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Assessment of Climates in Chhattisgarh Plain - A Moisture Regime Approach

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Abstract

The present study is an attempt to classify climates of Chhattisgarh plain based on the concept of moisture regime of Thornthwaite (1955). For that purpose meteorological data on mean monthly temperature and rainfall of seven IMD stations of Chhattisgarh Plain have been collected for a period of 30 years (1986-2015) and average water balance of all individual stations were computed by using Thornthwaite and Mather water balance technique (1955). Through water balance technique three indices were derived namely Index of aridity (Ia), Index of humidity (Ih) and Index of moisture (Im). The analysis of moisture indices revealed that, the entire Chhattisgarh plain is under the influence of dry sub humid type of climate (C1). The sub classification of moisture regime which has been carried out based on the seasonality of moisture effectiveness indicates that there is little or no water surplus (C1d) conditions existing in the study area. Among the representative stations, Bilaspur experiences the lowest values (-32.7) of moisture index which indicates that it is almost closer to semi arid climate. Similarly, the western parts of the study area also experience lower range of moisture indices. However, the extreme northern parts experiences comparatively high moisture indices.

Keywords: *Water balance, Moisture indices, Climate, Dry sub humid.*

Introduction

'Climate' refers to all weather conditions for a given location over a period of 30-35 years, while the term 'weather' refers to the momentary conditions of the atmosphere. Since, combination of various climatic elements namely temperature, rainfall, humidity, pressure, wind etc. are responsible for existing climate in a particular area, the variation in these elements from place to place result in the variations in climate. Thus, no two locations on the earth surface experiences similar kind of weather conditions (Carter et al., 1966; Oliver and Hidore, 2003). An area which experiences a homogenous set of climatic conditions is known as a climatic region (Critchfield, 1983). Numerous attempts have been made to identify and classify the climates by number of scientists with different approaches such as empirical, genetic and applied.

Empirical classification of climates is based on the observation of climatic features and their impact on the ecosystem. Genetic classification of climates is derived based on the cause of the climate. While applied climatic classifications assists in the solution of specialized problems that involve one or more climatic factors

(Oliver and Hidore, 2003). Among the empirical climatic classifications, the classifications namely, Koppen (1900 and 1936), Thornthwaite (1948 and 1955) and Miller (1965) have gained importance. Among which, Thornthwaite's climatic classification became more popular due to its rational, and conceptualized approach and multiple applicability in general and in the fields of ecology, agriculture and water resource development in particular (Ayoade, 1983; Subrahmanyam and Viswanandham, 1985; and Hema Malini, 1993).

Thornthwaite's climatic classification is mainly based on two parameters –thermal regime and moisture regime. Analysis of thermal regime provides the information regarding the average thermal potential measured in terms of amount of water that would be evaporated and also determines available energy for plant growth. However, apart from thermal efficiency, the moisture efficiency of a region has also equal influence on the distribution of vegetation pattern (Subrahmanyam and Hema Malini, 1979; Tigga, 2014). The nature of vegetation types and their distribution patterns in a region are largely dependent upon the availability of moisture. In the present paper, an attempt has been made to classify the climatic types of Chhattisgarh Plain using Thornthwaite's moisture regime concept (1955).

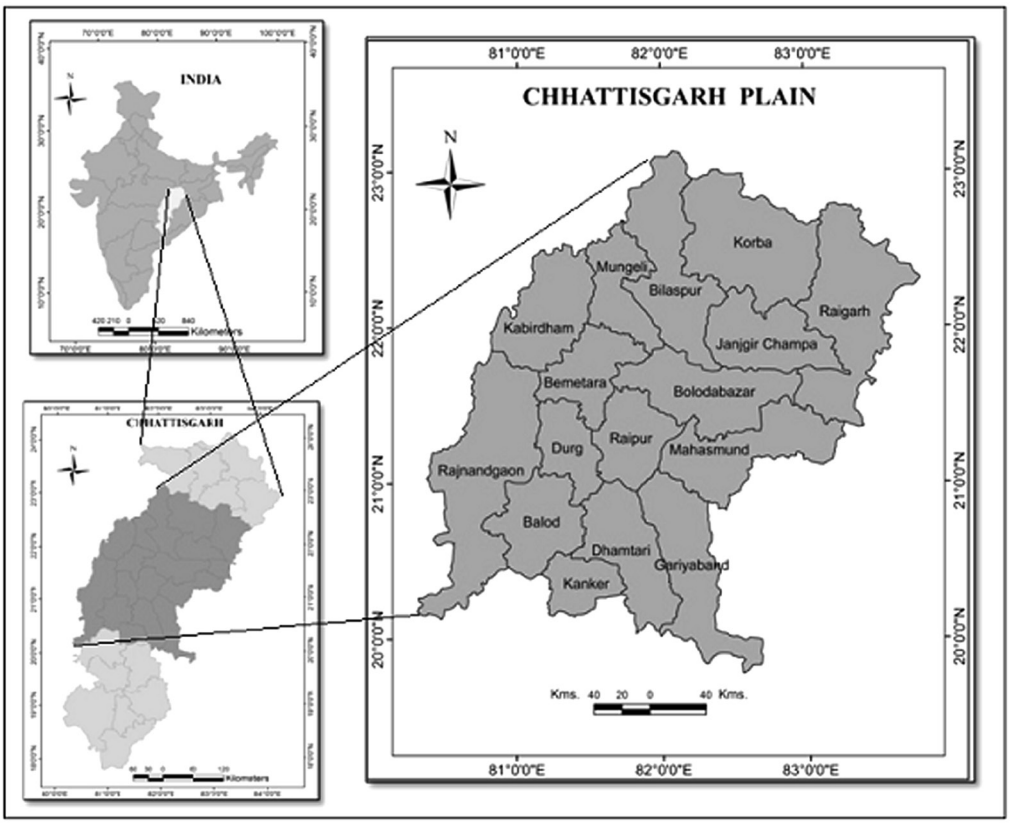

Fig. 1: Location Map of Chhattisgarh Plain, Chhattisgarh State

Study region

Chhattisgarh Plain lies between 19°47' 14.70'' N to 23°6' 58.63''N latitudes and 80° 23'55.7'' E to 83° 47'50.22''E longitudes. The Plain extends over the central portion of the Chattisgarh State. It is bounded by the Chotanagpur plateau to the north, Raigarh hills to the north-east, the Baster plateau to the south, and the Maikala range to the west. It is covering an area of 61, 872 km^2. The plain is mainly composed of sedimentary rocks. This Plain includes the administrative districts of the State namely, Korba, Bilaspur, Janjgir-Champa, Raipur, Mahasamund, Rajnandgaon, Dhamtari, Durg, Mungeli, Kabirdham, Baloda Bazar, Bemetara, Balod, Gariyaband, Kanker (northern part) and Raigarh. The average maximum temperature of the plain during summer is 42°C and the average minimum temperature in the winter is 12°C. The annual average rainfall varies from 1300 mm in eastern region to more than 1500 mm in the western region. The region is mainly drained by river Mahanadi and its tributaries. The study area is known to be agriculturally prosperous because of its even land surface, fertile soils and adequate water availability.

Data collection and methodology

This present study is carried out with the help of water balance technique developed by the Thornthwaite (1948) and Thornthwaite and Mather (1955). To compute water balance, mean monthly minimum and maximum temperature and monthly rainfall data for about 30 years were obtained from the records of India Meteorological Department (IMD) for the seven stations of the study area. Data on existing patterns of land use/land cover, forests were also obtained from the statistical handbooks and economic review of Chhattisgarh (2013-2014) published by Directorate of Economics and Statistics, Government of Chhattisgarh.

In concept of water balance, Precipitation (P) is considered as the income, Potential evapotranspiration (PE) as expenditure and the amount of moisture stored in the soil as a sort of reserve, which may be drawn from the soil during rainless period or scanty rainfall (Hema Malini, 1993). By comparing of PE and P a number of elements namely Actual evapotranspiration (AE), Water Deficit (WD) and Water Surplus (WS) are obtained. All these elements are essential to assess the climates of different regions.

The nature of climate of a region is significantly dependent upon the amount of Potential Evapotranspiration (PE) and Precipitation (P) of that region. If the PE is equal to precipitation, then it implies that there is neither water surplus nor deficiency conditions do exist. As a result, the climate is of neither moist nor dry nature. In the situation, where precipitation exceeds potential evapotranspiration, climate is of moist or humid nature due to the existence of water surplus conditions. Similarly, in the contrast situation, when precipitation is less than potential evapotranspiration, climate is of dry nature because of the existence of water deficit conditions.

Further, water deficit and water surplus elements helps to compute aridity index (Ia) and humidity index (Ih). Both these indices are percentage ratios of potential evapotranspiration which can be expressed as follows

$$Ia = (WD/PE) \times 100$$

$$Ih = (WS/PE) \times 100$$

Where, WD = water deficit, WS = water surplus and PE = potential evapotranspiration.

These two indices in turn used to derive Index of moisture (Im) which is expressed as below

Index of Moisture (Im) = index of humidity (Ih) – index of aridity (Ia)

Thornthwaite (1955), in his scheme of climatic classification used index of moisture (Im), as the basis to demarcate arbitrary boundaries between two major types of climate (Table.1). To demarcate the variations within the main categories, the seasonality of adequate and exceptional moisture conditions were used by Thornthwaite. Exceptional conditions means, a surplus in a dry climate and a deficit in a moist climate (Hema Malini, 1992).

Table 1.Thornthwaite Scheme of (1955) moisture regime climatic classification

Climatic Type	**Symbol**	**Moisture Index (Im %)**
Per-humid	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
Slightly Humid	B_1	20 to 40
Moist Sub-humid	C_2	0 to 20
Dry Sub-humid	C_1	- 33.3 to 0
Semi-arid	D	- 66.7 to - 33.3
Arid	E	- 100 to - 66.7

This type of analysis is very useful to highlight 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 of classification has the limitations to provide explanation for dry climate. Hence, Carter and Mather (1966) have extended the classification and given the appropriate classes to varying degree of dryness (Table.2). For the present study the same method has been adopted to delineate climatic types of Chhattisgarh plain.

Table 2. Scheme of Moisture Regime Sub Classification (Thornthwaite, 1955)

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+

Result and Discussion

To determine the climate of Chhattisgarh plain, several water balance elements such as potential evapotranspiration (PE), actual evapotranspiration (AE), water surplus (WS) and water deficiency (WD) were calculated. Table 3 provides the annual quantities of these elements for individual stations and their spatial patterns were represented in Fig.2. The average annual values of potential evapotranspiration show that the region is characterized by high thermal potential (PE) that ranges between 1394 mm and 1615 mm. The spatial distribution of PE indicates that except in the northern parts, higher PE conditions concentrates all over the study region (more than 1500 mm). The analysis of seasonal pattern reveals that potential evapotranspiration is high during the south-west monsoon season (656 mm) followed by hot weather season (517 mm), retreating monsoon season (192 mm) and cold weather season (169 mm).

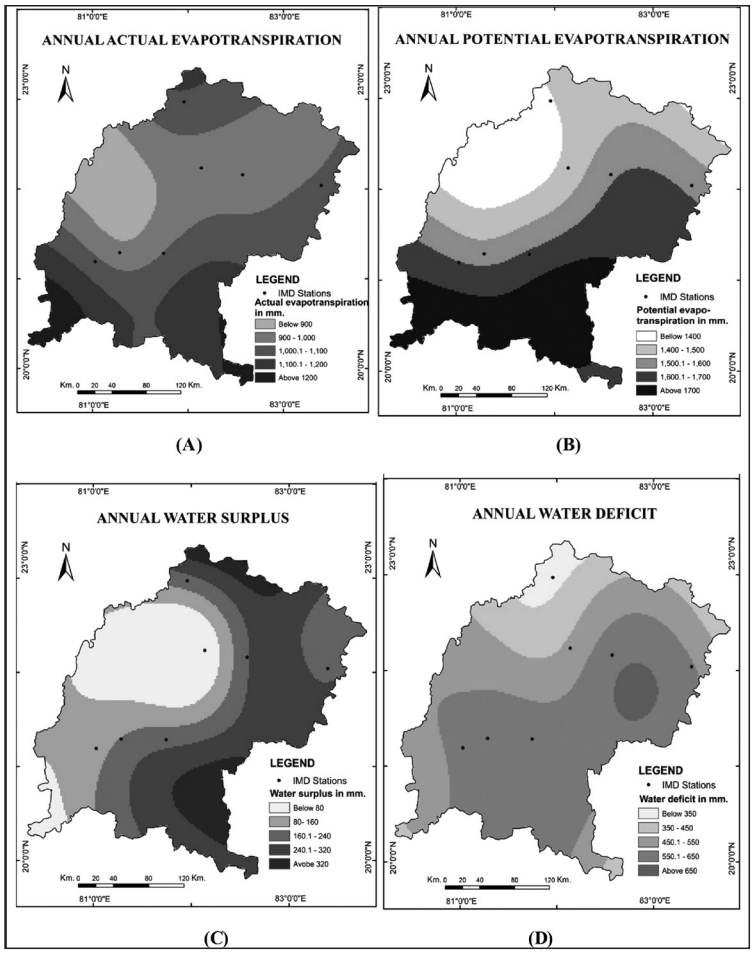

Fig. 2: Spatial distribution of average annual water balance elements in Chhattisgarh plain

Table 3. Distribution of average Annual Water Balance Elements (mm) of Chhattisgarh Plain

Stations	PE	P	AE	WD	WS
Pendra	1394.8	1281.1	1074.3	320.6	207.4
Raipur	1615.6	1213.7	1003.0	612.6	210.04
Bilaspur	1433.8	964.0	960.5	473.3	3.8
Durg	1553.4	1100.7	937.8	615.7	162.9
Ragarh	1575.3	1236.4	1015. 0	560.3	221.4
JanjgirChampa	1579.9	1196.0	966.3	613.6	229.7
Rajnandgaon	1605.4	1153.0	1025.1	580.3	127.8

The analysis indicated that the average annual actual evapotranspiration of the study area ranges between 937 mm and 1074 mm. The spatial distribution of AE is low in the central and western parts whereas it is high in the north-west, south-east and south-west parts. The seasonal pattern shows that the area experiences maximum actual evapotranspiration during the south-west monsoon season (639 mm) and minimum during cold weather season (89 mm).

The analysis of average annual water deficit indicates that the area experiences 320 mm to more than 600 mm WD. The north-western parts of the study area experiences comparatively low magnitude of water deficit conditions while these are highest in the eastern parts followed by southern parts. The seasonal distribution of water deficit shows that during south-west monsoon season, water deficit is low (17 mm) while it reaches to its maximum level during hot weather season (408 mm).

Table 4. Climatic Classification of Chhattisgarh Plain - Moisture Regime

Stations	Ia %	Ih %	Im %	Climate Type
Pendra	23.0	14.9	-8.1	C_1d (Dry sub humid with little or no water surplus)
Raipur	37.9	13.0	-24.9	C_1d (Dry sub humid with little or no water surplus)
Bilaspur	33.0	0.3	-32.7	C_1d(Dry sub humid with little or no water surplus)
Durg	39.6	10.5	-29.1	C_1d (Dry sub humid with little or no water surplus)
Raigarh	35.6	14.1	-21.5	C_1d (Dry sub humid with little or no water surplus)
Janjgirchampa	38.8	14.5	-24.3	C_1d (Dry sub humid with little or no water surplus)
Rajnandgaon	36.2	8.0	-28.2	C_1d (Dry sub humid with little or no water surplus)

The analysis of water surplus reveals that the average annual water surplus ranges between 3 mm to 229 mm. It is more than 200 mm all over the study area except in Durg (162 mm) Rajnandgaon (127 mm) and Bilaspur (3.8 mm). Except during south-west monsoon season, no other seasons experience water surplus conditions in the region. Spatial distribution indicates that the northern and south-eastern parts recorded higher amounts and central and western parts records lower quantities.

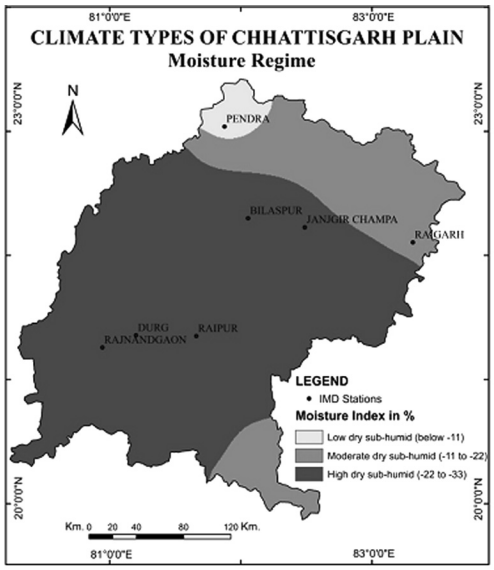

Fig. 3: Climatic Type of Chhattisgarh plain based on Moisture regime.

Classification of Climates of Chhattisgarh Plain

Index of moisture has been computed for all the stations to understand the moisture efficiency of the area by using indices namely aridity and humidity (Table 4). The analysis revealed that the moisture index of the plain ranges between -8.12 and -32.70 (Table 4). As per the general scheme of climatic classification, the study region is under the influence of dry sub humid climate ($C_{1)}$. However, the dry sub humidness is not uniform throughout the region. Bilaspur in the northwestern parts of the study area, experiences the drier side of dry sub humid climate with -32.7 percent which means it is almost inclined towards semi arid climate. However, the western (Rajnandgaon, Durg) and extreme northern (Pendra) parts are inclined more towards moist sub humid climate with -8 percent of Im. The sub classification based on seasonal variation of effective moisture (Table 2) indicates that this dry sub humid climate seasonally experiences little or no water surplus (d). Thus, according to moisture regime classification of Thornthwaite, this region can be categorized as Dry sub humid climate with little or no water surplus (C_1d) Fig. 3.

Conclusion

From the above study, it can be concluded that entire Chhattisgarh plain is under the influence of dry sub humid climate (C_1). However, nature of sub humid climate is not uniform throughout the region. The central and western parts with their lower moisture indices indicate the tendency of shifting towards semi arid climate in future if dryness increases. While the northern parts which experiences comparatively higher moisture effectiveness indicating inclination towards moist sub humid climates. Seasonal variation of moisture effectiveness indicates that that the entire study region experiencing with little or no water surplus (d) conditions. This type of study on climatic studies is helpful for proper agricultural planning and water resource management.

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