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**Hemant Kumar Bhuarya**
Department of Agrometeorology College of Agriculture. Indira Gandhi Krishi Vishwavidyalaya Raipur. Chhattisgarh, India

**R Singh**
Department of Agrometeorology College of Agriculture. Indira Gandhi Krishi Vishwavidyalaya Raipur. Chhattisgarh, India

**Correspondence**
**Hemant Kumar Bhuarya**
Department of Agrometeorology College of Agriculture. Indira Gandhi Krishi Vishwavidyalaya Raipur. Chhattisgarh, India

# Environmental characterization for sustainable crop production in Chhattisgarh Agroclimatic zones: A review

**Hemant Kumar Bhuarya and R Singh**

**Abstract**
A method for assessing and implementing sustainable crop production is needed to give practical relevance to the frequently used term "sustainable agriculture” Agro-climatic zones can be defined as a land unit having a greater degree of commonality or homogeneity with respect to various conditions and resources such as climatic parameters important for agriculture and cropping pattern etc. Food and agriculture Organization (FAO) of United Nations and International Institute of Applied System Analysis (IIASA) have developed a methodology for characterization of Agroclimati condition Agro-ecological zones. This method provides a wide range of different activities. Which are often related yet quite different in scope and objectives like characterization relevant to agriculture production. identifying crop specific limitations. Quantification of land productivity and population supporting capacity of land and multi criteria optimization. Agro-ecological zoning is one of the most important bases for agricultural developmental planning because the survival and failure of particular land use of farming system in a given region heavily realizes on careful assessment of agro-climatic resources.

**Keywords:** environmental, agro-climatic zones, FAO and sustainable

## Introduction

The Chhattisgarh came into existence on 1st November 2000 as a result of bifurcation of Madhya Pradesh state. Chhattisgarh is located in the central part of India between the latitudes of 17° 46’N - 24° 5’ N and the longitudes of 80° 15’ E - 84° 20’ E. Its proximate position with the Tropic of Cancer has a major influence on its climate. It is landlocked by the states of Maharashtra and Madhya Pradesh on the west. Uttar Pradesh on the north. Jharkhand on the north-east. Orissa on the east. and Andhra Pradesh on the south Sprawled in an area of 135. 194 sq km.

The climate of the state is dry sub humid type. The average rainfall of the state is around 1400 mm of which more than 90% is received during the south west monsoon (June-September). The onset of monsoon is around 10 June in southernmost tip of Bastar district and extends over the entire area by 25 June. The monsoon starts withdrawing from mid September and by 25th September it withdraws from the entire state. Chhattisgarh is divided into three distinct Agro – climatic zones *viz*. Chhattisgarh plains. Bastar plateau and Northern hills and it covers 50.52%. 28.62% and 20.86% geographic area. respectively. Similarly. topographically also the state varies a lot from high elevated areas of the state makes it to differ in their climatic elements also. There is a wide variability in climatic factors also on an average a total of 1200 – 1600 mm. annual rainfall is recorded in different parts of Chhattisgarh in about 64-91 rainy days. (About 90% of rainfall in C.G. concentrated to four monsoon months i.e. June – September.) It has been recorded that 1000-1200mm. 1200-1400mm and 1400-1600mm. annual rainfall are received in Chhattisgarh plains. Bastar plateau and northern hills respectively. Similarly variations can be seen in temperature and humidity.

In view of these studies on environmental characterization for sustainable crop production in Chhattisgarh is carried out mainly to capture the important agricultural features of the districts and to analyze the long term rainfall records in order to understand the pattern of rainfall and its spatial and temporal variability. In this study. Attempts are also made to examine the climate fluctuations and shifts in different districts to understand the pattern on climate variability that May influence the existing cropping pattern in the districts. Based on the historical data of crop productivity of major important crops like Rice. Wheat and Maize.

The relationship between rainfall quantum and productivity were also worked out.

## Review of Literature

### 1. Agroclimatic Characterization

Virmani *et al.* (1978) [42]. studied the climatological features of semi arid tropics (SAT). According to them these areas have unique set of climatic features. It was pointed out that such areas suitable for any crop which does not requires low temperature. in its life cycle. but lack of moisture is the key limiting factor to be addressed to stabilize and improve agriculture. Chakraborti *et al.* (1990) [10] conducted an agroclimatic study in Hoogly district of west Bengal by analyzing rainfall data for a period of 65 years (1920-85). A water balance approach was found quite effective to assess the water availability period for crop planning under rainfed condition. Oldmen (1990) [29] observed characterization of the agoclimatic environments involves two types of inventories. The first contains as long term historical records of climatic elements. The second set contains the elements which vary during the trial periods also compare the actual weather variables.

Sastri (1990) [34] focused on agroclimatic features of Madhya Pradesh. The study aimed of working out the three water availability periods in the 12 agroclimatic regions of the state. Baghel and Sastri (1992) studied Chhattisgarh which falls in the ACRP regional classifications of plateus and hills. The monsoon sets in around 10$^{th}$ June in the southernmost tip of the Bastar district. monsoon withdraw from different areas of the state between 15$^{th}$ and 25$^{th}$ September. In sub-humid climates the seasonal rainfall is too high to grow dry lands crops and insufficient to grow rice crop. Mohan *et al*. (1994) delineated AEZS and concluded that Arabic zones with decreasing level of potential for agricultural development. constitutes 85% of the chitwan district of Nepal. Seven different agro-ecological zones were delineated. Zone I. identified as the most potential zone for crop production with possibility of three crops a year occupies 21% of the arable area; while zone II. identified as the second important zone with potentials for two crops a year. covers 32% of the arable area Sastri *et al.* (1999) [35] studied environmental characterization for developing strategies to improve productivity. an agroclimatic inventory is a pre requisite. In eastern India. and northern India rice is grown mostly under rainfed conditions in upland. lowland and flood. Prone ecosystem. As this region comes under the influence of the southwest monsoon from June to October. crop productivity depends entirely upon the vagaries of monsoon activity. the sky is mOctly overcast and radiation becomes a limiting factor.

Jahagir (2004) [20] studied environmental characterization for improvement of rainfed rice productivity of Chhattisgarh. Studies on stable rainfall periods revealed that the duration of stable rainfall period varies from 74-101 days in different district of Chhattisgarh favourable rice growing enviroments indicates that Dantewada and Jagdalpur. In the entire state have largest duration of wet periods (<110 days) and major portion of the state lies in below 100 days. Agro-ecological zoning and GIS applications in Asia with special emphasis on land degradation assessment in dry lands (LADA). Messrs *et al.* (2005). They concluded that the AEZ methodology is well implemented in some countries in Asia. Owing to economic development. Increasing pressure on natural resources and related environmental degradation have become important problems constraining development in all the countries of the region. Bhelawe (2007) [7] studied the agro-climatic and agro-ecological characterization of Chhattisgarh to characterize the agro-climatic and agro-ecological parameters. The characterization was based on screening of distinct agro-ecological and agro-climatic parameter and preparation of data base for the zones of Chhattisgarh Goswami (2008) [18, 19] studied long term monthly and annual averages of mean temperature regressed against corresponding elevation data. Different agro-climatic indices were worked out using climatic parameters the values refer to the agroclimatic indices which express the relationship between climate and agricultural production in quantitative terms. The information to characterize the climate.

Sastri *et al.* (2009) studied in the northern hills agro-climatic zone in Chhattisgarh state (India) when the soils are undulating with 15 percent at the top to 0 percent slope in the valley areas. Analysis of field hydrological conditions in different soils in the topo-sequence revealed that in the top (sandy) soils agroforestry is better option while in the valley areas. In the clay tram soils rice is the best suited crop. Local climate analysis indicated that it varies from near arid type climate at the top of the topo-sequence to near moist sub-humid conditions in the valley areas. Rao *et al.* (2011) [32] studied agro-climatic analysis of the APRLP nucleus watersheds in three target districts has been carried out on the basis of agromet data. During the s outhwest monsoon season. more than 1000 mm rainfall was received at Nemmikal and Appayapally. While it was as low as 143 mm at Nandavaram. More than 85 % of the annual rainy days occur during five month periods. June to October. Assured rainfed crop growing season is about 165 to 175 days for the *ventisols* areas and about 130 to 150 days for the *ahfisols* areas.

### 2. Geographical Information System

Agrawal (1993) [1] classified whole India in five ISO yield wheat zones using crop simulation models (CSM) and GIS. He further divided each ISO yield zones in two sub-zones on the basis of rainfed wheat yield less than 50% of potential yield and rainfed yields greater than or equal to 50% of potential yield. Pascal and Damario (1997) [30] prepared agroclimatic maps for sunflower growing areas in Argentina by analyzing data for 79 observatories for a period of 30 years (1961-90). Temperature analysis and water balance computations were done particularly at critical period of sowing. flowering and harvest. They found that the increase in summer rainfall since 1997 had led to expansion of sunflower area with increased yield. Patel *et al.* (2000) [31] found that Agro-ecological zoning (AEZ) through remote sensing in an alternative to delineate areas having similar Agroclimatic and Agro-adaphic condition for better assigning crop yield potentialities. This AEZ concept includes representation of land in layers of spatial information and their combination using geographical information system (GIS). AGIS based model for Agro-ecological zoning was developed and optional land use was suggested for a watershed in Uttarakhand. India measuring 50 thousand hectares area. Ten Agro-ecological zones and 23 Agroecological sub zones and their production potential were identified. This zoning revealed that 27% and 14% of the study area could be allocated for irrigated double cropping and sole cropping respectively.

Dalli *et al*. (2002) studied application of GIS for Agroclimatological charectarization of northern Algeria to definedurum wheat production areas. A Geographical Information System on natural resources for northern Algeria was developed in order to: (1) charaterise the area of interest according to agro-climatic criteria and define potentially suitable areas for durum wheat cultivation; (2) provide research institutions and decision makers with a new tool for sustainable management of natural resources. Patel (2002) reported Agro-ecological zoning (AEZ) is one of the most important approaches for agricultural developmental planning because survival and failure of particular land use or farming system in a given region heavily relies on careful assessment of Agro-climatic resources. Thavone *et al.* (2003) observed the crop production in haos is affected by adverse weather conditions. They developed gridded surfaces (maps) for the mean monthly minimum and maximum temperature for the whole country using GIS also completed maps of monthly and weekly rainfall. These climate analyses provide a useful guideline for determining the crop growing period. annual rainfall varies greatly and variations in soil characterstics and toposequences position cause large spatial variation in water availability. Land use and land cover mapping of the simiyu catchment (Tanzania) using remote sersing techniques carried out by Revertabula and Florimond (2005) [33] and concluded that remote sensing. Idris-32 release 2 image processing software GIS and extensive detailed ground information are essential to map land use and land cover of the simiyu catchment. Land use and land cover is extremely valuable especially for water quantity and water quality predictors. and assessing the hydrological effects of land use changes. Satellite images data acquisition. digital image involved to map the land use of the simiyu catchment.

Ayansina *et al.* (2009) studied GIS approach in assessing seasonal rainfall variability in Guinea Savanna part of Nigeria. This study aimed at using Geographical Information Systems (GIS) to examine and map the spatiotemporal variation in Guinea Savanna of Nigeria. Rainfall data. for the periods between 1970 and 2000. were collected from the archives of the Nigerian Meteorological services. in this study; rainfall is considered as the primary and input for crop yield. Therefore. it was found out that rainfall varies both in time and space. These anomalies are detrimental to crop germination and yieid. resulting in little or no harvest at the end of the season. Chaudhari *et al*. (2010) studied spatial wheat yield prediction using crop simulation model. GIS. remote sersing and ground observed data for crop growth monitoring and yield forecasting which can provide periodical crop growth assessment with spatial information.

### 3. Rainfall Analysis

Virmani studied (1987) [42] the most variable element of the semiarid tropical climate is rainfall. Three types of rainfall variabilities are encountered: random year- to – year and within- year rainfall variability; variability due to a diminishing trend of annual and seasonal rainfall; and variability due to oscillating rainfall. characterized by a series of wet years followed by a number of dry years. Weerasinghe (1989) [43] Observed daily rainfall of the Mapalana meteorological station for 35 consecutive years were analysed for the Markov chain Probilities for weekly rainfall and the rainfall availability of the location is assessed in relation to rice agronomy for both yala and maha seasons.it was reveled that the rainfall probability of >10mm at 75% probability level. Patel *et al.* (1991) used water balance technique to delineate the climatiealy homogenous regions of semi arid climatic conditions. Maps were prepared with 8 different types of indices to represent the zonal climatic pattern of India. In the study the rainfall probability for major crops were estimated.

Sastri and Singh (1999) [35] studied to make an inventory to rainfall moisture availability and stable rainfall periods and observed that the weekly average rainfall lies in between 30-40 probability levels. This indicates that any planning regarding rainfed rice based on average weekly rainfall can be successful only ones in three years. Chaudhary and Tomar (1999). determined the rainfall pattern over 12 stations of Bastar district in Chhattisgarh region of Madhya Pradesh by analyzing 40 years of rainfall data (1957-86) and relationship between rainfall and rice yields were worked out. Weekly mears rainfall of 50 mm for lowland and 75 mm for upland with coefficient of variation of <100 percent were considered as stable rainfall period. Singh *et al.* (2008) observed daily rainfall data of fifty two years (1952-2004) have been analyzed for establishing the long term averages of weekly. monthly. seasonal and annual rainfall and its variability. The annual rainfall at pusa was 1222.3 mm and coefficient of variability indicated that rainfall was more or less stable over the years. The Penman- Monteith (P-M) equation with its new definition of reference crop evapotranspiration (ET0) is recommended by FAO as the standard method of crop water requirement calculation. and also to compare with other methods. The ET0 component of the CROPWAT model. which is based on the P-M equation. was examined for sensitivity to errors in input data under the environment of a semi- humid sub- tropic region of Bangladesh. The results showed that the ET0 estimates are most sensitive to maximum temperature and least sensitive to minimum temperature.

Maheshwara Babu and Sahoo (2009) observed daily rainfall data obtained from the rain gauge station. sulur were analyzed for fitting one day maximum rainfall. average. weekly. monthly and seasonal rainfall data. using different distributions like normal. log-normal. gumble and log pearson III to determine the best fit distribution Variation of seasonal rainfall and probabilities of occurrence of assured weekly rainfall provide useful information for efficient agricultural management Singh *et al*. (2009). In the present study. seven stations of Himachal Pradesh have been selected for the analysis of the rainfall data. In general. the station Dalhousie received the higher rainfall during both the growing and dormant seasons along with annual rainfall. Probability percentage of receiving 10 mm. 20 mm. 50 mm and 75 mm rainfall have been computed for standard weeks during growing and dormant seasons at four stations Katrain. Bajaura. Mashobra and Nauni (Solan).

### 4. Sustainability of crops

Stanhill (1976) reported the trends and deviations in English wheat yields for more than 750 yr. He found the best fit was a parabolic equation relating the log of yield to year. Combined analysis of variance is commonly used to identify the existence of genotypic environment interaction showed how to estimate the different interaction variance components. Where predictable environmental variations exits Francis *et al.* (1978). Rao and Vijayalaxmi (1986) worked out rainfall yield relation in rainfed sorghum at different location *viz.* Hyderabad. Jhansi. Udaipur and Akola studies revealed delayed seeding reduce the yield of sorghum. The crucial periods for rainfall were 8-10. 6-12. 3-6. 11-13. weeks for Hyderabad. Jhansi. Udaipur and Akola respectively. McCloud (1987) observed Rice yields from 1885 to 1949 did not increase appreciably. The slope was 0.0095 t/ha. $r = 0.08$ and the technology index was 0.5% The environmental index for

1885 to 1949 was an extremely high 32.6%. indicating very large year- to -year variability in yields and showing that rice was not well adapted to Hokkaido. Fluctuating rainfall patterns combined with soils of low moisture- holding capacity often lead to periodic drought. Effective soil moisture management. crop and variety selection. minimum tillage. organic matter preservation. and integrated pest management offer hope for sustainable yields.

Pendleton *et al*. (1987). Kasei and Afuakawa (1991) [21] results indicated that the growing season varied between 126 to 200 days. The best planting time for maize was found to be during the last two weeks of May in order to meet moisture requirements during flowering and growing period lengths. Sastri *et al.* (1999) [35] studied the rice ecosystem of Chhattisgarh. They divided the region into 4 different rice growing environments. The onset of monsoon plays an important role in rainfall quantum and water availability periods. They reported that the productivity of rice gets reduces in case of late onset while early onset year shows no increase in productivity. Gupta *et al.* (2000) [16] analysed the rainfall data for the period of 1971 to 1996. The total of rainfall for monsoon months showed higher degree of variability with 80% CV. Apturkar (2002) [4] studied on climate fluctuations in different stations of Bilaspur district revealed that in a few stations the climate shifted from dry sub-humid to semi-arid conditions. It was observed that rice productivity has no relation with rainfall quantum in different years but groundnut has a negative correlation. Interestingly soyabean yields have a positive correlation with rainfall quantum. The commercial ZP maize hybrids differ by both yield and stability parameters. According to mean values over locations the highest yield was recorded in Becej ’97 (13.222 t·ha-1). Then Zemun Polje with irrigation ‘97 (12.982 t·ha-1) and Zemun Polje dry land farming ’97 (12.244 t·ha-1) The lowest yield was detected in the location Žarkovac ‘00 Babic *et al*. (2006) [5]. Goswami *et al.* (2008) [18, 19] analysed the long term rainfall data for Sali rice season of Jaintia hills district. Meghalaya to estimate expected weekly rainfall at various probability levels. Based on expected rainfall at 50 and 70 % probability levels and water requirement. Malik *et al.* (2009) analysed varience for pod yield of groundnut genotypes reveale significant interaction between genotypes and locations. Indicating that the genotype effect is not the same at 10 locations. In the study. The regression coefficient ranged from 0.588 to 1.321. Two genotypes ICGV – 93163 had slope around unity. where as BARD – 479 (check).

**5. Zonation of Geographical area**

Murthy and Pandey (1978) first time attempted to classify India in 8 Agro-ecological regions based on physiography. Climate. Soils. and agricultural regions. The approach depict a good beginning of agro-ecological zoning in the country. But it suffers from several limitation due to over generalization. such as grouping together the areas having different physiography. Temperatures and soils in zone. Williams and Masteriton (1980) reported that the choice of an approach to climatic classification is dictated by the ultimate objectives. Variation in the responses among different kinds of plants are rarely dealt with in general classification systems. Subramanian (1983) based on the data of 160 meteorological stations in the country and using the concept of moisture adequacy index. delineated 29 agro-ecological zones with the possible 36 combinations of IMA anddominated soil groups as per FAO/UNESCO soil map. Muralimohana Rao (1990) prepared agroclimatic chart of Bijapur (Karnataka) on the basis of weekly potential evapotransipiration (PET) and weekly moisture availability periods and possible cropping systems for shallow medium and deep soil. Sehgal *et al.* (1992) [36] delineated geographical area of India in 20 Agro-ecological zone on the basis of physiography. climate. length of growing period (LPG) and soils for macro-level land use planning and effective transfer agrotechnology. The region is were nomenclature as western Himalaya. Central Himalaya. Eastern Himalaya. North east hills. Western Ghats. Eastern Ghats and Tamil Nadu upland. central high land. Eastern pleateau. Deccan plateau. Kanchchh and Kathiawar. Western plain. Eastern plain. Gujrat plain. Bengal and Assamplains. Western central plain. Eastern Islands and Western Islands. Catalano *et al*. (1994) [9] carried out a study to identify homogenous agro-climatic zones of land along the Adriatic coast in Italy. Definition of land zones was based on potential water deficit (combined with a mean temperature of the coldest month). Fourteen homogenous agro-climatic zones were identified (each of 5100km2) Sivakumar and Valentine (1997) [38] studied agroecological zones (AEZ) and the assessment of crop production potential. The AEZ approach presents a useful preliminary evaluation of this potential. and ensures that representation is maintained at an appropriate biogeographic scale for regional sustainable development planning. Mathur (1998) [25] studied land use planning in context of Agro-climatic sub region. The tropical. Sub-tropical and temperate climate prevalent in different parts of India enables cultivation throughout the year and offer tremendous oppurtunities in this relation. While sustaintial progress has been achived in conventing cultivable wastelands. Fallows etc. into arable land. The issue at the forefront of land for agricultural purpose is to better utilize the available land. To support adequately nearly 16% of the worlds population residing in India

Gajbhiye and Mandal (2000) [17] reported that India has heterogeneous land forms and variety of climatic conditions. These varying environmental situations in the country have resulted in a greater variety of soils. Depending upon the soil. bioclimatic type and physiographic situations. The country has been grouped into 20 agro-eco regions (AER) and 60 agro-ego sub regions (AESR). Each agro-eco sub region has further been classified into agro-eco unit at district level for developing long term land use strategies. Mendoza *et al*. (2003) evaluated the land use/land cover mapping in Brazilion Amazon ueing neural network with Advanced Spaceborn Termal Emission and Reflection Radiometer (ASTER/TERRA) data. Goswami (2008) [18, 19] worked out different agroclimatic indices were worked out using climatic parameters. The values refer to the agroclimatic indices which express the relationship between the climate and agricultural production in quantitative terms. The work can be extended to characterize climatic zones of other north eastern states.

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