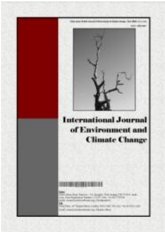

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Assessment of Long Term Spatio-temporal Climatic Changes Over the Central India: A GIS Approach

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The climatic data of 107 meteorological stations of Central India were collected and maps of various climatic parameters were generated by using ArcGIS 10.5 software. Potential evapotranspiration (PET), rainfall, water deficit and moisture index trends were analyzed for 30 years (1988-2018). PET was computed by using Modified Penman-Monteith method as recommended by FAO. It concludes that though the amount of mean annual rainfall is moreover same but the variation in duration and distribution exists. The analysis shows that number of rainy days has decreased in this long period, which led to increase the PET. High water deficit resulted in shifting of bio-climate towards arid condition. The results indicates that Maximum mean annual rainfall was observed in Mahabaleswar station of Maharashtra (6098 mm) and minimum mean annual rainfall also reported in Malegaon (545 mm) of Maharashtra, in Central India. It was observed that western districts of Madhya Pradesh (Barwani, Alirajpur) are shifting significantly towards drier side during the period of 30 years. Thus, information of long term spatial climatic changes can be effectively used for contingent crop planning, irrigation scheduling and diversification of crops.

Keywords: Climate change; evapotranspiration; rainfall; crop planning.

1. INTRODUCTION

In India, there has been a disastrous change in climate in the last three decades due to uncontrolled industrialization, deforestation, emissions of greenhouse gases, changes in land use patterns and many more. India's average temperature has increased by 0.7^0C which in

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turn increases the temperature of the warmest day and coldest night of the year. Agriculture is one of the important sectors as 75% of the rising population depends for their livelihood. Climate change affects both the crop as well as the yield. Crops are highly responsive to temperature in different stages of their life cycle. As temperature increases, crop development accelerates which causes the plant to mature early [1]. Today, many parts of the country is shifted towards drier sites due to high maximum temperature, reduction in number of rainy days and high evapotranspiration (ET). Water is very much essential for the sustainable crop production and livelihoods of the people. The availability of water in any area depends on the amount and distribution of rainfall of that region. Hence, the demand of water for irrigation to agricultural crops increases due to increased dryness [2]. The maximum portion of total rainfall reaching the earth's surface is lost through ET and is one of the important components of hydrological cycle. High ET, temperature and low rainfall causes depletion in soil moisture retention capacity and increases salinity at surface soils in semi-arid to arid condition [3]. The annual minimum temperature in long term is expected to increase (by < 1.2 °C) significantly in 80% of the districts in Central India [4]. Higher temperature reduces crop yield and favours pest and disease infestation.

To study the change in climatic attributes, water balance techniques have been widely used as it involves both rainfall and evapotranspiration. The assessment of evapotranspiration plays important role in many fields like water resource management, irrigation scheduling and applied climatology. Modified Penman's method is universally accepted as the most appropriate method for estimating potential ET [5]. The spatial distribution of various climatic parameters over a period is very much important for agriculture and hydro-climatological modelling. Many researchers use water balance approach for crop planning in a specific region [6, 7]. The water balance equation also helps to compute the length of growing period (LGP) for crop planning and exploring crop diversification. In this study, an attempt has been made to study the climatic variations over a long period in Central India (Chhattisgarh, Madhya Pradesh and Maharashtra) by using Modified Penman method for estimating PET in GIS environment.

2. MATERIALS AND METHODS

The central India physiography extends from Plateau to West Coast Plain and bio-climate Semi-arid dry to Humid condition. The Peninsular Plateau is the major physiography region in the state of Chhattisgarh, Madhya Pradesh has the Central Highlands and The Peninsular Plateau and Maharashtra has the Peninsular Plateau and the West Coast Plain. The climatic parameters (viz. minimum temperature, maximum temperature and precipitation) were downloaded online from www.worldclim.org for the period 1988-2018 so that each district of Central India is covered by one point data. Total 107 stations data were recorded (Fig. 1) and computed (Chhattisgarh-19, Madhya Pradesh-51 and Maharashtra- 37). The climatic data has been analysed by using Mann-Kendell statistical test to assess the trends.

Potential evapotranspiration (PET) is calculated by using Modified Penman-Monteith (1991) method as recommended by FAO (http://www.fao.org/docrep/x0490e/x0490e06.htm). This algorithm is based on the physical principles of energy balance over a wet surface and is empirically superior. Using the mean monthly rainfall and PET values in each district, the climatic water balance was computed using the book-keeping procedure of Thornthwaite and Mather [8]. The soil map (1: 250000) of National Bureau of Soil Survey & Land Use Planning (NBSS&LUP, 1985) was used. Various climatic parameters were calculated and geo-statistically mapped using ArcGIS 10.5 by Kriging (Ordinary) interpolation techniques.

In water balance calculation Storage, Actual Potential Water Loss (APWL), Actual Evapotranspiration (AET), Precipitation (P) and Moisture Index were computed by using relations as follows:

Storage=AWC ($e^{APWL/AWC}$)… *Under Saturated Condition else*

AWC=last month storageAET=PET when P>PET *else*

AET=P+ΔS

WD=PET-AET where, WD=Water Deficit WS=(P-PET)- ΔS where, WS=Water Surplus Moisture Index (%) by Krishnan and Singh, 1972 was calculated as:MI=(P-PET)/PET *100

Or,

MI=HI-AI

where,

HI=Humidity Index=[(WS/PET)]*100 AI=Aridity Index=[(WD/PET)]*100

Various climatic parameters were calculated and geo-statistically mapped using ArcGIS 10.5 by Kriging interpolation techniques.

3. RESULTS AND DISCUSSION

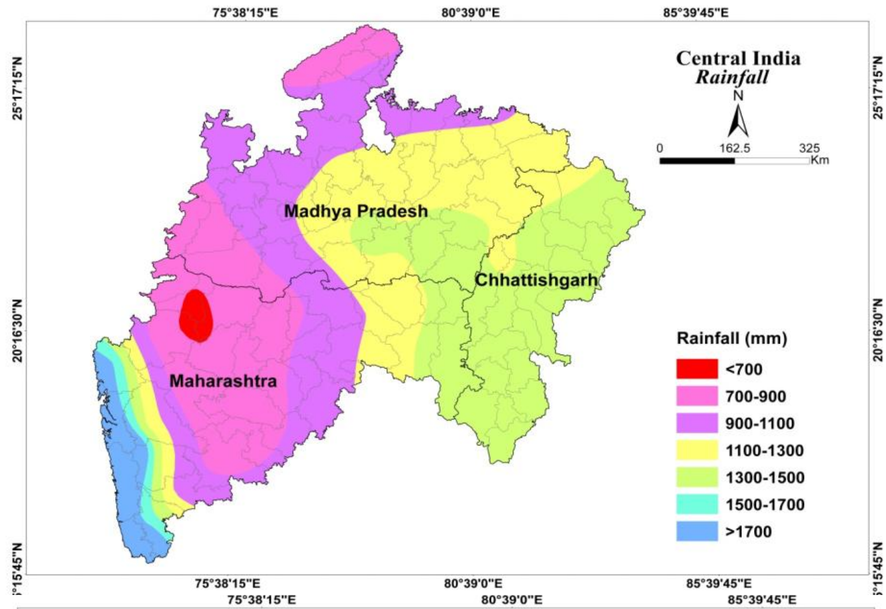
Rainfall variability is one of the important factor which influences crop productivity in agriculture. All the three states in Central India receive maximum rainfall (80%) during south-west monsoon period (June to October) with their peak values in July-August. In Chhattisgarh, the maximum annual mean rainfall of 30 years was recorded in Korba (1487 mm) district and about 80-85 % area of the state covers rainfall between the ranges of 1300-1500 mm. The state comes under Sub humid (dry) bio-climate with moisture index (MI) value (0 to -33.3) (Table.1) and water deficit ranges between 600-800 mm. The water deficit in the water balance sheet defines when all the available soil moisture is used up and rainfall fails to meet the demand of evapotranspiration, this situation exists. In Madhya Pradesh, the trend of rainfall decreases was observed from east to west. The western districts (Barwani, Alirajpur, Burhanpur, Khargone) receives less rainfall between 600-800 mm. Due to low rainfall and high water deficit (>1000 mm), western region of the state comes under Semi-arid (dry) bio-climate much drier compared to other part of the state. In Maharashtra, lowest rainfall receives in Malegaon (Nasik district) and highest in Mahabaleshwar (Satara district) district. The pattern of rainfall increases when we move from east to west. The west coast plain districts like Mahabaleshwar, Sawantwadi, Ratanagiri, Mumbai receives maximum rainfall (>2000 mm), low water deficit and MI between 20-100 % classifies for Humid bio-climate. The Spatial variability of mean annual Water deficit, Rainfall and Moisture Index of Central India are presented in Fig. 2.

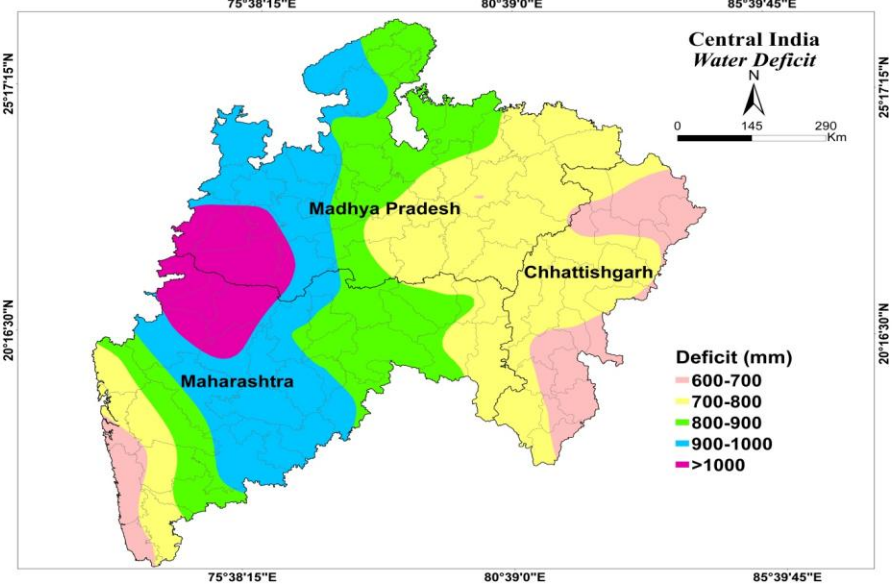
The trend analysis of long term (1988-2018) climatic data (MI, rainfall, PET and water deficit) of Central India was carried out by using Mann-Kendell's test. The results indicates that the Annual mean PET and water deficit showed increasing trend statistically but not significant, whereas, the amount of mean annual rainfall trend across the stations was significant (Fig. 3). The increasing trend in the extent of arid and semi-arid climatic zones of India has also been reported by Sahu *et al.* [9]. Similar result of increasing trend of mean maximum temperature in the Raipur district of Chhattisgarh was observed by Khavse *et al.*, 2015. The impact of climate variability and change in crop production in Maharashtra was reported by Kelkar *et al.*, 2020. Due to change in aridity parameters in central India the crop pattern is also changed due to less length of growing periods. Many crops productivity reduce at high temperature and low rainy days. In some patches the crops are replaced with other one to cope up with changing adverse situation [10]. The annual mean rainfall data year wise was near about same but the distribution and the number of rainy days in each station and in each state of central India significantly varies. The pattern of PET was statistically non-significant in increasing trend due to which water deficit also exist in each station. In MI non-significant changes was observed and therefore bio-climate shifts towards aridity due to high PET and water deficit condition [11].

Table 1. Classification of Bio-climate based on moisture index

Bio-climate class	Synchronized moisture index (Mather, 1956)
Arid	**<-66.7**
Hyper arid	<-88.3
Typic arid	-66.7 to -83.2
Semi arid	**-33.3 to -66.6**
Semi arid (dry)	-50.0 to -66.6
Semi arid (moist)	-33.4 to -49.9
Sub-humid	**-0.20 to -33.3**
Sub-humid (dry)	0 to -33.3
Sub-humid (moist)	0 to +20
Humid	+20 to +100
Perhumid	> +100

Fig. 1. Location of climatic point data of Central India





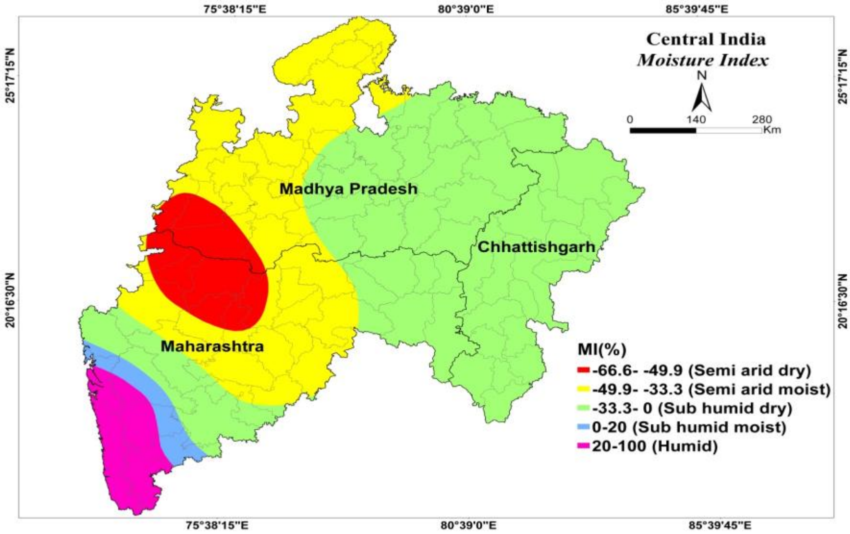


Fig. 2. Spatial variability of mean annual rainfall, water deficit and moisture indexof central india

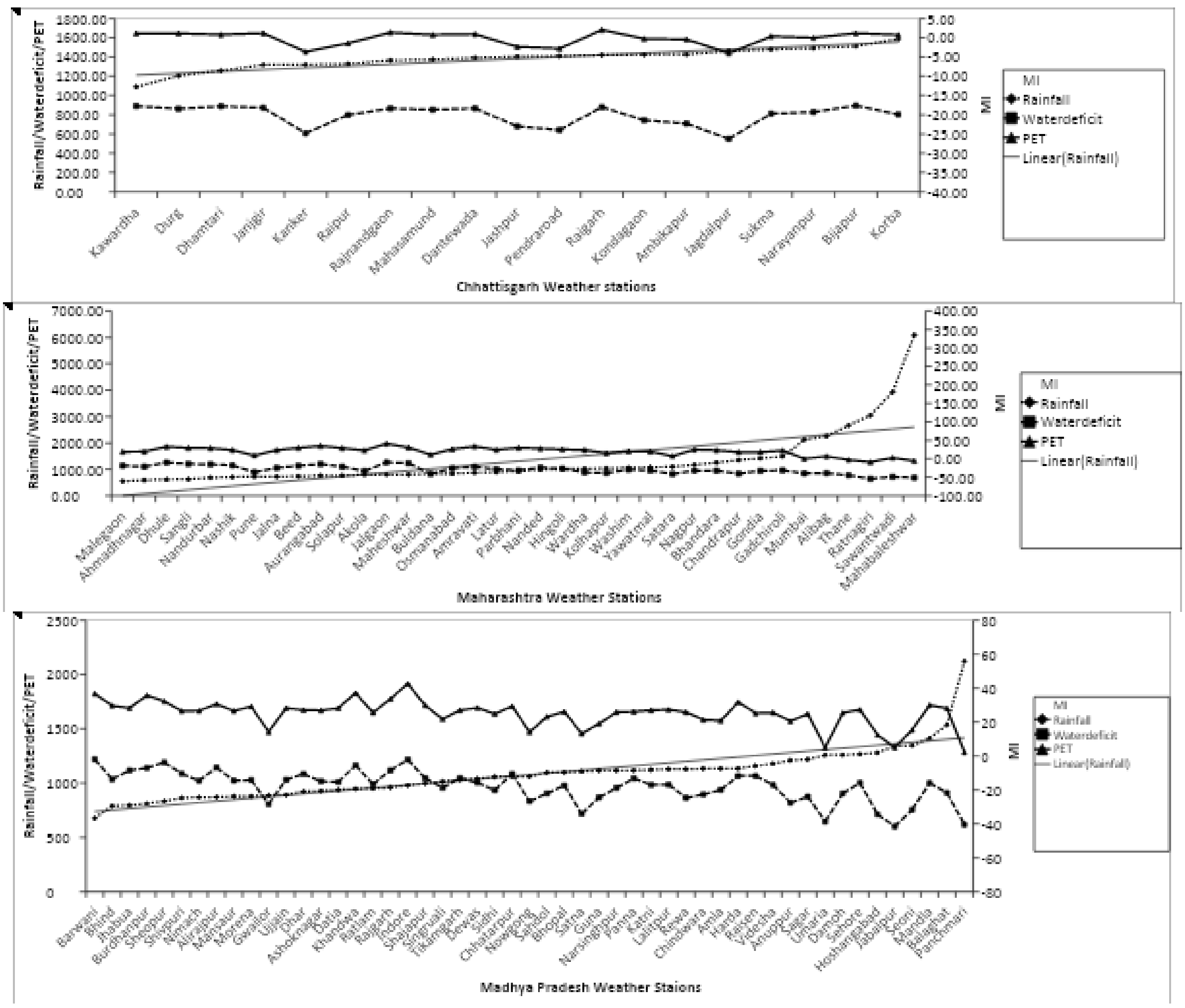


Fig. 3. Trends of mean annual rainfall, water deficit, pet and mi of chhattisgarh, maharashtra and madhya pradesh weatherstations over a period of 1988-2018

4. CONCLUSION

Analysis of 30 years mean monthly climatic data of Central India indicates that there is a change in rainfall patterns in association with rising maximum temperature due to global warming, which can cause change in aridity trend. In central India the lowest rainfall was recorded in Malegaon (545 mm) and highest in Mahabaleshwar (6098 mm) among all three states which indicates that there is a lot of variations in climatic parameters of Maharashtra. The bio-climate from semi-arid dry to humid class exists in this state. More dry spells in monsoon, reduced rainfall intensity, reduction in number of rainy days and high potential evapotranspiration has changed the crop pattern in Central India. The spatial variation of different climatic parameters is useful for planning and development of management strategies in central India. The use of various algorithms to forecast climatic parameters can play a very vital role in predicting crop yield using different models. Thus, this study is very much helpful to precisely decide the crop and water scheduling based upon the periods of water deficit and high evapotranspiration.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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