Trans.Inst.Indian Geographers
ISSN 0970-9851

Impact of global warming on climatic patterns of Chhattisgarh Plain- an analytical modeling

Agnisha Chakraborty*, West Bengal; B. Hema Malini and Anuja Tigga, Visakhapatnam

Abstract

In the context of global warming, the study predicts the possible changes in existing climates in Chhatisgarh plain with 2°C and 6°C temperature increase based on meteorological data on mean monthly temperature and rainfall for seven IMD stations collected for a period of 30 years (1986-2015) and average monthly water balance of all the individual stations using Thornthwaite and Mather water balance technique (1955). Analysis of thermal regime conditions revealed that the entire region at present experiences Megathermal climate (A′a′) with varying intensities but with increasing temperatures to the tune of 2°C and 6°C, Megathermal climates will intensify all over Chhattisgarh plain. On the other hand, analysis of moisture index (Im) indicated that the study area which is at present experiencing dry sub humid type of climate (C1) may experience semi-arid (D) climate with an increase of 6°C and there may not be any part of Chhattisgarh plain which will experience dry sub humid type of climate in future. The region is likely to become drier with rise in temperature..

Keywords: *Water balance, mega thermal, moisture index, climate, dry sub humid, semiarid.*

Introduction

Systematic categorization of climate of any region is more important in the present times of great climate concern as the influence of climate on living things has both immediate effects as well as complicated responses associated with climatic change. Thus, the purpose of climatic classification is to provide a comprehensive description of the climate in terms of active factors of which heat and moisture are the most decisive in determining climatic types.

Based on the significance of classification of climates, around 169 schemes have evolved, which are mainly based on genetic and empirical approaches. Of which, 21 are based on genetic approach and 148 are based on empirical approach (Terjung and Louie, 1972). Among the numerous classifications that have been formulated by empirical approach, three schemes have gained wider acceptance, which include Koppen's (1900 and 1936), Thornthwaite (1948 and 1955) and Miller (1959) schemes. Among those, Thornthwaite's scheme of classification has been found to be more rational with practical value. He coined the concept 'Potential Evapotranspiration' (PE) which is the maximum amount of water which would be lost to the atmosphere from a surface comparatively covered with vegetation, if there is sufficient water in the soil at all times for full use (Thornthwaite, 1948), a unique characteristic feature of PE which can be applicable to derive both thermal as well as moisture regime climatic types (Subrahmanyam and Sastri, 1969a). Thornthwaite developed a book-keeping procedure namely water balance which is helpful in the evaluation of various hydrological elements like water storage, water surplus and water deficit, which in turn provide quantitative solutions to many hydrological questions in a given region (Hema Malini, 1993). A systematic analysis of water balance of any region clearly explains the water need of a region and provides a more realistic and clear idea about the wetness and dryness of a climate (Hema Malini, 1988). Further, water balance analysis is not only useful for the identification of climatic types but also useful for the identification of drought spells, their duration, intensity and spread and also to assess the suitability of crops in a particular region. These types of analyses are useful for the farmers and planners of agriculture (Hema Malini and Pampa Choudhury, 2010). Thus, Thornthwaite scheme has gained popularity even among the ecologists, agricultural scientists and many others who carry out regional studies as its benefits are immense.

The main objective of the paper is to assess the existing climate types of the Chhattisgarh plain by applying thermal and

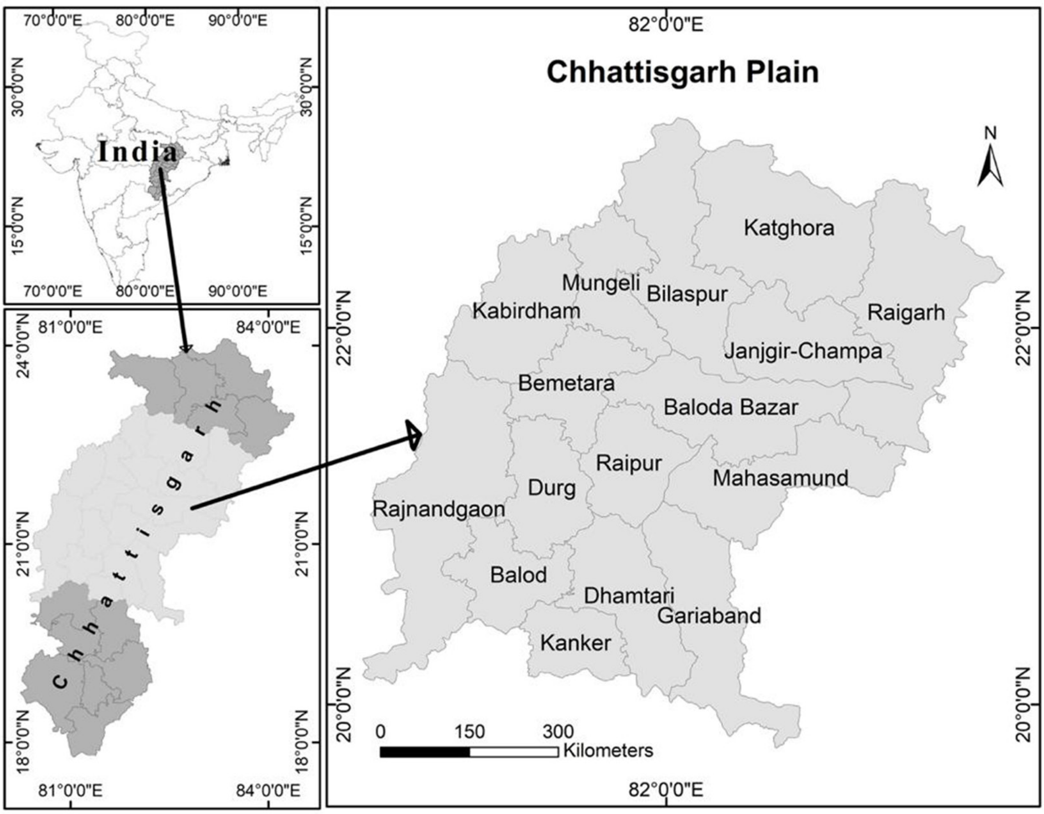

Fig 1: Chhattisgarh Plain: Location

moisture regime concepts of Thornthwaite and Mather (1955) and to predict the impact of global warming on the present climatic patterns of Chhattisgarh plain.

Study area

Chhattisgarh Plain lies between19°47′ 14″ N and 23° 6′ 58″N latitudes and 80° 23′ 55″ E and 83° 47′ 50″ E longitudes which covers an area of 72184 Sq. Km. This extensive Plain is located in the central part of the State of Chhattisgarh (Fig. 1). The average annual rainfall is more than 1500 mm in the eastern region, and 1300 mm in the western region. The region is mainly drained by the river Mahanadi and its tributaries. Because of the presence of flat and fertile soils with adequate water supply, this region is prosperous in agriculture. The paper aims at analyzing the existing climatic types in Chhattisgarh plain and to assess whether there will be any change in the climatic patterns due to temperature rise.

Data and methodology

Water balance technique of Thornthwaite and Mather (1955) has been applied for the present climatic analysis. To compute the water balance, monthly minimum, maximum temperature and monthly rainfall data for about 30 years have been obtained from the records of India Meteorology Department (IMD) for the seven IMD stations existing in the study area. Data on existing patterns of land use/land cover and forests have also been obtained from the statistical handbook and economic review of Chhattisgarh (2013-14) published by Directorate of Economics and Statistics, Government of Chhattisgarh.

Climatic classification

Thornthwaite's scheme of classification of climates (1948) is based on the fundamental consideration of thermal efficiency and moisture affectivity (Subrahmanyam and Hema Malini, 1978). For the luxuriant growth and development of vegetation, the two important climatic requirements are thermal efficiency and moisture affectivity. The tropical regions have high thermal efficiencies on account of high air temperatures and almost constant length of the day throughout the year. Moisture affectivity is not such simple parameter because it depends upon the precipitation regime, which in turn is governed by general circulation of the atmosphere. Analysis of thermal regime provides the information regarding the available thermal potentiality, which is essential for the growth of vegetation. It is only where both the thermal efficiency and moisture affectivity are optimal that the development of vegetation is very prosperous and therefore the ecosystems are well balanced climatically (Subrahmanyam and Hema Malini, 1977).

Thermal regime

Thornthwaite considered PE, a parametric index of thermal efficiency and is expression of day length as well as temperature of a region to classify the climates. PE which is also termed as Thermal Efficiency (TE) is not only a growth Index but expresses growth in terms of the amount of water that is needed for the growth (Thornthwaite, 1948). Based on the annual values of PE/TE, five major thermal provinces namely Megathermal, Mesothermal, Micro thermal, Tundra and Frost were identified by Thornthwaite. A Mega thermal climate is the climate which experience highest temperatures throughout the years with PE/TE above 1140 mm. Mesothermal climate experiences persistent cold or heat conditions and experience PE between 570 mm and 1140 mm. Micro thermal climate is the one where mean annual temperatures are low and PE varies between

Table 1: Classification scheme of thermal regime

Thermal Efficiency(mm)	Symbol	Climatic Type
Above 1140	A'	Megathermal
1140-997	B'_4	Mesothermal
997-855	B'_3	
855-712	B'_2	
712-570	B'_1	
570-427	C'_2	Microthermal
427-285	C'_1	
285-142	D'	Tundra
Below 142	E'	Frost

Source: Thornthwaite and Mather, 1955

285 and 570 mm. Frost and Tundra are the cold climates with low thermal efficiency. To find out climate types based on thermal regime, the parameters namely annual Thermal Efficiency and Summer Concentration of Thermal Efficiency (SCTE) has been computed for the main and sub classifications respectively. Thornthwaite's general scheme of thermal regime classification is presented in Table 1 and Table 2 used as a basis to demarcate major and sub thermal regime categories. Scheme of Thornthwaite climatic classification to derive major climates based on Thermal regime classes is given in the Table.1.

Thornthwaite made sub classification to find out the seasonal variation of TE by computing Summer Concentration of Thermal Efficiency (SCTE). SCTE is the percentage of the sum of the thermal efficiencies for the three highest summer months to the annual total (Table 2).

Based on the scheme of main classification (Table1) and sub classification (Table2) of Thornthwaite's thermal regime, it was revealed that all the seven stations of study area are experiencing major type of Mega thermal type of climate (A') as their annual thermal efficiency values are above

Table 2: Thermal Regime Sub-classification

SCTE (%)	Symbol	Climate Type
Below 48.0	a'	Megathermal
48.0-51.9	b'_4	Mesothermal
51.9-56.3	b'_3	
56.3-61.6	b'_2	
61.6-68.0	b'_1	
68.0-76.3	c'_2	Microthermal
76.3-88.0	c'_1	
Above 88.0	d	Tundra

Source: Thornthwaite and Mather, 1955

Table 3: Sub classification of Megathermal (A’) and SCTE megathermal (a’) Climates

Thermal Efficiency (mm)	Intensity	Symbol	SCTE (%)	Symbol
1885 and above	Very extreme	A'_6	34.0-31.9	a'_6
1713-1884	Extreme	A'_5	36.3-34.0	a'_5
1570-1712	Very high	A'_4	38.8-36.3	a'_4
1427-1569	High	A'_3	41.6-38.8	a'_3
1283-1426	Moderate	A'_2	44.6-41.6	a'_2
1140-1282	Low	A'_1	48.0-44.6	a'_1

Source: compiled by the authors

Table 4: Climatic classification of Chhattisgarh plain - thermal regime

Stations	Thermal Regime Classification- Present Situation				
	Annual TE (mm)	Megathermal Type	Symbol	SCTE (%)	Symbol
Pendra	1394	Moderate	A'_2	39.26	a'_3
Raipur	1615	Very high	A'_4	35.80	a'_5
Bilaspur	1433	High	A'_3	41.8	a'_2
Durg	1553	High	A'_3	36.40	a'_4
Raigarh	1575	Very high	A'_4	36.64	a'_4
JanjgirChampa	1579	Very high	A'_4	36.54	a'_4
Rajnandgaon	1605	Very high	A'_4	35.18	a'_5

Source: computed by the authors

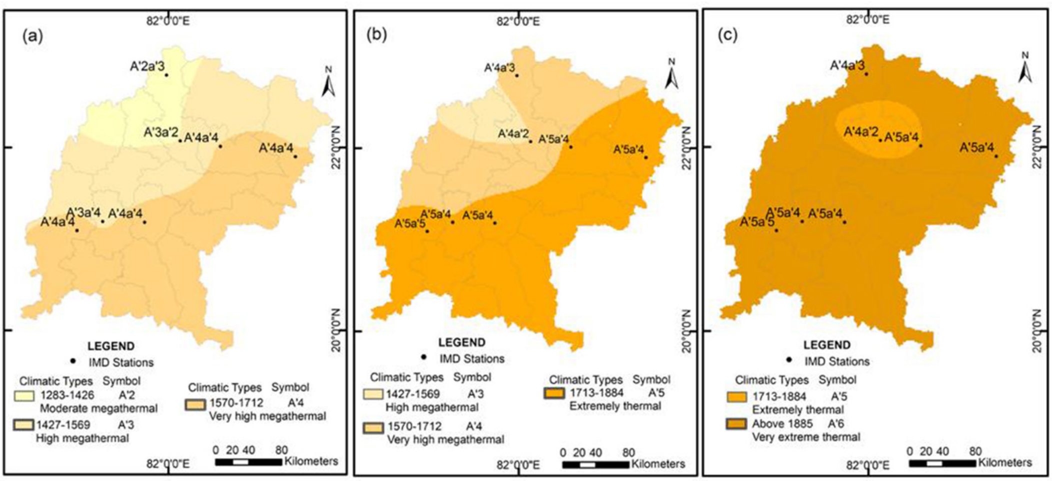

Fig 2 (a-c): Climate types of Chhattisgarh Plain – Thermal Regime. (a) Present condition (b) Rise of 2°C temperature (c) Rise of 6°C temperature

1140 mm and Megathermal sub type (a') type. To find out the variations in the intensity of major (A') and sub type (a') of Megathermal types of climates the values above 1140 mm of TE and below 48 % of SCTE were further divided into sub categories respectively. Table 3 provides sub divisions of A' and a' categories of thermal regime.

Table-4 shows that Pendra and its adjacent parts in the north-west of the study region experience Megathermal A'_2 type of climate with the thermal efficiencies below 1425 mm. The north-eastern and the central parts (area around Bilaspur and Durg) experience A'_3 type of Megathermal climate with thermal efficiency values ranging from 1425 mm to 1567 mm. The south-western, southern and south-eastern parts surrounding Rajnandgaon, Raipur, Janjgir Champa and Raigarh experience Megathermal A'_4 type of climate with the thermal efficiencies above 1567 mm (Fig.2 a).

To understand the spatial distribution pattern of climates, isopleths of annual thermal efficiencies values and the percentage of summer concentration of thermal efficiencies have been interpolated to generate maps in the GIS environment. Considering the spatial extent of the study area it was found that about 14,717 Km^2 experiences A'_2 Megathermal climate, about 19,328. Km^2 comes under A'_3 Megathermal type of climate and more than half of the region (35,767Km^2) experiences A'_4 Megathermal type of climate.

The spatial patterns of SCTE percentage indicates that the northwestern and northern parts of the study area, experience SCTE above 37.5%, thus comes under the influence of a'_3 Megathermal sub type. Considerable part of central Chhattisgarh plain (surrounding Bilaspur) experience SCTE above 41 percent, thus, a'_2 megathermal sub-type of climate is observed here. The remaining area of the plain including southern, south-western, south-eastern and some part of the central plain experience a'_4 and a'_5 type of climate.

On the basis of the above analysis it is found that the Chhattisgarh plain comes under Megathermal climate with varying magnitudes of SCTE. The distribution of thermal efficiency over Chhattisgarh Plain revealed that the entire region has Megathermal types of annual and summer thermal efficiencies, more than adequate to support Megathermal type of vegetation.

Table 5: Moisture regime

Climatic Type	Symbol	Moisture Index (Im %)
Perhumid	A	100 and above
Extremely humid	B_4	80 to 100
Very humid	B_3	60 to 80
Moderately humid	B_2	40 to 60
Low humid	B_1	20 to 40
Moist subhumid	C_2	0 to 20
Dry subhumid	C_1	-33.3 to 0
Semiarid	D	-66.7 to -33.3
Arid	E	-100 to -66.7

Source: Thornthwaite and Mather (1955)

Moisture regime

Thermal potentiality is responsible for the growth of greenery in any region. But it is only moisture regime that determines the luxuriance of vegetation development. Thus in eco-climatological investigations, both thermal as well as the moisture factors are to be considered to understand the real thermal and moisture potentialities of a region (Subrahmanyam and Hema Malini, 1979).

To analyze climates, based on moisture regime of any region it is essential to derive the water balance elements namely Potential Evapotranspiration (PE) water surplus (WS) and water deficit (WD). These elements help computing aridity index (Ia) and humidity index (Ih). Index of aridity is the ratio of water deficit to PE (Ia = (WD/PE) x 100) and Ih is the ratio of water surplus to PE (Ih = (WS/PE) x100). As water surplus and water deficiency alternate seasonally they play an important role in the determination of Index of Moisture (Im) which determines the classification of climates. Moisture index is computed with the help of the following formula:

Im = Ih – Ia; Where, Im = Moisture Index, Ih = Humidity Index, Ia = Aridity Index

Thornthwaite (1955), in his scheme of climatic classification used index of moisture (Im), as the basis to demarcate arbitrary boundaries between major types of climate. Table 5 gives the moisture regimes (Im) according to Carter and Mather (1966) in so far as the dry regions (Im< 0) are concerned and categorizations of humid regions (Im> 0) is originally proposed by Thornthwaite (1948) is given in Table 5.

To demarcate the variations within the broad categories, Thornthwaite had adopted the seasonality of adequate and exceptional moisture conditions. Exceptional conditions mean a surplus in a dry climate and a deficit in a moist climate (Hema Malini, 1993). This type of analysis is very useful to identify the degree of intensity (large, moderate or little) of water deficiency and water surplus in the moist and dry climatic regions respectively (Tigga and Rao, 2011). Thornthwaite's scheme has the limitation to explain for dry climate. Hence, Carter and Mather (1966) have extended the classification and have given appropriate classes to varying degree of dryness. Table 6 represents the sub classification based on seasonal variation in moisture effectiveness. In order to derive sub classification of moisture regime of Chhattisgarh plain based on seasonal variation, Index of aridity and Index of humidity are considered.

The analysis of moisture indices of Chhattisgarh plain revealed that the plain experiences moisture index between -8.12 and -32.7 percent. Thus, all the stations come under the category of dry sub humid climate (C_1;Im= -33.3 to 0). Bilaspur, Rajnandgaon and Durg in the western part of the study area are experiencing lower range of moisture indices indicating the dryness in the climate. Pendra in the extreme northern part of the plain is experiencing comparatively high moisture effectiveness (-8.0%).

The sub classification based on seasonal variation of effective moisture indicates little or no water surplus (d) condition which means that water deficiency prevails throughout the year except in one or two months. Thus, as a whole the study area comes under the influence of 'C_1d' type of climate. The spatial distribution of moisture indices indicates that though the Chhattisgarh plain is broadly coming under the influence of dry sub humid climate (C_1), there is a variation in moisture

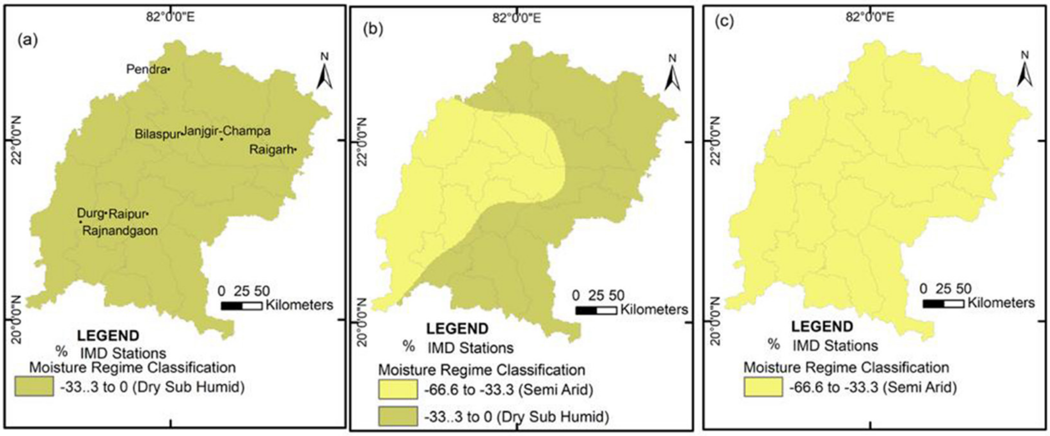

Fig 3 (a-c): Climate types of Chhattisgarh plain – Moisture Regime. (a) Present condition (b) Rise of 2°C temperature (c) Rise of 6°C temperature

Table 6: Moisture regime sub classification

Moist Climate (A, B, C_2)	*Aridity Index*
r Little or no water deficiency	0-10
s Moderate summer water deficiency	10 to 20
w Moderate winter water deficiency	10 to 20
s Large summer water deficiency	20+
w Large winter water deficiency	20+
Dry Climates (C_1, D, E)	*Humidity Index*
d Little or no water surplus	0 to 16.7
s Moderate winter water surplus	16.7 to 33.3
w Moderate summer water surplus	16.7 to 33.3
s Large winter water surplus	33.3+
w large summer water surplus	33.3+

Source: Thornthwaite and Mather (1955)

effectiveness throughout the region. At present, the northern parts of the plain is experiencing comparatively higher moisture effectiveness than the central and western parts (Fig.3.a), while the sub classification indicates that the region is experiencing'd' type of climate with little or no water surplus. Thus, the plain is experiencing dry sub humid climate with little or no water surplus (C_1d) and the entire plain can support dry deciduous type of natural vegetation.

Global warming and its impact

The climate models show the variations in both temperature and precipitation patterns with significant regional variability due to anthropogenic activities (Giorgi, 2006). Analysis of the past 140 years of temperature data of the world revealed that global temperature is rising at a rapid rate. In several studies made by Basu (1990), Mithra (1991), Liu and Chen (2000), Oliver and Hiddore (2002) Kothawale and Kumar (2005), IPCC

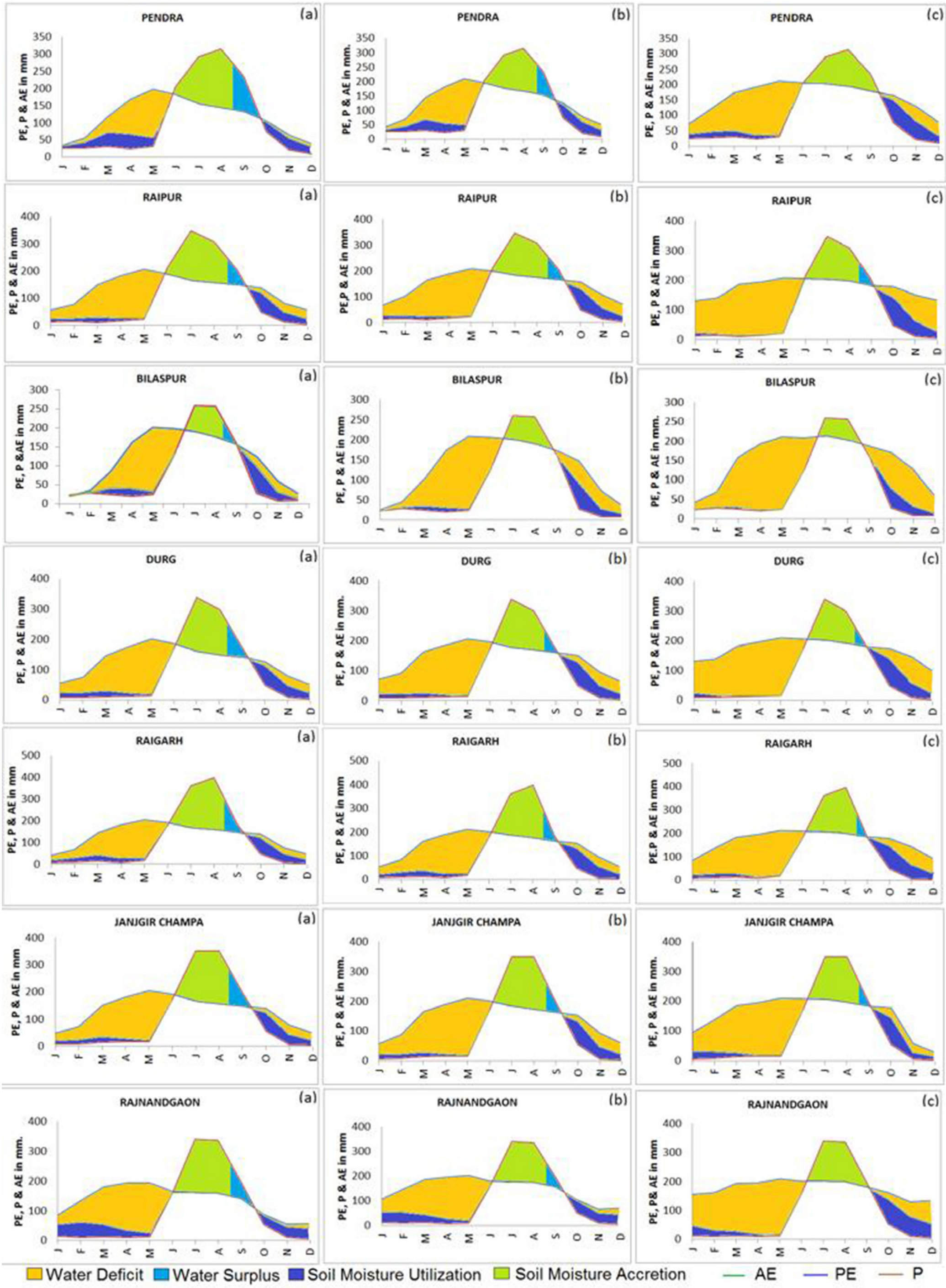

Fig 4: Water Balance elements (mm) of Chhattisgarh Plain (a) Present condition (b) Rise of 2°C temperature (c) Rise of 6°C temperature

(2007) Bhutiyani et al., (2007) and You et al (2008) warming trend has been reported in their respective study regions. These studies suggested an overall increase of temperature between 0.4 °C and 0.8 °C over past century. Further, studies of Riebeek (2010) and US Environment Protection Agency (2012) predicted a rise of temperature between 1.5°C and 5.8°C by 2100. These changes in temperature patterns certainly impact the water balance of any given region which in turn alters the existing climatic patterns. Hema Malini (1997, 2014) found shifting of climatic pattern towards drier side of the climatic spectrum in India as well as in Hokkaido (Japan), if the temperatures rise by 4°C. Keeping the change in the water balances of the study region with the rising temperatures, an attempt is made to assess the possible changes in the climatic patterns of Chhattisgarh region.

Influence of Warming

To assess any change in the existing climatic pattern due to global warming, monthly average water balances were recomputed for the predicted rise of temperatures after adding 2°C and 6°C for each month. Fig.4 (a, b, c) provides graphical representations of water balance predictive models for 2°C and 6°C rise of temperatures. Based on the annual Thermal Efficiency (TE) of each representative station, thermal regime types of climates of Chhattisgarh plain were categorized.

The analysis revealed that with the rising temperatures by 2°C and 6°C there will be a significant change in the existing thermal regime climates of Chhattisgarh Plain. At present, Chhattisgarh Plain is experiencing Megathermal (A') climate with varying intensities such as low (A'1) moderate (A'_2), high (A'_3) and very high (A'_4), extreme (A'5) and very extreme (A'6). Table 8represents thermal regime climates for the present and with rise of temperatures.

Table 8 reveals that with the temperature increase by 2°C and 6°C, thermal conditions are intensified in the entire Chhattisgarh plain from the existing thermal regime conditions (Fig. 2 a, b). The entire region will come under the influence of very high intensities of Mega thermal climate without exception. The intensification is more with 6°C of increase (Fig. 2c).This means the thermal potential of the region will be increased enormously

Table 8: Shifts in thermal regime climates of Chhattisgarh plain due to global warming

Stations	With Existing Temperature Conditions			With 2 °C Temperature Increase			With 6 °C Temperature Increase		
	TE in mm	Megathermal type	Symbol	TE in mm	Megathermal type	Symbol	TE in mm	Megathermal type	Symbol
Pendra	1394	Moderate	A'_2	1589	Very high	A'_4	1923	Very extreme	A'_6
Raipur	1615	Very high	A'_4	1790	Extreme	A'_5	2120	Very extreme	A'_6
Bilaspur	1433	High	A'_3	1576	Very high	A'_4	1846	Very high	A'_5
Durg	1553	High	A'_3	1726	Extreme	A'_5	2059	Very extreme	A'_6
Raigarh	*1575*	Very high	A'_4	*1733*	Extreme	A'_5	*2026*	Very extreme	A'_6
Janjgir Champa	1579	Very high	A'_4	1741	Extreme	A'_5	1889	Very extreme	A'_6
Rajnandgaon	1605	Very high	A'_4	1773	Extreme	A'_5	2114	Very extreme	A'_6

Source: Computed by authors

Table 9: Shifts of moisture regime in Chhattisgarh plain due to global warming

Stations	Present Situation			With Temperature Rise					
				By 2.0 °C			By 6.0 °C		
	Im%	Climate type	Symbol	Im%	Climate Type	Symbol	Im%	Climate Type	Symbol
Pendra	-8.12	Dry Sub humid	C_1	-19.4	Dry Sub humid	C_1	-33.4	Semi-arid	D
Raipur	-24.9	Dry Sub humid	C_1	-32.2	Dry Sub humid	C_1	-42.8	Semi-arid	D
Bilaspur	-32.7	Dry Sub humid	C_1	-38.9	Semi-arid	D	-47.8	Semi-arid	D
Durg	-29.1	Dry Sub humid	C_1	-36.3	Semi-arid	D	-46.5	Semi-arid	D
Raigarh	-21.5	Dry Sub humid	C_1	-28.7	Dry Sub humid	C_1	-38.9	Semi-arid	D
Janjgir Champa	-24.3	Dry Sub humid	C_1	-31.3	Dry Sub humid	C_1	-36.7	Semi-arid	D
Rajnandgaon	-28.2	Dry Sub humid	C_1	-34.9	Semi-arid	D	-45.5	Semi-arid	D

Source: Computed by authors

with rising temperature. Table 9 shows the changes in the moisture regime climates in Chhattisgarh with temperature increase.

With 2°C of temperature increase, the areas around Bilaspur, Durg and Rajnandgaon will experience semi-arid climate while remaining four stations will experience same dry sub humid climate (Fig.3b). With 6°C increase of temperature all the station will experience semi-arid type of climate (Fig.3c) and dry sub humid type of climate will be completely eliminated to support only thorn type of vegetation.

Conclusion

Climate types based on Thornthwaite's thermal regime and moisture regime revealed that at present the Chhatisgarh plain comes under Megathermal climate as it has rich thermal potential. However, because of rainfall limitation, the region is experiencing dry sub humid type of moisture regime climate. Further, assumption of temperature increase by 2°C and 6°C indicates that the thermal potential of the region may be increased enormously and present day Megathermal climates may be intensified. As a result, dryness will increase leading to the shifting of dry sub humid climate towards semi-arid climate. Remedial measures can be adopted to combat the repercussions of the global warming.

References

Bhutiyani, M. R., Kale, V. S., & Pawar, N. J. (2007). Long-term trends in maximum, minimum and mean annual air temperatures across the Northwestern Himalaya during the twentieth century. *Climatic Change, 85*(1), 159-177.

Carter, D. B., & Mather, J. R. (1966). Climatic classification for environmental biology. CW Thornthwaite Associates, Laboratory of Climatology. *Publ. in climatology, lab of climate*, Centerton, Vol. 19 (4).305-395.

Giorgi, F. (2006). Climate change hot-spots. *Geophysical research letters, 33*(8).

Griffiths, J. F. (1978). *Applied climatology : An Introduction* (2nd ed.). Oxford University Press.

Intergovernmental Panel on Climate Change (IPCC) (2007). Climate Change 2007: Climate change impacts, adaptation and vulnerability - Summary for policymakers. *Contribution of Working Group II to the Fourth Assessment Report of the IPCC.*

IPCC (1996). Climate Change 1995: Impacts, adaptations and mitigation of climate change: scientific-technical analyses, *Contribution of working group II to the second assessment report of the Intergovernmental Panel on Climate Change*. (R. T. Watson, M. C. Zinyowera, & R. H. Moss, Eds.) Cambridge University Press.

Koppen, W., (1900). Versuch einer Klassification der Kilimate, Vorzugsweise nach ihren Beziehungen zur Pflenzenwelt, *Geograph*. 2, Vol. 6, pp. 593-611.

Koppen, W. (1936). Das Geographische system der Kilimate. In: Handbuch der Klimatologic. *Getruder Borntraeger*, Berlin, Vol.1, Part C.

Kothawale, D.R., and Rupa Kumar K. (2005). On the recent changes in surface temperature trends over India, *Geophysical Research Letters*, 32, L18714.

Liu, X., & Chen, B. (2000). Climatic warming in the Tibetan Plateau during recent decades. *International Journal of Climatology: A Journal of the Royal Meteorological Society, 20*(14), 1729-1742.

Malini B. H. (1984). Water balance techniques and their applicability. *Research Bulletin No.22, Indian Geographical Studies, Geographical Research Center*. pp. 48-58.

Malini B. H. (1988) Ecoclimatological aspects of drought prone area of Andhra Pradesh - Anantapur. *Report submitted to University Grants Commission*, New Delhi. Pp. 21-79.

Malini B. H. (1993). Daily water balance and irrigation scheduling in Visakhapatnam district-Andhra Pradesh. *Report Submitted to the University Grants Commission*, New Delhi.

Malini B. H. (1997). Global warming and climate change predictive models for temperate and tropical regions, *The Deccan Geographer*, Vol.35 (1), Pp. 35-47.

Malini B. H., Sumiko K., Rao N. K., Reddy, V. B., & Naidu, T. G., (2014). Impact of global warming on cropping patterns – case studies of India and Hokkaido island (Japan), *Journal of Urban and Regional studies*, Vol.1 (1), Pp. 81- 91.

Malini B. H., & Chaudhuri, P. (2010). Drought Vulnerability and its implications on Agriculture in Orissa State. *Punjab Geographer, 6*, 1-15.

Miller, A. A. (1959). *Climatology*. New York: Mehtewn London and E. P. Dulton and Co. INC

Mithra, A.P. (1991). Global warming-green house effect on the environment ,The Hindu, Kasturi and sons Ltd., Madras, Pp. 76-79.

Oliver, J. E., & Hidore, J. J. (2002). *Climatology - An Atmospheric Science*. Singapore: Pearson Education Ptc. Ltd.

Riebeek Holli (2010). Global Warming: Feature articles. http://earthobservatory.nasa.gov/Features/GlobalWarming/

Subrahmanyam, V. P., & Hema Malini, B. (1977). Studies in ecoclimatology of Andhra Pradesh- Thermal regime, *The Deccan Geographer*, Vol. 15 (2), Pp.297- 306.

Subrahmanyam, V. P., & Hema Malini, B. (1978). Drought prone areas of Andhra Pradesh. *The Deccan Geographer*, Vol. 17 (2), Pp. 442-449.

Subrahmanyam, V. P., & Sastry, C.V. S. (1969). Climatic analogues for the dry regions of India. *Tropical Ecology*, Vol.10 (1),Pp. 34-44.

Terjung, W. H., & Louie, S. S. (1972). Energy input-output climates of the world: A preliminary attempt. *Archiv für Meteorologie, Geophysik und Bioklimatologie, Serie B, 20*(2), 129-166.

Thornthwaite, C. W. (1948). An approach toward a rational classification of climate, *Geographical Review*, Vol. 38, (1), Pp. 55-94.

Thornthwaite, C.W. & Mather, J.R. (1955). The water balance, Publication of climatology, *Laboratory of Climatology*, Vol.5 (1), Pp. 1-104.

Thornthwaite, C. W. & Mather, J.R. (1957). Instruction and tables for computing potential evapotranspiration and the water balance, *Publi. In Climatology, Lab. of Climate, Vol. 10*(3), Pp. 185-311.

Tigga, A., & Rao, G.V. N. (2011). Assessment of climates in Jharkhand State- A moisture regime approach, *Eastern Geographer*, Vol. XVII (1), Pp. 79-84.

You, Q., Kang, S., Aguilar, E., & Yan, Y. (2008). Changes in daily climate extremes in the eastern and central Tibetan Plateau during 1961 to 2005. *Journal of Geophysical Research*, 113.

Agnisha Chakraborty*
Lecturer,
Prabhu Jagatbandhu College,
Andul, Howrah, West Bengal

B. Hema Malini
Senior Fellow, ICSSR,
Department of Geography,
Andhra University,
Vishakhapatnam

Anuja Tigga
Professor,
Department of Geography,
Andhra University,
Vishakhapatnam

*Author for correspondence
E-mail: chakrabortyagnisha@gmail.com