SUMMARY AND CONCLUSION

The present study is an attempt to analyze the “Impact of Climatic Change on Agriculture in Chhattisgarh Plain”. The main purposes of this study are –

8. To study the spatial distribution of water balance elements namely potential evapotranspiration, actual evapotranspiration, water deficit and water surplus.
9. To classify the climate in Chhattisgarh plain.
10. To study the rainfall and temperature trends over Chhattisgarh plain.
11. To analyze the spatial and temporal variability in annual and seasonal rainfall.
12. To identify the climatic shifts, drought incidences and agro climatic regions.
13. To analyze the existing cropping pattern of Chhattisgarh plain.
14. To analyze the impact of climate change on crop production, yield and cropped area.

For this present study, climatic data, monthly rainfall, monthly minimum and maximum temperatures for seven meteorological stations, existing in Chhattisgarh plain have been obtained from the records of India Meteorological Department for a period of 1986-2015. Statistical analysis of rainfall and temperature data has been carried out to identify the trends in the annual and seasonal distribution. The water balance elements are derived using the rainfall and temperature data, which in turn enabled to understand and assess the climate types, climatic shifts, moisture availability status, drought frequency, intensities, as well as the demarcation of drought prone areas, crop suitability and agro climatic regions. Agricultural statistics regarding crop production, yields, and cropped area of major crops, irrigation, and other infrastructures have been obtained from the district hand books, directorate of Economics and Statistics, Chhattisgarh. To analyze the different aspects of agriculture following methods have been used. Such as Agricultural Intensity has been measured by using Jashbir Shing’s formula as:

\[ \text{Cropping Intensity} = \left( \frac{\text{Gross cropped area}}{\text{Net Sown Area}} \right) \times 100 \]

To delineate the crop combination regions in the study area Weaver’s method (1954) has been applied. To measure the crop diversification Gibbs and Martin’s (1962) formula has been used. To delineate the crop concentration region, Bhatia’s formula has been followed here. The spatial distribution of
productivity of major crops is computed by applying Enyedi’s crop productivity method. Intensity of irrigation has been extracted as the percentage ratio of net irrigated area to the net sown area. Correlation has been work out to analyze the relation between climatic elements and agriculture. Maps have been prepared by using Arc GIS software.

The thesis comprises seven chapters.

**Geographical Setting of Chhattisgarh Plain**

In first chapter physical and socio-cultural settings of the study region has been discussed. The Chhattisgarh Plain extends over the large central portion of the state. Geographical extension of their plain is between 80° 23’ 55.7” E to 83° 47’ 50.22” E longitude and 19° 47’ 14.70” N to 23° 6’ 58.63” N latitude. Chhattisgarh Plain consists 16 districts (Kanken includes only 3 tehsils) covering an area of 72184.16Sq. Km. Physiography of the Chhattisgarh plain is an ideal example of a geographical unit. The plain is surrounded by Maikal scrap in the west, Raigarh hills in the north-east, upland of Odisha in the east, Chotanagpur plateau in the north and Bastar Plateau in the south. The Chhattisgarh plain is almost a homogeneous region of gentle slope with an average slope of less than 10°. Broadly, the region can be divided into Chhattisgarh Plain and Rimland. The most important geological formation of this region is Cuddapah system or Purana rocks. Mahanadi and its major tributaries (Hasdo, Mand, Seonath, Pairi etc.) drained over Chhattisgarh Plain. Climate of this region is Dry sub humid type, characterized by hot and dry summers and moderately cool winters. The total forest covered area in Chhattisgarh plain is 7218416 hectares, occupying only 12% of its total geographical area. Major types of soil found in this region are-Deep clay soil with limestone (Kanker), Yellow sandy loam soils (Matasi) and a mixture of the above two having a medium structure (Dorsa). According to 2011 census, the total population of the plain is 18904873, which accounts about 74% of total population of Chhattisgarh and population density of the Plain is 262. The population Growth rate of the plain is 23.27%. (2011), it has increased by 5.72% than its previous decade (2001). According to 2011 census, the sex ratio of the whole Chhattisgarh plain is 989, whereas the rural sex ratio of the plain is 1001. Chhattisgarh plain has 1205208 literate people, including 6868640 male and 5183867 female literate people. The average literacy rate of the region is 63.75%. The male literacy rate depicts 72.26% and female 55.15%. In Chhattisgarh plain, total number of working population is 87, 88,754 that accounts 46.49% of its total population. Major portion of population is involved in agricultural sectors.
Analysis of Climates in Chhattisgarh Plain

The second chapter deals with the analysis of water balance elements and climatic classification of Chhattisgarh plain region. Broadly the study is divided into three sections. In the first section, monthly water balance analysis of each individual representative station (IMD) has been discussed through the water balance technique of Thornthwaite and Mather (1955). From the basic water balance elements such as Potential evapotranspiration (PE) and Precipitation (P), the other parameters namely actual evapotranspiration (AE), water deficit (WD) and water surplus (WS) have been computed which in turn enabled to derive some other components such as Aridity Index (AE), Humidity Index (Ih) and Moisture Index (Im). Monthly distributions of water balance elements are graphically presented. The study indicated that all the stations of the study region experience a good quantity of rainfall ranges from 934.3 mm to 1281.1 mm, till it is not sufficient to fulfill the water need of the atmosphere. Due to the uneven distribution of potential evapotranspiration and precipitation, the atmospheric demand not sufficiently met. Chhattisgarh Plain experiences significant thermal potential throughout the year. All the stations are experiencing water deficit as well as water surplus also. Water surplus conditions occur during rainy season while except some months in rainy season all the months experience water deficit conditions. Acute water deficit prevails during April and May months. The water surplus is a seasonal phenomenon as this condition is mainly confined only to the month of south-west monsoon season (June-September).

The second section deals with the nature and distribution of water balance elements over the study region. Maps showing the spatial distribution patterns of these parameters on annual and seasonal basis are prepared by using Geographical Information System (GIS). The study indicates that thermal efficiencies of the region range between 1394.81 mm to 1615.64 mm. The spatial distribution shows that the thermal efficiencies are relatively lower in the north-western part and gradually increased towards the south-western, southern and south eastern parts (Fig. 2.2A). The stations namely Raipur, Durg, Raigarh, Janjgir Champa and Rajnandgaon are experiencing high thermal efficiencies (more than 1550 mm.). While the stations namely Pendra and Bilaspur are experiencing 1394.81mm and 1433.80 mm thermal efficiency respectively. Seasonal analysis depicts that thermal potential is higher during south-west monsoon season and lower during cold weather season. The annual actual evapotranspiration of the study region ranges from 937.76 mm to 1074.26 mm and the spatial distribution of actual evapotranspiration indicate that central and western parts are experiencing low concentration while there is an
increasing trend towards north, south-west and south-east parts of the region. From the analysis of water deficit it is revealed that the region experiences 320.62 mm to 615.65 mm of water deficit annually. The acute water deficit condition prevails in the eastern and southern parts while northern and western parts experience low magnitude of water deficit. The distribution of annual average water surplus of the study region ranges from 3.73 mm to 229.69 mm.

A comparative analysis of water balance conditions has been done between the present and with the temperature increase. The analysis exposed that the intensities of all the water balance elements namely potential evapotranspiration (PE), water surplus (WS) and water deficit (WD) have been changed throughout the Chhattisgarh Plain with the predictive increase of 2°C and 6°C temperature respectively (Fig.2.8 and Fig.2.9). Potential evapotranspiration ranges from 1394.81 mm to 1615.64 mm at present temperature condition but it has increased up to 1576.97 mm to 1790 and 1846.57 mm to 2120.86 mm with 2°C and 6°C temperatures rise respectively. It is found that with the temperature increasing condition all the station experience high water deficit condition and less quantities of water surplus. There will be a complete absence of water surplus condition in Bilaspur and Rajnandgaon with 6°C temperatures rise.

Third section deals with climatic classification of the region based on thermal and moisture regime. The study revealed that the entire region experiences Megathermal type of climate (A’) and divided into three sub types climate, namely A’₂, A’₃ and A’₄ within Mega thermal climate. Northern Pendra, indicated Megathermal A’₂ (with thermal efficiencies ranging between 1282-1425 mm) and Bilaspur, Durg experiences Megathermal A’₃ climate. While rests of the parts of the Chhattisgarh plain experiences A’₄ climate with comparatively more thermal potential. Based on the moisture regime, all the stations namely Pendra, Raipur, Bilaspur, Durg, Raigarh, Janjgir Champa and Rajnandgaon are come under Dry sub humid climate (C1; Im= -33.3 to 0). The analysis also exposed that with the temperature increase by 2°C and 6°C there will be a significant change in the existing thermal regime and moisture regime climates of Chhattisgarh Plain. With 6°C temperature the whole region will experience semi-arid type of climate. The analysis of this chapter helps to fulfill the objective e.g. to study the spatial distribution of water balance elements namely potential evapotranspiration, actual evapotranspiration, water deficit and water surplus and to classify the climate in Chhattisgarh plain.
Assessment of Climate Change in Chhattisgarh Plain

The third chapter assessed the climate change in Chhattisgarh Plain. The study is divided into four sections. In the first section, trend analysis of temperature and rainfall has been done. Trend analysis of mean annual temperatures at Chhattisgarh Plain, depicted a long term significant positive trend. At the beginning of the study period the temperature was 25.81° C and at the end of the study period it was 26.83° C, which indicates a positive difference of about 1.2° C in last 30 years. At all the stations, April or May is considered as the hottest month and the temperatures range from 32.7° C to 35.08° C. December and January months experienced more coldness in all the decades. During these months the temperature ranges from 13.23° C to 21.5° C. At regional level, the Chhattisgarh plain experienced continue increasing temperature from first decade (1986-1995) up to last decade (2006-2015). Even the temperature of coldest and hottest month’s are also showing an increasing trend from one decade to another. Time trend analysis of annual, south-west and post monsoon rainfall indicates a positive trend over the region, though the rainfall trend varied specially. Raipur, Bilaspur, Durg and Janjgir champa indicate a positive trend in annual rainfall while Pendra, Raigarh and Rajnandgaon indicate a negative trend in annual rainfall distribution.

The second section analyzed the climatic shifts in Chhattisgarh Plain. The study revealed that Janjgir Champa has more stability with 26.7 % of shifting tendency while Durg indicates very unstable nature of climate with 50% of shifting followed by Raipur (46.7%) and Bilaspur (43%). That means the central part of the region is more vulnerable to climatic shifts or variability. To gain a clear concept of climatic variability the spread map of percentage variability has been prepared in GIS, which indicates that the fluctuations of climate are more in the western part and considerable central part of the region. The low variability of climate is observed in the eastern part, north western and considerable central part experiences moderate fluctuation ranges from 35-45%.

Third section deals with the drought analysis in terms of intensities, frequency, categorization and demarcation of drought proneness areas. The study revealed that as a whole, the Chhattisgarh Plain experienced 35 moderate droughts, 32 large type of drought, 30 severe nature of drought, and 8 disastrous nature of droughts during the study period (1986-2015). Generally, the Chhattisgarh plain is prone to all intensities of droughts though disastrous droughts were very less frequent than large and severe nature of droughts. Raipur and Pendra are not
experienced any disastrous droughts but they are more frequented by severe nature of droughts. Remaining parts are experienced disastrous droughts as a very rare phenomenon. North eastern and central parts of the study region experienced more droughts of low intensity. As a whole the area has 50% drought proneness.

The fourth section deals with the analysis of moisture potentiality status and the delineation of agro-climatic region in the study area. Using the monthly ratio of actual evapotranspiration (AE) by potential evapotranspiration, water potential calendar has been made. Four categories of water potential period namely humid, wet, moderate dry and large dry have been identified over the region. The study indicates that as a whole Chhattisgarh Plain experiences 5-8 humid phase, 2-5 wet phase, one moderate dry phase and 1-3 large dry phase. It is observed from the analysis that all the stations except Bilaspur, experienced humid phase during south-west monsoon season (June- September). During kharif season, the region gets abundant moisture supply and experience humid phase. But during Ravi season, water potentiality status fluctuates spatially. In the first four months of Ravi season (October to January), the whole region experience the combination of humid and wet phase, while in last two months, central parts experience the complete dryness. So that high water demand crops can be grown efficiently during Kharif season but during Ravi season, low water requirement crops like wheat, pulses, and millets may be grown without any aid of irrigation but for water demand crops strong and abundant source of irrigation is must. In Chhattisgarh Plain cereals crops can be cultivated throughout the year (even in the dry phase) with the proper irrigation facilities. Otherwise drought resistant crops can be grown successfully without any irrigational aids. The analysis of agro climatic regionalization at local and regional level revealed that overall the plain falls under the only one agro climatic zone, namely zone suitable to paddy but efficiently suitable to millets as all the moisture adequacy index (Ima) values are ranging between 60% - 80%. For other water demand crops cultivation the region needs strong irrigational facilities. With 2°C assumed temperature increase, four stations namely, Pendra, Bilaspur, Raigarh and Rajnandgaon are indicating suitability to paddy but efficiently suitable to millets (Fig.3.14B). Remaining stations are indicating suitability to millet crops only. Further, with 6 °C temperature increase, except Pendra the remaining stations are indicating suitability to millet crops only (Fig.3.14C).

This chapter fulfills the objectives e.g. to study the rainfall and temperature trends over Chhattisgarh plain, to analyze the spatial and temporal variability in annual and seasonal rainfall, to identify the climatic shifts, drought incidences and agro climatic regions. The
findings of this chapter also prove the hypotheses that temperature is increasing in Chhattisgarh plain and there are spatial variations in temperature and rainfall distribution over Chhattisgarh Plain.

**Agricultural scenario of Chhattisgarh Plain**

The fourth chapter deals with present agricultural scenario of Chhattisgarh Plain. This chapter divided into four broad sections. First section discussed the agricultural land use in the study region. The Chhattisgarh Plain is the most suitable cultivated region in the state. Agriculture of the region is mainly subsistence and traditional by nature. As a whole the region occupies 30, 98,339 hectare net sown area and about 902838.7 hectare double cropped area which are about 43% and 12.50% of it’s the total geographical area. Overall the plain constitutes 55.43% Gross Cropped Area (GCA) to its total geographical area. It is found that as a whole over the Chhattisgarh plain, the total cropped area/ Gross cropped area exceeds the net sown area. The Agriculture Intensity index or land use efficiency of the region varies from about 108 to 163 percent, showing a great regional disparity depending upon the spatial difference in the physical and non physical factors.

Rice is the First ranking and most dominated crop in all districts of the Chhattisgarh Plain, but along with this several crops are also significantly grown in this region. The major crops include Paddy/Rice, Wheat, gram, Teora, Urad, Tuar, Kodo-Kutki, Maize, Pea, Sugarcane and oilseeds. As a whole the rice production of Chhattisgarh Plain is 5583726.7 MT which is 86.87 percent to the total principal crop production of the region. Gram and teora are the second and third ranking crop in respect of production, accounting 4.24% and 3.26% to its total principal crop production. Productivity is largely influenced by the climate, soil type and physiography of the region. It is found that the districts having good irrigation intensity are good in crop productivity.

The irrigation intensity over the plain has been largely determined by the terrain types, crop raised and availability of water resources. Overall the Chhattisgarh plain has about 44% irrigation intensity with 13, 61,439 hectares net irrigated area. The study at local level depicts that the highest irrigation intensity is observed in Raipur district (86%), and lowest irrigation intensity is found in Korba district with 8456.67 hectares net irrigated land, accounting only 6.46% of its net area sown. Canal, tube wells, wells and ponds are the main sources of irrigation in the plain. 951816 hectares area irrigated through canals, which occupied about 58% of its
total irrigated area. Electricity plays an important role in irrigation and other farm activities. Among the total electricity consumption 18.23% electricity is consumed for irrigation purpose over the region. Bemetara and Kabirdham districts record a satisfactory consumption of electricity in irrigation purpose, accounting 67.97% and 67.78% of their total electricity consumption.

Farmers of this region basically belong to backward and poor classes, they believed in the traditional way of agriculture still with the span of time they are using some importance tools and equipments such as plough, carts, tractors, pump, cane crushers, along with fertilizers, HYV seeds and pesticides to improve the agriculture. Overall in Chhattisgarh plain 362938.9 tons nitrogen, 186740.5 tons phosphate and 54754.35 tons potash are used in 2860550, 2864260 and 2625747 hectares agricultural land. As a whole 581174.9 quintal HYV seeds and 792051.1 quintal pesticides are used over 194, 04,04 hectares and 1814077 hectares land in Chhattisgarh plain. This chapter fulfills the objectives e.g. to analyze the existing cropping pattern of Chhattisgarh plain.

**Impact of Climatic Change on Agriculture**

Fifth chapter analyzed the impact of climate change on Chhattisgarh Plain. This chapter deals with four sections. First section deals with impact of climate change on agricultural area. Net sown area and total cropped area of a region are largely determined by water availability. In Chhattisgarh plain maximum agricultural areas are rain fed because of the limited irrigation facilities.

For assessing the impact of rainfall on net sown area, correlation co-efficient has been work out between net sown area and inter annual rainfall variations and it is found that there is negative correlation between the net sown area and annual rainfall and there is no long term impact of south-west monsoon rainfall on net sown area. The net sown area has decreased by about 3 lakh hectares in last 30 years. This is mainly because of increasing settlement, urbanization and industrialization. Agricultural lands are mainly occupied by human settlement industries and other type of land use.

The impact of rainfall variability on crops area also examined and it is found that there is no such correlation between the total cropped area of rice, wheat, maize, kodo – kutki, gram and tuor. That means there is no long term impact of rainfall on cropped area of these crops, though
it is evident that when the rainfall dropped down much, the cropped areas are also affected. Specially, high water requirement crops are largely influenced by water availability. During drought periods rice cropped areas are affected much as rice is a high water requirement crop. Moderate droughts could not affect cropped area much, but the impact of large, severe and disastrous droughts on the cropped hectareage are observed clearly.

In the second section, impacts of rainfall and temperature variability on crop production have also been assessed, but no such correlation has been found between rainfall, temperature variations and crop production. Only tuor and kodokuki production have shown a relation with respect to rainfall and temperature variations. Both the crop’s production has reduced with increasing rainfall and temperature. The extreme events especially droughts have an influence on crop production. High intensity drought affected the crop production.

The third section analyzed the impact of climatic variability (temperature, rainfall) and extreme events on crop productivity. Correlation coefficient between inter – annual temperature and crop productivity has been worked out. It is evident that there is positive correlation between the productivity of rice, wheat, maize, gram and annual average temperature while the productivity of tuor has decreased with increasing temperature; slight decreasing trend is also observed in Kodo – kutki productivity. The correlation between the long term rainfall and crop productivity depicted that except tuor crop, the entire crop’s productivity has been increased though the year to year fluctuation in crop productivity is because of rainfall variability is observed. The effect of climate change on the productivity of rice, wheat, maize, gram and kodo-kutki is not visible. The increasing trend in crop productivity is due to the technological and infrastructural development during last 30 years. When the crop productivity and drought years are correlated it is found that during disastrous drought period (2009) except gram, yield of all other crops have dropped down. As a whole there is no such impact of climate change on agriculture has been found. Crop production and productivity are influenced by so many other factors.

In the study region, the crop production and productivity appeared to be more influenced by moisture regime than thermal regime. The rainfall during monsoon and post monsoon seasons is very important for kharif and Rabi crops in the region. Time series data on the occurrence of rainfall during monsoon shows significant inconsistency in the quantum of rainfall received. The deficiency of rainfall has numerous social, economic and environmental implications. Both scenarios adversely affect the life and economy. Government should take initiative to cope with
this problem. This chapter fulfills the objective e.g. to analyze the impact of climate change on crop production, yield and cropped area. Findings of this chapter also prove the hypothesis e.g. Cropping pattern and crop productivity are influenced by climatic change in Chhattisgarh plain.

**Climate Change: Socio Economic Aspects**

Sixth chapter deals with the climate change and its socio-economic impacts. This chapter discussed food security, health impact, water resources, poverty and climate change impact on labour migration and displacement. This present chapter is totally based on the secondary data sources. Data on food security, fresh water availability, poverty rate, migration, diseases and health status are obtained from statistical abstract of Chhattisgarh, Directorate of economic and statistics newspaper, journals and related websites.

Climate is not just an environmental issue but also a social issue. It is scientifically proved that global climate is changing in a way that has major implications for human life. Entire world population is at risk of the impact of climate change with different level of severity. With the physical elements climate change also affect the socio-economic aspects. The developing country suffered most by changing climate. The normal climate of Chhattisgarh plain is Dry sub humid but there is a trend to shift the climate towards semi-arid type which may have a great impact on the social and economic as well as environmental structures of the region. Temperature in the region is in increasing trend that would lead to more evaporation, drought incidences, heat waves etc. As a result, food production, health, fresh water scarcity, labour displacement would be happened. In many places of Chhattisgarh plain, people belong to poor classes and they don’t have adequate food and water supply. Because of uncomfortable weather condition and extreme temperature people of this region frequently suffer from heat stroke, dengue, malaria, skin disease etc. During the lean season people of this region become job less as agriculture is mainly confined to rainy season, and they prefer to move to another place for livelihood. Thus, climatic variability has an impact on socio-economic aspects of the people of Chhattisgarh plain region.

**Agricultural Adaptation Strategies to Climate Change Impacts in Chhattisgarh Plain**

In the last chapter, agricultural adaptation strategies to climate change have been discussed. Several strategies have been chosen to cope with the climatic variability, such as-Planting of
drought resistant varieties of crops, Crop diversification, Changes in cropping pattern and calendar of planting, Mixed cropping, Improved irrigation efficiency and innovation adaptation, Adopting soil conservation measures that conserve soil moisture, Planting of trees and agro forestry, Labour migration, Income diversification and Government response measure. These strategies would help the local people and farmers of the region to cope with the future climate change and its affects.

After the computation of water balance and analysis of long term data of mean annual and monthly temperature, monthly and annual rainfall and crop data from 1986-2015, it is concluded that rainfall is in insignificantly increasing trend over the region at significance level 1% and temperature indicating a significant positive trend over Chhattisgarh plain at significance level 1%. All the stations namely Pendra, Raipur, Bilaspur, Durg, Raigarh, Janjgir Champa and Rajnandgaon are come under Dry sub humid climate though the western part and considerable central part of the region are more vulnerable to climatic shifts or variability. The low variability of climate is observed in the eastern part. The plain is really vulnerable to drought with 50% drought proneness. The analysis of agro climatic regionalization at local and regional level revealed that overall the plain fall under the only one agro climatic zone, namely zone suitable to paddy but efficiently suitable to millets as all the Ima values are ranging between 60% - 80%. The region needs strong irrigational facilities for the other water demand crops cultivation.

In case of major crops, inter annual variability in production and yield is the often attributed to changes in weather condition from year to year. Therefore, there is a need for developing cropping strategies and management practices in accordance with the variability in seasonal and annual rainfall and other parameters. There is a wide scope of improvement in crop productivity and production by enhancing the infrastructures and technologies in field practices.

**Suggestions for future research Work**

Looking into the result of the present study, the following suggestions are given for the future work:

1. Future projections of temperature and rainfall changes need to be assessed at regional level.
2. Long term temperature data need to be analyzed to assess the temperature changes.
3. Empirical study on socio-economic issues concerning the impact of climate change on agriculture.