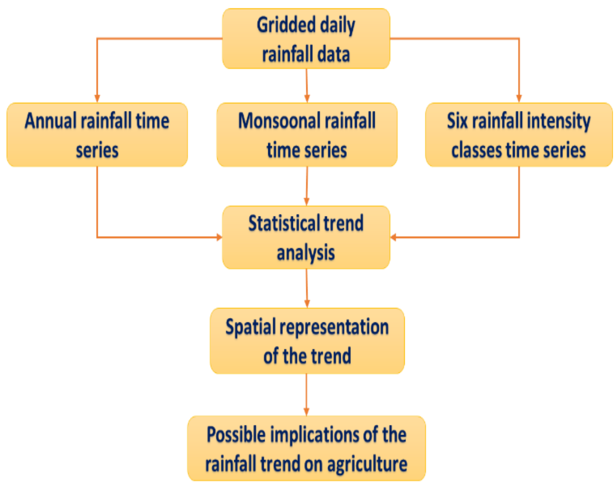

Figure 2 Methodology flowchart

rainfall time series data of 113 years at the time-series data, the magnitude of the positive or negative trend is assessed by a non-parametric test, known as Theil-Sen estimator. Besides, daily rainfall data of each year of each grid has been classified into six rainfall intensity classes based on Alpert *et al*. (2002). Time series consisting of data of annual occurrence of each rainfall class at each grid is also evaluated for trend. The inverse distance weighting interpolation method is used for representing the spatial variation of annual rainfall and its trend (Curtarelli *et al*., 2015). Besides, the spatial variation of the trend of each rainfall class is displayed over the study area. A flowchart describing the methodology used for carrying this study is shown in Figure 2.

3. Results and discussion

3.1 Annual rainfall variation and its trend analysis

Mean annual rainfall over Bundelkhand varies from 760 mm (lowest) to 1227 mm (highest) at Datia and Damoh districts, respectively (Figure 3). An increase in annual rainfall amount is observed from north to south of the study area. Trend analysis of annual rainfall time series displays a decreasing trend almost throughout Bundelkhand except in few places of Datia and Sagar districts where an insignificant increasing trend in annual rainfall has been detected (Figure 3).

The highest declining trend of 2.16 mm per year in annual rainfall was shown in Hamirpur taluk of Hamirpur district; Banda, Baberu, Karwi, and Mau taluks of Banda district and Lauri taluk of Chhatarpur district, whereas the lowest decreasing trend of 0.49 mm per year was shown in Jhansi and Mau Ranipur taluks of Jhansi district; Nivari and Jatara taluks of Tikamgarh district; Lalitpur taluk of Sagar district and

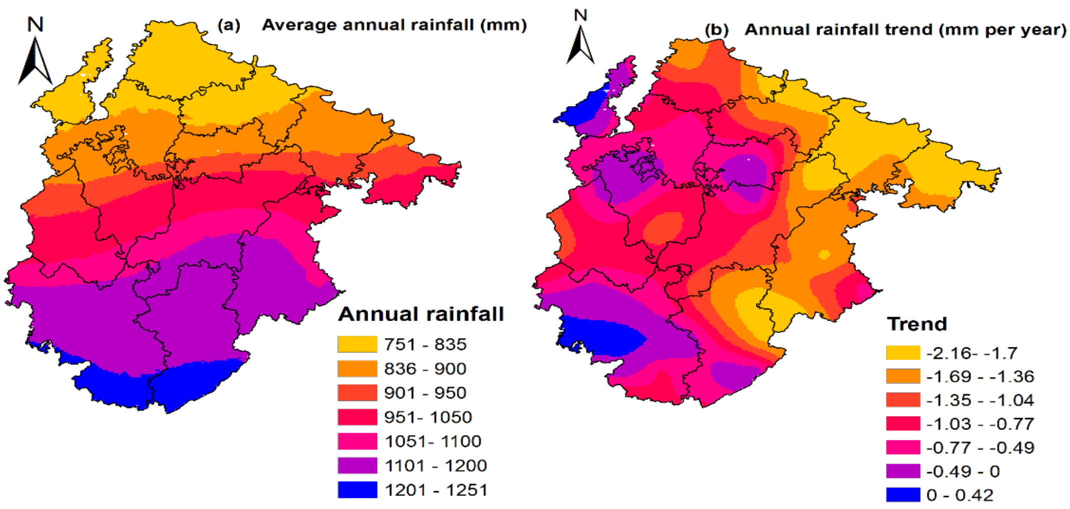

Figure 3 (a) Spatial variation of annual rainfall in mm (b) Annual rainfall trend (mm per year)

Damoh taluk of Damoh district. The monthly rainfall variation of Lalitpur district; Khurai and Rehli taluks and its trend over the Bundelkhand region can be shown in Ahmed *et al.* (2019). They have revealed that like annual rainfall, monsoonal rainfall is also following a decreasing trend in most parts of Bundelkhand.

3.2 Trend analysis of rainfall classes

On an average, the frequency of class 1 (0.1 mm day^{-1} ≤ intensity < 4 mm day^{-1}), was found to be 42 whereas, the frequency of classes 2 to 5 (class 2: intensity < 4 mm day^{-1}, class 3: intensity <32 mm day^{-1}, class 4: intensity <64 mm day^{-1}, class 5: intensity < 128 mm day^{-1}) was found to be 30, 12, 6 and 2 respectively, in a year. The occurrence of class 6 (intensity ≥ 128 mm day^{-1}) rainfall type was rarely found. While analyzing

the trend of time series of rainfall classes, it has been found that frequency of light to moderate rainfall class types, viz. classes 1 to 3 follow a decreasing trend in most places of Bundelkhand (Figure 4). No trend in rainfall class 4 was observed in the vast area of Bundelkhand. Few places located in the central part of Bundelkhand have shown an increasing trend for the rainfall classes 3 and 4, although none of the grids have shown a significant increasing trend for class 3. Almost no trend for rainfall class 5 was found throughout Bundelkhand except at two grids, of which one grid has shown a significant decreasing trend, and the other has shown a nonsignificant increasing trend. It was revealed that the occurrence of rainfall class 6 types is very less for the study period. Hence, no trend was shown for rainfall class 6 in any of the grids.

3.3 Implications of rainfall variability on rain-fed agriculture in Bundelkhand

Cereals (54.6%) are the major agricultural produce followed by pulses (32.4%), oilseeds (8.0%), sugarcane (0.2%), and other crops (4.8%) of this area. Among cereals, Jowar and wheat are mostly cultivated during *Kharif* and R*abi* season, respectively. Among pulses, urad and chickpea are mostly cultivated during *Kharif* and *Rabi* season, respectively. Groundnut is the main oilseed crop grown in this region during the *Kharif* season. *Kharif* crops of this region are mainly rain-fed. Pulses and oilseed crops are grown in this region greatly depends on monsoon residual moisture content. Monsoonal rainfall is the mainstay of *Kharif* agriculture of the study region. Decreasing trends in annual and monsoonal rainfall amounts will be a challenge in mitigating the water requirements in *Kharif* as well as *Rabi* crops and affects the rain-fed agriculture of Bundelkhand.

Several parameters derived from monsoonal rainfall such as monsoonal rainfall amount, cumulative rainfall amount in June-July, monsoonal rainfall onset date, etc. derived for Jhansi district have been correlated with groundnut yield to see their effect on groundnut yield. In this study, groundnut yield has shown the highest correlation with rainfall class 3 (0.46) followed by class 2 (0.31) than class 1 (0.10) and class 4 (0.05). It implies more influence of light to moderate intensity rainfall (classes 1 to 3) on groundnut yield compared to heavy rainfall class 4. Groundnut yield has shown a negative correlation with class 5 type (–0.0006) rainfall events and delays in the onset of monsoon (-0.13).

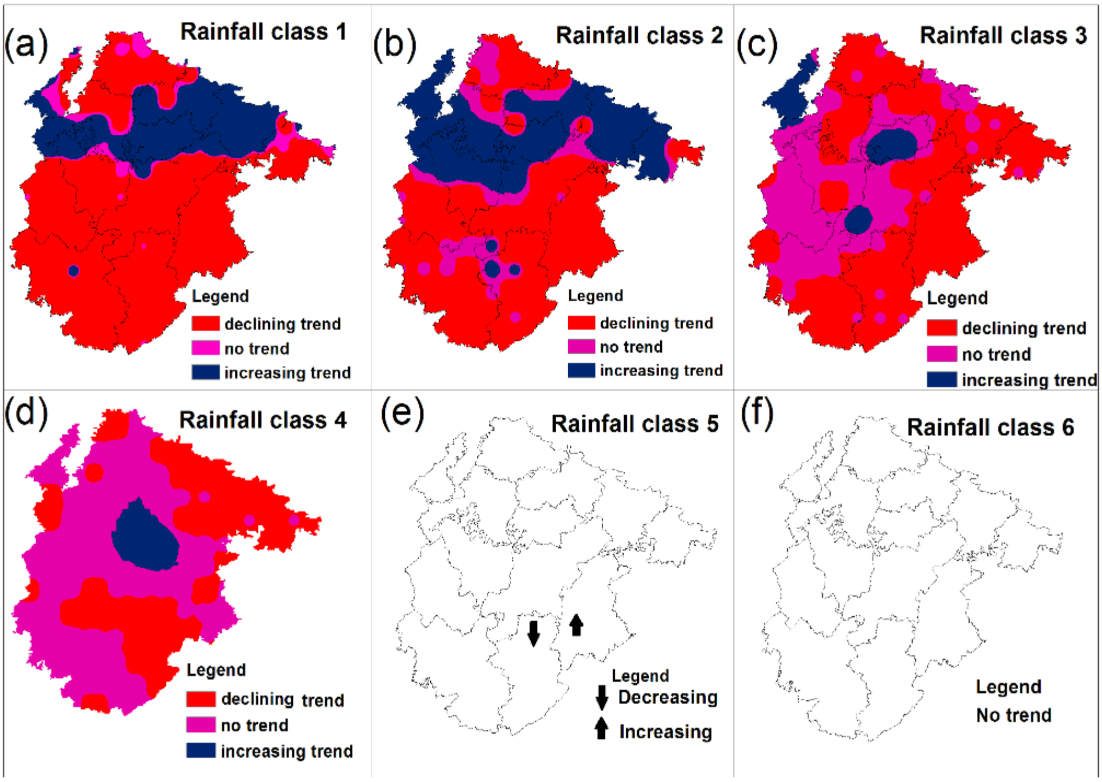

Figure 4: Spatial variation of trend of rainfall: (a) Class 1 (b) Class 2 (c) Class 3 (d) Class 4 (e) Class 5 (f) Class 6

3.4 Advisories for risk reduction in crop yield due to rainfall variability

The few advisories which are essential for risk reduction in crop yield are listed below:

- Promotion of improved drought-tolerant varieties of linseed, chickpeas, sesamum, lentil, dual-purpose Bundela Sorghum and pearl millet in areas where the more declining trend of rainfall is observed.

- There is also a need to promote agroforestry systems like agri-silviculture and silvopasture, particularly in degraded land to compensate for the crop yield loss by additional income in form of fuel-wood and fodder.
- Similarly, to deal with water stress, the soil and water conservation measures like mulching, raising bunds, gully plugs, check dams, ponds, etc. should be promoted.
- Promotion of fertigation system through drip and sprinkler as these modern irrigation systems has high water and nutrient use efficiency.
- Early forecasting of rainfall to farmers may be helping in scheduling application agricultural inputs such as irrigation water, fertilizers, pesticides, etc.
- Imparting knowledge to the farming community for sustainable management of natural resources.

4. Conclusions

This study shows that annual rainfall as well as light to moderate intensity rainfall events in most of the places in the Bundelkhand region is following a declining trend. It indicates a gradual drying up of the Bundelkhand region due to the declining trend of rainfall. A positive correlation between groundnut yield and frequency of light to moderate intensity rainfall events in a year and in addition, a declining trend in annual rainfall amount and light to moderate intensity rainfall events indicates a challenge to sustain rainfed crop yield in coming days.

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