ASSESSMENT OF DESERTIFICATION IN RAJASTHAN

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CERTIFICATE

This is to certify that the dissertation entitled ***"ASSESSMENT OF DESERTIFICATION IN RAJASTHAN"*** submitted in partial fulfilment for the degree of **MASTER OF PHILOSOPHY** is my bonafide work and may be placed before the examiners for evaluation. This Dissertation has not been submitted for any other degree of this University or any other University.

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TO

MY PARENTS

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Introduction to the Study

1.1 INTRODUCTION: - Desertification is the degradation of the land in arid, semi-arid and sub-humid dry areas caused by climatic changes and human activities. It is accompanied by a reduction in the natural potential of the land and depletion in surface and ground-water resources. But above all it has negative repercussions on the living conditions and the economic development of people. Desertification not only occurs in natural deserts, but can also take place on land which is prone to desertification processes.

The vulnerability of land to desertification is mainly due to the climate, the relief, the state of the soil and the natural vegetation, and the ways in which these two resources are used. Climate affects soil erosion and the chemical and biological deterioration of the soil. The state of the soil (texture, structure and chemical and biological properties) is a major factor, particularly in the sub-humid zones where the influence of climatic factors is less marked. It plays an essential role in causing vulnerability to desertification caused by human activities.

Even though the cycles of drought years and climatic changes can contribute to the advance of desertification, it is mainly caused by changes in the ways man uses the natural resources, mainly by over-grazing, land clearance, over-cropping cultivated land and wood formations and more generally using land in a way that is inappropriate for the local conditions. Human activities connected with agriculture, livestock and forestry production vary widely from one country and from one type of society to another, as do the strategies for land-use and the technologies employed.

Following United Nations Conference on Desertification (UNCOD), a number of studies purported to show that changes were occurring in dry land environments which indicated that desertification was an increasing phenomenon. In many cases overgrazing has been seen as a major cause of desert expansion with over cultivation (Ibrahim, 1984), including irrigated cultivation systems (Joshi and Agnihotri, 1984) and the domestic use of vegetation, especially for fuel as other major causes. As well as views being expressed about physically expanding deserts the United Nations has produced figures for the annual amounts of productive land lost through desertification. United Nations Environment Programme (UNEP 1987) quoted an annual figure of 27 million hectares lost. This was emotively called 'the time bomb of desertification'. It was noted that in a little less than 200 years at the current rate of desertification there will not be a single, fully productive hectare of land on earth' (UNEP, 1987). Little details of the basis of such figures have been given.

Definitions of Desertification:-

Desertification has been viewed from different angles by different scholars. According to Odingo (1990) the term desertification originated at a conference by Aubriville in 1949. It was referred to areas with an annual rainfall ranging from 700 to 1500 mm/year. The term desert has never been precisely defined. In popular thinking, it generally means a region where vegetation is scarce or absent because of deficient precipitation or aridity but may also mean "wasteland" and areas of low production of vegetation not considering of the reason.

Desertification, as defined by United Nations Environment Programme (UNEP) in 1992 and adopted by United Nations Convention to Combat Desertification (UNCCD), is 'land degradation in arid, semiarid and dry sub humid areas resulting from various factors, including climatic variations and human activities'.

Desertification as defined by Food And Agricultural Organization (FAO) and UNEP(1982) is "A comprehensive expression of economic and social processes as well as those natural or induced ones which destroy the equilibrium of soil, vegetation, air and water in the areas subject to climatic aridity. Continued deterioration leads to a decrease of the biological potential of the land, deterioration of living conditions and an increase of desert landscapes."

It is evident from the above definitions that desertification is the process caused mainly by climatic and anthropogenic factors.

Based on the above definitions it is evident that desertification may result because of either of the climatic or anthropogenic factors. The short term fluctuations in temperature and precipitation are not taken in account in the long term desertification process. The climate induced desertification is mainly caused by long term changes in climate. It includes slow long term changes in length of season, changes in temperature and precipitation pattern of an area etc.

Desertification monitoring:-

Whether at global, national or local scales, an important component of identifying the onset and impacts of desertification as well as measuring the effectiveness of anti desertification measures is effective monitoring. Monitoring depends not only on having an agreed and realistic definition, but also on having a reproducible monitoring system. At the global scale, various estimates have been produced for the extent of desertification but only in 1990 was the first scientifically systematic desertification assessment programme, Global Assessment of Human Induced Soil Degradation (GLASOD), established.

Desertification Monitoring has further dimensions, at a range of scales. Studies utilizing satellite imagery have played important roles in distinguishing the ephemeral impacts of drought on dryland vegetation systems from the longer-term impacts of desertification. As remote sensing techniques are developed, their capacity to contribute to monitoring the complexities of environmental and ecosystem components of desertification at a higher spatial resolution in comparison of conventional observation systems may increase. It is, however, important that studies based on imagery are supported by work in the field that allows the type of vegetation re-growth after disturbance to be identified.

Monitoring is also a potentially important component of identifying the detailed operation of systems in relation to degradation processes. Desertification processes may onset slowly, and recognizing the early indicators of system change may prove to be a valuable approach to dealing with the issue not only in rangelands but in other system types, for example irrigated lands.

Knowing the severity and extent of the land degradation helps the policy makers, resource managers as well as local communities and nomads in taking decisions for effective control of the land degradation (Gisladottir and Stocking, 2005).

1.2 NEED OF STUDY:-

India occupies only 2.4% of the world's geographical area, yet supports about 16.7% of the world's human population; it has only 0.5% of the world's grazing land but supports 18% of the world's cattle population. Thus there is tremendous pressure on India's land-based natural resources. India is endowed with a variety of soils, climate, biodiversity and ecological regions.

About 50.8 million hectare land area (15.8% of the country's geographical area) is arid, 123.4 million hectare (37.6%) is semi-arid and 54.1 million hectare (16.5%) area falls in the dry sub humid region. All put together, about 228 million hectare area, i.e. 69% of the geographical area of the country is dry land (arid, semiarid and dry sub humid).

As per the Desertification and Land Degradation Atlas of India published by the Space Application Centre in 2007, about 32.07 % of the land is undergoing various forms of degradation and 25% of the geographical area is affected by desertification. About 69% of the country's lands are dry lands and degradation of these lands has severe implications for the livelihood and food security of millions.

Desertification has become a major worldwide environmental problem. In India arid zone covers about 12% area of the country. The Thar Desert of Rajasthan is located partly in India and partly in Pakistan. About 85% of the desert lies in India and the rest lies in Pakistan. About 91% of the desert i.e. 2.08 million square kilometers falls in Rajasthan which covers about 61% of the geographical area of the state (Sinha et al., 2000). Bordering the desert on four sides are Indus Plains to the west, Aravali range to the south east, Rann of Kutch to the south and Punjab plains to the east and north east. Also known as "The Great Indian Desert", Thar covers an area of 200,000 square kilometers. Desertification is one of the major slow hazards found in north western part of the country especially in Rajasthan State.

The encroachment of Thar Desert towards its eastern border has become a serious problem to the districts like Churu, Jhunjhunu, Nagaur and Sikar. A large number of population and animals of this region are at risk due to shifting of sand dunes, dust storms, land degradation and as a consequence decreasing agricultural productivity.

1.3 STUDY AREA:-

The study area comprises four most vulnerable districts to desertification namely Churu, Jhunjhunu, Nagaur and Sikar. Keeping study area in consideration, a very large part of land surface is covered by sand although at some places rocks and hillocks may also be seen. Generally, the region remains pasted with problems of drought and famine due to scanty and variable rainfall. As a result of constant flow of strong high speed gust of wind, huge deposits of sands are noticed all over the desert region which keeps shifting from one place to another furthering the process of desertification. The topography of Churu, Jhunjhunu, Nagaur and Sikar districts is characterized by an undulating sandy terrain traversed by longitudinal sand dunes. There is only one seasonal river Kantli and that is also lost in the sandy terrain, when it enters into Churu district. Thus this area is of inland drainage or of no rivers. Here sand dunes are of Barchan type (transverse).In some places calcareous substratum is exposed. Nagaur uplands are sterile and sandy. In fact, study region lies on the eastern edges of Marusthali.

Churu is a district of enchanting topography in Thar Desert. Churu is located at 28° 19' N longitude and 75° 01' E latitude. The Churu City is encircled by large shifting sand dunes. The area is scanty in vegetation. Phoge and Kair bushes and Khejra, Royara and Babul trees are to be mainly found on the sand dunes. In the towns Neem and Peepal and Siras trees can also be noticed. One can find Sand dunes all over the area with a couple of small limestone hills. The region boasts record temperatures ranging from below freezing point in the winters to over 50 degrees in the summer afternoons. One may be surprised to notice ice in small water pots or frozen water dews on the little vegetation before dawn in the months of December/ January. Yet one may find that summer nights are cooler and winter days are warmer. The variation in the minimum and maximum temperature is perhaps greatest for any place in the world. Perhaps it is the only place in the world where temperature dips below sub-zero but does not have snowfall.

Jhunjhunu is located between 28°08'N 75°24'E and 28°13'N 75°40'E.It has an average elevation of 323 metres (1059 feet). Jhunjhunu primarily lies in the semi-arid Rajasthan. Scattered Aravali hills constitute major portion of the city and nearby towns like Khetri, Udaipurwati, Sakambhari etc. Climate is harsh and subjected to frequent drought and sandstorms. Sand dunes are common phenomena in this district.

Nagaur is located between 27°12'N 73°44'E and 27°20'N 73°73'E. It has an average elevation of 302 metres (990 feet). It is situated amidst seven districts namely Bikaner, Churu, Sikar, Jaipur, Ajmer, Pali and Jodhpur. Nagaur is the fifth largest district in Rajasthan with a vast terrain spreading over 17,718 km². Its geographical spread is a good combine of plain, hills, sand mounds and it is a part of the great Indian Thar desert. Nagaur has a dry climate with a hot summer. Sand storms are common in summer. The climate of the district is conspicuous by extreme dryness, large variations of temperature & highly variable rainfall. The mercury keeps on rising intensely from March till June. These are the hottest months. The district of Nagaur is poor in forest resources.

Sikar is located between 27°37'N 75°09'E and 27°62'N 75°15'E.It has an average elevation of 427 metres (1400 feet). Churu is located at 28°18'N 74°57'E28 and 30°N 74°95'E. It has an average elevation of 292 m (958 ft).Physiography of Sikar is composed of dissected uplands of Aravali.

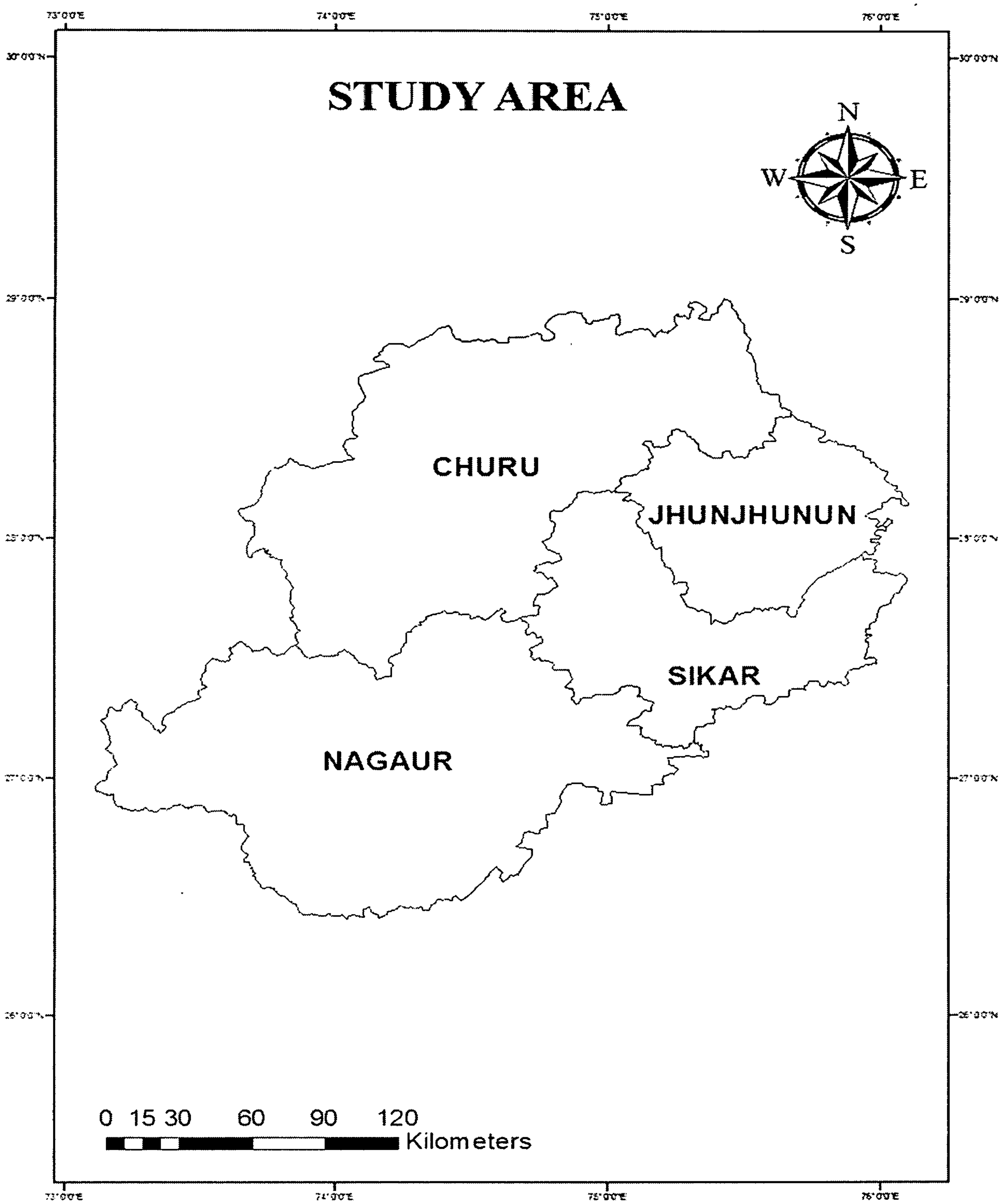


Figure 1.1: Study Area

Wind erosion leading to shifting of sand dunes is the dominant factor fuelling the desertification process in Thar. Recent studies on desertification process carried out by Central Arid Zone Research Institute (CAZRI), Jodhpur shows that 4.35 percent area of Western Rajasthan has already been affected by the process of desertification and another 76 percent area is moderately vulnerable to desertification. There are several climatic and anthropogenic causes for expansion of desert in Rajasthan which includes high temperature (sometimes up to 48°C) during summer season, wind erosion, scarcity of monsoonal rainfall, overgrazing, over cultivation in some parts of the state etc. Despite of several attempts by the government, the lack of well planned management and actual information on climate and human induced desertification has resulted in failure of the government's efforts for controlling desertification.

It is true that climate induced desertification is inevitable and difficult to prevent. But, it is possible to reduce the human induced desertification. Appropriate action plan for arresting land degradation and desertification requires thorough information about the areas where desertification process is driven by anthropogenic factors. This study attempts to investigate the areas where human induced desertification is more prevalent. Nowadays, Remote Sensing (RS) and Geographic Information System (GIS) is the most successful approach for detecting and monitoring the long term changes of the desertification process. The same has been used in this study.

1.4 GEOLOGY:-

The state of Rajasthan can be broadly divided into three natural regions: Aeolian sands, Alluvium and Aravalis. The Aeolian deposits belong to Pleistocene and recent times. And the dune free areas of Barmer, Bikaner and Jaisalmer contain exposed marine deposits of Jurassic and Eocene periods, showing an anomaly in the nature of rock deposits of the region. Besides, the Vindhyan system crops out around Jodhpur, whereas the alluvium, covering a part of the eastern plain, south-eastern plain and flood plain, belongs to the recent and sub-recent periods. The ravines flanking the river Chambal and its tributaries are of recent origin. The entire rock system of the state belongs to Palaeozoic, Proterozoic and Archaen era. The Aravali system is largely composed of argillaceous deposits, metamorphosed to mica schists, which crop out around Alwar, Udaipur, Ajmer and their surroundings. The Deccan trap covers south-eastern part of the state forming Malwa plateau.

1.4.1 REGIONAL GEOLOGY:- The desert region has scanty rocky outcrops, which generally provide data for conception of geological formations. The interpretative geology of desert region has been drawn by Geological Survey of India by gradually pooling the data from the dug wells, logs of bore holes drilled by various agencies like ONGC, UNDP, central Ground Water Board and Rajasthan Ground Water Department. The western desert is considered as a shelf together with the Indus plain in Pakistan, bounded on the east by Aravali range, on the west by Indus geo syncline and dissected by the basement ridges on the south and Delhi- Lahore ridge on the north. The interference drawn from a number of bore holes and drilling data is that entire is covered by a blanket of windblown sand with older alluvium underneath. Examination of litho logos of exploratory holes reveals that the surface soil is normally sandy with varying amounts of clay; at places clay and kankar are also observed at surface. Shale/clay, hard compact friable carbonate nodules and lime coated gravel with clay are present at varying depth having poor infiltration rate and behaving as impervious barrier.

Examination of the bore hole data shows that most of the desert area has the alluvial cover of more than 20 m and can be a potential source of ground water depending upon the aquifers characteristics and the quality of recharged water. Along the course of buried drainage channels and younger alluvial plain the formation comprises shallow aquifers where depth of water table varies from 10 m to 20 m and quality of water is good but this area is very limited. Among the deep aquifers, the most potential aquifers have developed under limestone and sandstone strata due to well defined joints, fractures and cavities.

1.4.2 GROUD WATER:- The Thar Desert can be divided into 6 zones on the basis of common geological and hydro-geological condition, hydraulic characteristics, ground water potential and drainage of the subsurface. The zones are arranged in order of the geological age and stratigraphic position of the rock formation as under:

Zone	Geological Formation	% of CCA (approx)
1.	Quaternary formation	47.0
2.	Tertiary formation	47.0
3.	Lathi formation	1.5
4.	Jaisalmer formation	1.3
5.	Marwar super group	
	(a) Nagaur group	1.9
	(b) Bilara group	0.3
	(c) Jodhpur group	nil
	(d) Bap boulder beds	negligible
6.	Parihar formation	1.0

1. Quaternary Formation: - Quaternary formation consists of a superficial layer of Aeolian (wind blown) deposits followed by fluvial deposits. It occurs in 50 to 100 km wide belts along the international border. Its thickness ranges from a featheredge to over 200 m increasing towards the international border. The deposits comprises moistly fine to medium grained, well sorted , loose to poorly cemented, rounded to sub rounded sand, silt and clay.

Although the thickness of saturated zone exceeds 150 m near Khara in eastern part and close to the international border the thickness of useable aquifers is limited to a thin lens of a few meters at the top. The formation of Jaisalmer and Barmer districts contains water that is highly mineralized.

2. Tertiary Formation: - The tertiary rock extend from Sam in the south west to Bikaner in north east in an arc type belt. They underlined a thin veneer of blown sand and alluvium. In Bikaner district the tertiary formation is represented by Palana series comprising essentially sandstone and shale and clays with subordinate limestone, fuller's earth and lignite.

Ground water in this formation occurs under the water table, in confined and unconfined conditions. It occurs in the pore spaces, joints and fissures. The thickness of unconfined aquifers in Palana range from 10 m to 80 m, increasing northwards. The main water table lies at depths ranging from 75 m to 100 m in the western part of Jaisalmer district.

3. Lathi Formation: - The quality of ground water varies widely in this formation. It is best in central part of Lathi basin. The ground water becomes more mineralized in the direction of flow, deteriorating rapidly close to its contact with younger formation. The comparatively better quality of ground water in perched zones indicates that the materials in vadose zone are well leached.

4. Jaisalmer Formation: - Quality of ground water is generally poor in Jaisalmer formation. Water of comparatively better quality occurs in isolated pockets and in perched aquifers.

5. Marwar Formation: - The quality of ground water in phreatic aquifers zone tapped by dug wells in mostly brackish to saline in greater part of area occupied by Nagaur group

6. Parihar Formation: - The water on evaporation leaves saline residue in the bed of Rann which are leached into ground water. Thus the ground water is not only saline in these formations but also in the sandstone aquifers in the Parihars, which are on the down gradient side.

1.5: OBJECTIVES:-

The main objective of the study is mapping and monitoring of climatic and human induced desertification processes in study area by long term satellite and meteorological data under the following headings:-

1. To detect human induced land degradation using long term period LANDSAT TM/ETM+ satellite data for selected districts.
2. To analyze changes in agricultural or cultivable area, production and yield in Kharif & Rabi seasons during 1956 to 2008 in the study area.
3. To analyze the temporal variations in temperature and rainfall in the study area with available data using simple and moving average methods.
4. Recording seasonal variations by dividing the meteorological data in IMD guide lined four seasons of the country as Winter (January-February), Pre-Monsoon (March-May) Summer, Monsoon (June-September) and Post-Monsoon (October-December) .
5. Trend analysis of temperature and rainfall by using Linear Regression Method and graphical representation (best fit trend line method).
6. Measurement of seasonal variation in climatic extremes i.e. highest maximum and lowest minimum temperature and highest rainfall along with variation in number of rainy days.

1.6: DATA-BASE

The data used in the study are obtained from the following sources

1. Multi temporal Remote Sensing data of the study area obtained from LANDSAT (MSS, TM, ETM+) for classification.
2. LAND USE LAND COVER PROJECT REPORT MANUAL, National Remote Sensing Centre.
3. RAJASTHAN AGRICULTURE STATISTICS AT A GLANCE (1956 TO 2008), Commissionerate of Agriculture, Rajasthan, Jaipur
4. District Census Hand Book.

5. In this study mainly instrumental data like temperature (in ^{0}C) and rainfall (in mm) are used. The sources of data are follows;

- **National Data Centre (NDC), IMD, Pune** provided monthly data for
  (1) Mean Maximum Temperature (MMAX),
  (2) Highest Maximum Temperature (HMAX),
  (3) Mean Minimum Temperature (MMIN),
  (4) Lowest Minimum Temperature (LMIN),
  (5) Total Monthly Rainfall (TMRF),
  (6) Heaviest Rainfall in 24 Hours (HVYRF),
  (7) No. of Rainy Days (RD)
  (8) Average temperature (MMT), calculated by taking average of the mean monthly maximum and mean monthly minimum temperature.
- **Data Gaps:** Meteorological data provided by NDC, Pune for four meteorological stations were not regular. The data series were having small gaps. For the analysis, these gaps have to be filled up. So temporal interpolation method was used for the filling the data gaps. In case of Nagaur, NDC Pune provided data up to 1998 only. So data from India Water Portal were used for the period of 1998-2009 (temperature) and 1998-2004 (rainfall) for Nagaur in Simple Average Analysis and Analysis of Spatial Variation of Climatic Indicators. The same procedure was followed for filling the data gap (1991-1996) in case of Churu.
- **IMD Classification of the Seasons in India:** Indian Meteorological Department has divided the year in four seasons. These are;

Table 1.1: IMD Classification of Seasons in India

Season	Months
Winter	January-Fabruary
Pre-Monsoon	March-May
Monsoon	June-September
Post-Monsoon	October-December

1.7: METHODOLOGY:-

- Remote sensing techniques have been used for change detection in land use and land cover in the study area. Change detection has been analyzed with the help of GIS to measure how the attributes of a particular class have changed between two or more time periods. The temporal changes in the study area were shown by using the satellite images for the years of 1989, 2000 and 2010. ERDAS & ARC-GIS softwares were used for processing and classification of data obtained from the satellite imagery.
- Secondary data of Agricultural area, production and yield in four districts of Churu, Jhunjhunu, Nagaur and Sikar were used to assess desertification. These data were analyzed with the help of line diagrams.
- **Temporal Interpolation**

Temporal interpolation method was used for filling the missing data in the series. Monthly value was computed as an average of the same month for a period between ± 3 years (Mitchell et al. 1966).

- **The Moving Average**

The moving average method is widely applied to study trends in temperature and rainfall data of a long period of time. This method smoothed out fluctuations in the curves that can be plotted on either a three, a five or ten year bases (**Monkhouse and Milkenson**). In the study, moving average was calculated for every five years.

- **Normalized Accumulated Departure from Mean (NADM)**

The normalized accumulated departure from mean (NADM) is a suitable method to analyze the temporal fluctuations and trends in temperature and rainfall. NADM permits visual as well as statistical comparison of unlike data periods characterized by above average (below average) conditions are indicated by positive (negative) slopes of the graph. The NADM permits the distinction between periods of high and low values by clearly defining the limits.

NADM = (X-Xm)/ largest number in X-Xm series

Where, X = Rainfall/temperature data series

Xm = Mean of rainfall/temperature data series

- **The Simple Average**

Simple average method facilitate the comparison of two climatic or base line periods and identify the variation occurred in the second period over the first one. The calculated simple average of climatic data (divided into 25 years base line period) suggests about the seasonal and temporal variation in rainfall and temperature.

- **Simple Linear Regression analysis**

The simple linear regression method was used for the trend analysis and for visual representation of climatic element the best-fit trend line (linear trend line) was used. Both the techniques were applied with the help of Microsoft Excel workbook to determine the nature of trends i.e. whether positive or negative. The b-values were calculated while putting the time series data (years) as the independent variable and climatic data (temperature, rainfall etc.) as the dependent variable. The b-value in a simple linear regression model represents the slope of the regression line which explicitly indicates trend in the dependent data series. The equation for the slope of the regression line is:

$$b = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sum(x-\bar{x})^2}$$

Where, x and y are independent and dependent (in Y on X regression line i.e., y = a + bx) variables respectively.

- **F-test statistical logistics**

The results of trend analysis were scrutinized with the help of F-test. The confidence levels derived with the help of F-test, determines whether a trend is a significant or insignificant. F-test was applied with the help of SPSS computer application.

- **Line Graphical Representation**

The seasonal-spatial variation analysis using Moving Average, NADM and simple average method provided many important results which were visualized using line graphs which depicts long term trend in rainfall and temperature regimes.

- **Coefficient of Variation**

Coefficient of variation is one of the best statistical methods to calculate the spatial variability and it also provides data to analyze variability of two or more stations. The high value of CV implies high inconsistency or low consistency in time series data while a low value of CV indicates high consistency in data records.

1.8: LITERATURE REVIEW

Desertification, the aggravation or extension of such conditions, is a human phenomenon that arises from society's search for secure livelihoods in dry environments (Hare F. Kenneth, Kates Robert W., Warren Andrew 1997). Even where this search is successful some environmental deterioration is inevitable. These desertification processes, unlike the one- to five-year period's characteristic of drought, are long-term, chronic, and pervasive; yet, these same long-term processes are intimately affected by short-term climatic variability and by changes in human social systems at varying scales. Climates of the desert margin are characteristically variable, especially as regards rainfall. The record shows clearly that the desert margin shifted appreciably during the Holocene (the past 10,000 years), and that some of these shifts must have been due to natural variations in rain-fall. Nomadic herdsmen made extensive use of savannas in regions that are now. Recent advances of the desert edge, or spotty deteriorations of semi-arid and sub-humid ecosystems, have generally involved the interaction of such natural, temporary phases of desiccation with human and animal population dynamics or the extension of rain-fed cultivation. If grass and shrubs are over-grazed to the point of extinction, the soil becomes naked and subject to ready wind or sheet erosion. It also becomes hotter and more reflective to solar radiation.

"Degradation of Arid Rangelands in Thar Desert provides an account of Land degradation by overgrazing. Land Degradation has recently been exacerbated in rangelands of arid Rajasthan by heavy grazing pressures. The total livestock population in the arid region of Rajasthan has reached 29.25 million in the year 2001 from 10.34 million in the year 1951. In terms of adult cattle units (ACU) the livestock pressure was 9.58 million in 1983, which increased to 11.27 million in 2001. Local grazing pressures are surpassing he recommended stocking rates of the rangelands at an enormous pace (Tewari V. P. & Arya Ranjana 2005). The carrying capacities of the rangelands were estimated several decades ago, however, qualitative evidence is available regarding changes in soil and vegetation patterns. There is need to evolve practices for improving the long-term productivity and sustainability of rangeland ecosystems.

Traditional Percept abilities of Environment and Desertification: A Case Study (T.K.Ghosh) confined its study to Luni Panchayat Samiti (a Community Development Block in the district of Jodhpur) located in the arid zone of Rajasthan and is spread over an area of about two thousand sq kms. The major occupation of the people in the region is cultivation, and with the increase in the working force overcrowding on agricultural land has been increasing particularly as the region lacks a diversified economic base. Livestock pressure on the grazing lands is very high and the total forage production often falls short of requirements, thereby leading to an over-exploitation of grazing lands. The data clearly reveal that the disproportionate pressure of livestock population since 1957 inevitably must have caused excessive exploitation of an already shrinking grassland that would activate desertification processes in this area. Additionally, socio-religious feelings and deeply in grained attitudes towards animal life often override prudence, and rituals connected to these values add to the deterioration of already meagre available resources. The increasing demand for fuel wood has led to excessive use of the vegetation resource. The increase in population has inflated the wood demand for different purposes: (1) meeting the fuel requirement; (2) the top-feed of livestock; (3) thorn fencing; and (4) construction of thatched huts. Author surveys indicated that 85 percent of households in the area felt a shortage in meeting their fuel requirements.

V. P. TEWARI and RANJANA ARYA's study primarily provides an account of Land degradation by overgrazing. Land Degradation has recently been exacerbated in rangelands of arid Rajasthan by heavy grazing pressures. The total livestock population in the arid region of Rajasthan has reached 29.25 million in the year 2001 from 10.34 million in the year 1951. In terms of adult cattle units (ACU) the livestock pressure was 9.58 million in 1983, which increased to 11.27 million in 2001. Local grazing pressures are surpassing the recommended stocking rates of the rangelands at an enormous pace.

Trevor Birkenholtz (2000) used an actor–network (ANT) and materialist approach to examine the changing relations among nature, society, and technology in dynamic groundwater-irrigated landscapes. Drawing on a case study from Rajasthan, India, it merges these frameworks to advance our understanding of the role that tube well irrigation technologies play, through their associations with other objects, in altering existing social power relationships, environmental practices, and socio ecologies, paying attention to the directedness of these relationships. Irrigated Landscapes, Produced Scarcity, and Adaptive Social Institutions in Rajasthan demonstrate, first, that tube well adoption is made possible through the creation of tube well partnerships, a new social institution. Second, although tube well adoption initially enhances production, significant groundwater withdrawal negatively alters groundwater and soil chemistry. This undermines farmers' abilities to grow high yielding seed varieties, prompting a return to traditional crops, and exacerbates existing social inequalities both within and between partnerships. Third, irrigation practices and daily production activities follow from the demands and constraints of the tube well, enabling and constraining human and nonhuman action. The adoption of the technology, therefore, sets in motion a recursive process of technological adaptation, social institution formation, and ecological change. Although this is presently leading to socio ecological differentiation, the results suggest that these social institutions formed around the tube well are very durable. The conclusion offers suggestions for encouraging them toward more equitable outcomes.

Rakecha P. & Dhar D.N (2005) analyzed annual aridity indices values obtained from water balance considerations for a group of 9 representative observations for Andhra Pradesh by standard statistical methods in order to find out trends if any. Soil moisture is critical determinant of aridity index. Traditional methods of farming and range management practices in the Republic of Kalmykia (Russian Federation) had been disregarded and undervalued for many decades as regional economic growth privileged modern technology as a means of increasing productivity. Aridity index is dependent on rainfall. So it is sensitive to rainfall variability. There is also recognition that the problems are not simply technical, in that they involve the adjustment of technology to human as well as to physical set-tings, and comprise not only questions of education but also of motivation at national, community, and individual levels. Here the paths of the social scientist and the technologist meet. Author has finally suggested that Andhra Pradesh is vulnerable to expansion of desert on account of having poor rain harvesting technique and continuously increasing overgrazing and deforestation.

According to Aldakheel Yousef Y. (2011) sustainability of irrigated agriculture in arid and semi arid lands depends, mainly on the level of soil salinity and the quality of irrigation water. Remotely sensed data can provide information about the extent of vegetated irrigated areas. NDVI Spatial Pattern related to Irrigation and Soil Salinity Management in Al-Hassa Oasis, Saudi Arabia was investigated using the extent of soil salinity and the quality of irrigation water and the relationship with vegetation growth, employing NDVI derived from Landsat imagery..

In the high-cost systems of dry land use in developed countries the relative advantage of extensive; cheap land must offset lower yields, higher transport costs, the risk of drought, and a vulnerable dependence on the sale of specialized products outside the region. Population pressure on resources and generally low living standards are not unexpected under this view. In the developing countries with substantial dry-land settlement, a common indicator of the limited capacity of the dry lands to support their existing populations under present conditions is the out-migration of workers and the importance of subsidy from their remittances. This is accepted in several of the studies of desertification as a fact of life, i.e., a supplement that must be maintained and humanized (Mabbutt J. A. 1997).

Report on Combating Desertification with the help of traditional knowledge and modern technology for the sustainable management of dry land ecosystems show that the United Nations Convention to Combat Desertification (UNCCD) recognizes the role of 'traditional knowledge' in Article 18 of the Convention stating that such technology should be ensured, encouraged and facilitated when attempting to combat desertification. There is much valuable information to be learnt from the traditional lifestyles of the Kalmyk people and other rural communities the world over, which have evolved over centuries and have thus carved both the natural and cultural landscape. This traditional knowledge can form the basis of site- and context-specific solutions in combating desertification in the world's dry land areas.

.Assessing potential desertification environmental impact in life cycle assessment focuses on the development of a methodology for including the desertification environmental impact derived from land use in LCA studies. A set of variables to be measured in the life cycle inventory (LCI), their characterisation factors (CFs) and an impact assessment method for the life cycle impact assessment (LCIA) phase is suggested (Núñez Montserrat, Civit Bárbara & Pere Muñoz 2009). Discussion Using GIS, calculation of the CF for the aridity variable shows that 38% of the world area, in eight out of 15 existing eco regions, is at risk of desertification

Choubisa S.L. (2007) examined Fluoridated ground water and its toxic effects on domesticated animals residing in rural tribal areas of Rajasthan. Chronic exposure to fluoridated ground water creates a health problem not only in human beings, but also in domesticated animals in the form of fluorosis. The prevalence and severity of osteo-dental fluorosis in these animals was progressive with age. Different effects of fluoride toxicity in cattle and buffaloes are also discussed. The present investigation therefore was undertaken to determine the prevalence and severity of fluorosis in native breeds of animals at mean fluoride concentrations of 1.0 to 5.2 ppm in various drinking ground water sources.

The impact of global climatic change on agriculture has recently become a subject of increasing importance (Glantz 1988). Most studies, however, confine their inquiries to the biological and physical domains, concentrating mainly on representing the responses of crops to various changes in climate. Studies focusing on the socioeconomic aspects of global climatic change are sparse and have almost exclusively restricted their analyses to the impact of environmental modifications on agricultural production (e.g. Parry 1978, Lamb 1985, Post 1985, Parry et al. 1989, Scott et al. 1990, Chmielewski 1992).

Micro-level studies of the impact of climatic variability on people's livelihoods at the farm level and their consequent responses are relatively few, although Glantz (1994) has had some success in linking macro change with micro effects by researching institutional mechanisms that respond to environmental perturbations. In light of the uncertainties involved in diachronically modelling climatic events, as well as the general paucity of long-term climatic data in developing countries, it has been suggested that research on cultural adaptations and climate would yield useful insights (Crumley & Marquarat 1987, Gunn 1994, Orlove et. al. 2000). To this end, individual farmers' understandings and perceptions of climate assume critical importance.

Paul Sillitoe's (1996) study demonstrates that even in a region with what can only be described as an undifferentiated weather regime; two distinct seasons are perceived that correspond closely to the meteorological data. Moreover, the perception of climate is structured by the distinct agro-ecological outcomes associated with different parameters of the two seasons. The study demonstrates that the perceptions of weather and weather fluctuations are tied closely to the material conditions being affected, but fails to provide a sense of the broader system of meaning and signification in which the perceptions are embedded.

Ingold and Kurttila's (2000) study of the perception of weather, in contrast, reveals an almost seamless relationship between the people and their environment. The local people and their environment—experienced through inhabiting particular places are bound in a mutually constitutive relationship through the simultaneous inscription of a set of meanings in the bodies of the inhabitants and the places they inhabit. Weather is experienced not through the prism of its impact on livelihoods alone, but is refracted through the human multi-sensory apparatus.

Gopal Krishan, S.P.S. Kushwaha, A. Velmurugan did a study on land degradation in the upper catchment of river Tons, a tributary of Yamuna river, in Uttarkashi district of the Uttarakhand state, was carried out using on-screen visual interpretation of IRS LISS-III + PAN merged data. The study area, which is largely mountainous, includes Govind

Wildlife Sanctuary and National Park. Vegetation cover, slope and erosion status were used as criteria for the delineation of four major land degradation categories *viz.*, undegraded, moderately degraded, degraded and severely degraded. The depletion of vegetation cover on mountainous terrain and subsequent cultivation without proper protection measures is the reason for severe soil erosion and land degradation. The present study in the upper catchment of river Tons using remote sensing and GIS revealed that the soils are shallow-to-medium deep and that the depth of the soil is a major constraint in sustaining natural vegetation as well as crops. Soil erosion, reduction in forest density, over-grazing, forest fires and inadequate conservation measures are the main causes of land degradation.

Mayank Kumar examined the multiple dimensions associated with the management of the meagre water available in the region. The one section of the article highlights various systems of water management developed and maintained at the local and individual levels alongside state initiatives on a larger scale for irrigation and potable purposes. Pre-colonial polities of Rajasthan were flexible in extracting revenue from a highly erratic, monsoon-dependent agricultural society.

Julia C. Allen and Douglas F. Barnest have gone for three recent estimates of the rate of deforestation in developing countries between 1968 and 1978 are compared using rank order correlation. Two of the estimates, of closed forest and moist tropical forest, are in significant agreement but differ from a third estimate that includes open woodland and regenerating forest. Agreement is strong among all three sources for a restricted group of countries. A cross-national analysis confirms the most fre- quently cited causes of deforestation. Deforestation from 1968-78 in 39 countries in Africa, Latin America, and Asia is significantly related to the rate of population growth over the period and to wood fuels production and wood exports in 1968; it is indirectly related to agricultural expansion and not related to the growth of per capita GNP. Results indicate that in the short term, deforestation is due to population growth and agricultural expansion, aggravated over the long term by wood harvesting for fuel and export.

At the global level, many studies with the help of instrumental and proxy data sets and climate-modeling reconstruct the past climate with much more accuracy and acceptability. Crowley (2000) counted the major causes for global climate change over the past 1000 years. This study included Comparisons of observations with simulations from an energy balance climate model indicate that as much as 41 to 64 per cents of pre-anthropogenic (pre-1850) decadal-scale temperature variations was due to changes in solar irradiance and volcanism. The combination of a unique level of temperature increase in the late 20th century and improved constraints on the role of natural variability provides further evidence that the greenhouse effect has already established itself above the level of natural variability in the climate system. Global surface temperature analysis by Easterling, et al. (1997) suggests long-term trends for the maximum and minimum temperature. It is found that temperature increase is due, at least in part, to differential changes in daily maximum and minimum temperatures, resulting in a narrowing of the diurnal temperature range (DTR). The analysis, using station metadata and improved areal coverage for much of the Southern Hemisphere landmass, indicates that the DTR is continuing to decrease in most parts of the world, that urban effect on globally and hemispherically averaged time series are negligible, and that circulation variations in parts of the Northern Hemisphere appear to be related to the DTR. Atmospheric aerosol loading in the Southern Hemisphere is much less than that in the Northern Hemisphere, suggesting that there are likely a number of factors, such as increases in cloudiness, contributing to the decrease in DTR.

Study by Thompson at el. (2000) revealed that Tibet has been sensitive to fluctuations in the intensity of the South Asian Monsoon. Study incorporated the ice cores from Dasuopu, Tibet. Reductions in monsoonal intensity are recorded by dust and chloride concentrations. The deeper, older sections of the Dasuopu cores suggest many periods of drought in this region, but none have been of greater intensity than the greatest recorded drought, during 1790 to 1796 A.D. of the last millennium. The 20th century increase in anthropogenic activity in India and Nepal, upwind from this site, is recorded by a doubling of chloride concentrations and a fourfold increase in dust. Like other ice cores from the Tibetan Plateau, Dasuopu suggests a large-scale, plateau-wide 20th-century warming trend that appears to be amplified at higher elevations.

The work of Pal and Al-Tabbaa (2009) provided the pattern of long-term changes and variability of monthly extreme temperatures in India. This study investigated the long-term trends and variations of the monthly maximum and minimum temperatures and their effects on seasonal fluctuations in various climatological regions in India. The results showed that the monthly maximum temperature increased, though unevenly, over the last century. Minimum temperature changes were more variable than maximum temperature changes, both temporally and spatially, with results of lesser significance.

K. Krishna Kumar, S. K. Patwardhan, A. Kulkarni1, K. Kamala, K. Koteswara Rao and R. Jones (2011) examined impact of global warming on the Indian monsoon climate using Hadley Centre's high resolution regional climate model, PRECIS (Providing Regional Climates for Impact Studies). Three simulations from a 17-member Perturbed Physics Ensemble generated using Hadley Center Coupled Model (HadCM3) for the QUMP project, are used to drive PRECIS. The PRECIS simulations corresponding to the IPCC-SRES A1B emission scenario are carried out for a continuous period 1961–2098. The model shows reasonable skill in simulating the monsoon climate over India. The climate projections are examined over three time slices viz. short (2020s i.e. 2011– 2040), medium (2050s, i.e. 2041–2070) and long (2080s, i.e. 2071–2098). The model projections indicate significant warming over India towards the end of the 21st century. The summer monsoon precipitation over India is expected to be 9–16% more in 2080s compared to the baseline (1970s, i.e. 1961–1990) under global warming conditions. Also, the rainy days are projected to be less frequent and more intense over central India.

K. Rajendran, A. Kitoh (2008) investigated the impact of future climate change on the Indian summer monsoon has been (using a super high-resolution global general circulation model. The model with approximately 20-km mesh horizontal resolution can resolve features on finer spatial scales, which were till now resolved by employing high resolution regional models. Regional models are known to have high dependency on the lateral boundary forcing and significant inability to represent regional, global scale interactions comprehensively. Another advantage of the 20-km global model is its fidelity in representing the regional distribution of the present day monsoon rainfall. Super high-resolution future scenario for the Indian summer monsoon shows widespread but spatially varying increase in rainfall over the interior regions and significant reduction in orographic rainfall over the west coasts of Kerala and Karnataka and the eastern hilly regions around Assam. Over these regions, the drastic reduction of wind by steep orography predominates over the moisture build-up effect (that causes enhanced rainfall over other parts) in reducing the rainfall. This indicates that monsoon rainfall is strongly controlled by parameterized physics and high-resolution processes which need to be resolved with adequately high resolution. The model projects substantial, spatially heterogeneous increase in both extreme hot and heavy rainfall events over most parts of India by the end of the century. While fine-scale surface moisture feedbacks influence the response of extreme hot events, extreme precipitation is influenced by fine-scale orography, evaporation, moisture content and circulation. Thus, the results indicate that consideration of fine-scale processes is critical for accurate assessment of local and regional scale vulnerability to climate change.

1.9 CHAPTERISATION SCHEME

Chapter 1: **Introduction to the study**

A brief Introduction of the study with stating its relative importance and need based on a comprehensive literature review. Objectives of the study determined after reviewing the literature. Information about the source of data procurement is given under the head of Data base. A detailed presentation of the methods and applications used in the study is given under the sub-head of Methodology. A detailed Chapterisation Scheme is placed at the end.

Chapter 2: **Spatio-Temporal analysis of Land Use Land Cover in Churu, Jhunjhunu, Nagaur and Sikar Districts (1989-2010):** Spatio-temporal analysis of land use land cover during 1989-2010 was carried out using LANDSAT images of the study area with the help of unsupervised classification for assessment of desertification in the study area.

Chapter 3: **Spatio-Temporal Analysis of Agricultural Area, Production and Yield in Churu, Jhunjhunu, Nagaur and Sikar Districts (1956-2008)**

Spatio-temporal analysis of agricultural area, production and yield during 1956-2008 was carried out using secondary data of agriculture for rabi and kharif seasons to find out the trend in above mentioned parameters in the study area.

Chapter 4: **Temporal and seasonal climatic variation in Churu, Jhunjhunu, Nagaur and Sikar Districts**

The seasonal-temporal climatic variation analysis for rainfall and temperature was carried out using simple and moving average and normalized accumulated departure from mean methods. The calculation of seasonal variability in temperature and rainfall records was the main purpose of this chapter.

Chapter 5: **Trend analysis of temperature and rainfall for Churu, Jhunjhunu, Nagaur and Sikar Districts**

Trends in temperature and rainfall records in the Churu, Jhunjhunu, Nagaur and Sikar Districts were analyzed using simple linear regression method and these trends were visualized by the best-fit lines. The main objective of this chapter is to mark significant trend in the time series data of the region.

Chapter 6: **Summary and Conclusion**

A concise summary of the study with concluding remarks, stating major findings of the study is incorporated in this chapter.

Chapter Two

Spatio-Temporal analysis of Land Use Land Cover in Churu, Jhunjhunu, Nagaur and Sikar Districts (1989-2010)

2.1 INTRODUCTION:

Land cover is distinct from land use despite the two terms often being used interchangeably. Land use is a description of how people utilize the land and socio-economic activity - urban and agricultural land uses are two of the most commonly known land use classes. At any one point or place, there may be multiple and alternate land uses, the specification of which may have a political dimension. Land use and land cover is of dynamic nature and need proper monitoring for the sake of optimum utilization of land resources. Land cover and land use are often assumed to be identical, they are rather quite different. Land cover may be defined as the biophysical earth surface while land use is often shaped by human, socioeconomic and political influences on the land.

The land use & land cover pattern of a region is an outcome of the natural & socio-economic factor and their utilization by man in time & space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use & land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. Remote Sensing (RS) and Geographic Information System (GIS) are now providing new dimensions for advanced ecosystem management. According to Wilkie and Finn (1996), the collection of remotely sensed data facilitates the synoptic analyses of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity.

2.2 SPATIO TEMPORAL ANALYSIS OF LAND USE LAND COVER PATTERN:

Land cover refers to different features covering the earth's surface including vegetation cover, water body, rocky outcrops etc. Land use term refers to man's use of the land and its cover (FAO;1990). The land use and land cover study of the study area has been attempted in order to identify and map the various types of land use and land cover classes in the study area both by visual and digital interpretation. The major procedure in preparing the temporal maps of land use is through combined help of toposheets and application of remote sensing data, which provide an aid in the rapid assessment of the land use in a GIS environment. And the land use classification is presented by the statistical data that present the land use distribution of the study area.

The primary aim of this study is to replace visual analysis of the image data with quantitative techniques for automating the identification of features in a scene. This process of study involves the analysis of multispectral image data and application of statistically based decision. The common land use and land cover classification procedures is of two types: supervised classification and unsupervised classification. In the present study unsupervised classification of land use & land cover has been used in which spectral classes are grouped first, based solely on numerical information in the data, and are then matched by the analyst to information classes (if possible). The basic premise is that values within a given cover type should be close together in the measurement space whereas data in different classes should be comparatively well separated. Unsupervised classification involves clustering algorithms that examine the unknown pixels in an image and aggregate them into a number of classes based on the natural groupings or clusters present in the image values (Lillesand and Kiefer, 2002).

Land use & land cover classes in all four district namely Churu, Jhunjhunu, Nagaur and Sikar were divided into five categories:

1. *Barren & Wasteland:* The land which may be classified as the wasteland such as barren hilly terrains, desert lands, ravines, etc. normally cannot be cultivated with available technology. In this category saline area was also

included, where agriculture land has been left due to the problem of hard pan & water logging.

2. *Vegetation*: It is important to note that area under actual forest cover is different from area classified as vegetation. Forests can be classified in different ways and to different degrees of specificity. It may be reserved, protected, classified or many types as open, dense etc.
3. *Urban and Built up area (Land put to non agricultural uses):* Land under settlements (rural and urban), infrastructure, industries, shops, etc. are included in this category. An expansion in the secondary and tertiary activities would lead to an increase in this category of land use. It refers to that part of land use which covers the area used for making houses and associated features.
4. *Water Body:* This class includes all types of water bodies such as rivers, lakes, ponds etc.
5. *Agriculture area:* In this category mainly net sown area, current fallow & other than current fallow land were included.

The land use and land cover map prepared from the LANDSAT imagery of 1989, 1999 and 2010 has revealed the spatial distribution and dynamic nature of different classes in the area which results into formation of complex physiographic features. All the satellite imageries have been acquired for October month. All satellite imageries were spectrally standardized, geo-registered to UTM zone 43N. Unsupervised classification has been used for analysis of land use & land cover in the study area.

2.2.1 CHURU DISTRICT: Churu is located at 28°18'N 74°57'E and 30°N 74°95'E. It has an average elevation of 292 m (958 ft). Churu City is encircled by large shifting sand dunes. The area is scanty in vegetation. Phoge and Kair bushes and Khejri, Royara and Babul trees are mainly found on the sand dunes. In the towns Neem and Peepal trees can also be noticed. One can find Sand dunes all over the area with a couple of small limestone hills. The region boasts record temperatures ranging from below freezing point in the winters to over 50 degrees in the summer afternoons. One may be surprised to notice ice in small water pots or frozen water dews on the little vegetation before dawn in the months of December/ January.

Land use & land cover of Churu has been shown by using unsupervised classification. Change has been studied for the period from 1989 to 2010. The change has been shown by difference in percentage of total area of each land use land cover class.

Table 2.1: Churu- Land Use Land Cover (Area in hectare)

CHURU LAND USE & LAND COVER(Area in hectare)			
	YEAR		
CATEGORY	1989	2000	2010
BARREN LAND	489678	469825	492257
AGRICULTURE LAND	847757.9	859293.9	835226.1
URBAN & BUILT UP AREA	29658	35314	38256
FOREST	11964	14214	13704.74
WATER BODY	2954	3365	2568
TOTAL	1382012	1382012	1382012

Churu land use land cover shows a distinctive trend. Change in land use & land cover during 1989-2010 is shown in table 2.1. In 1989 barren land occupied 35.43 % which decreased over time period. It was reduced to 34 % in 2000 and then it registered a slight increase and reached up to 35.62 % in 2010. It can be attributed to land degradation in the district and consequently to desertification.

Table 2.2: Churu- Land Use Land Cover (Area in %)

CHURU LAND USE & LAND COVER(area in %)			
	YEAR		
CATEGORY	1989	2000	2010
BARREN LAND	35.43	34.00	35.62
AGRICULTURE LAND	61.34	62.18	60.44
URBAN & BUILT UP AREA	2.15	2.56	2.77
FOREST	0.87	1.03	0.99
WATER BODY	0.21	0.24	0.19

Urban and built up area increased during 1989-21010 from 2.15 % to 2.77 % . Forest area in Churu is very low. It was as low as 0.87 % in 1989. It slightly increased to 0.99 % in 2010. Paucity of potable water, harsh climatic conditions, lack of water bodies etc. are some of the causes responsible for low forest cover and built up area in the district. Land use land cover in Churu shows decline in agriculture area during 1989-2010. Though it increased slightly in 2000 but again decreased in 2010 to 60.44% which almost 1% less than its value in 1989.

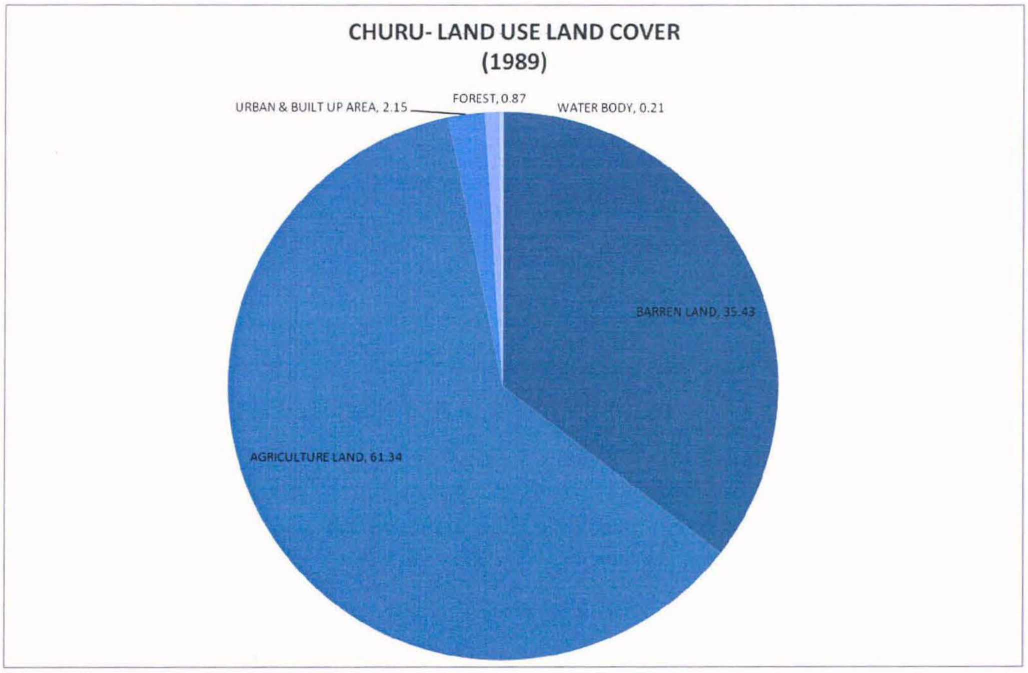


Figure: 2.1: Churu- Land Use Land Cover (Area in %) (1989)

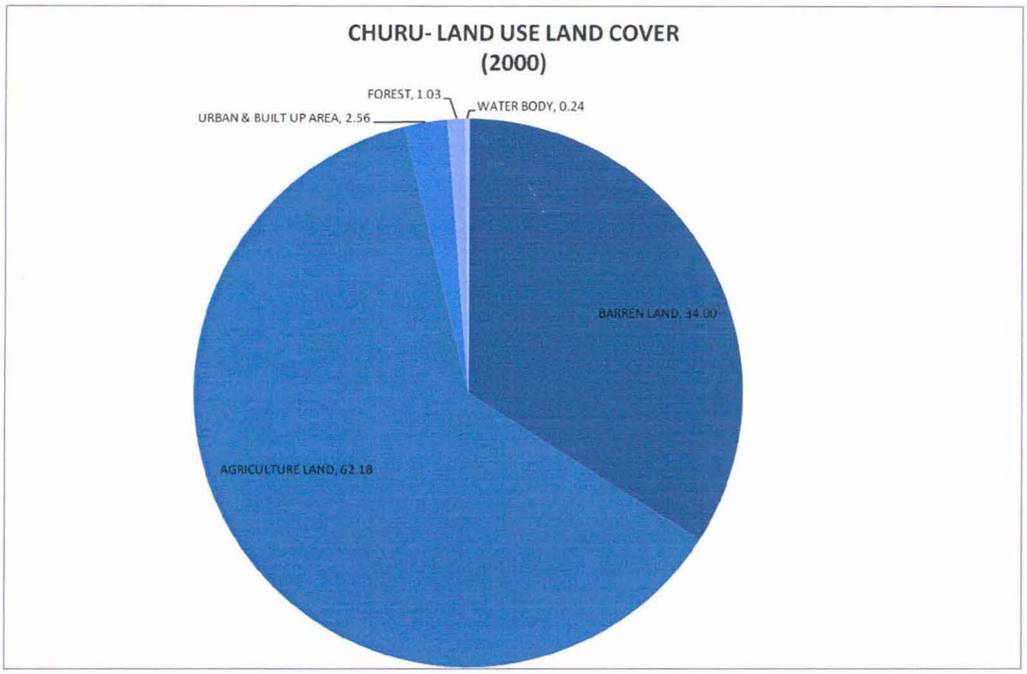


Figure: 2.2: Churu- Land Use Land Cover (Area in %) (2000)

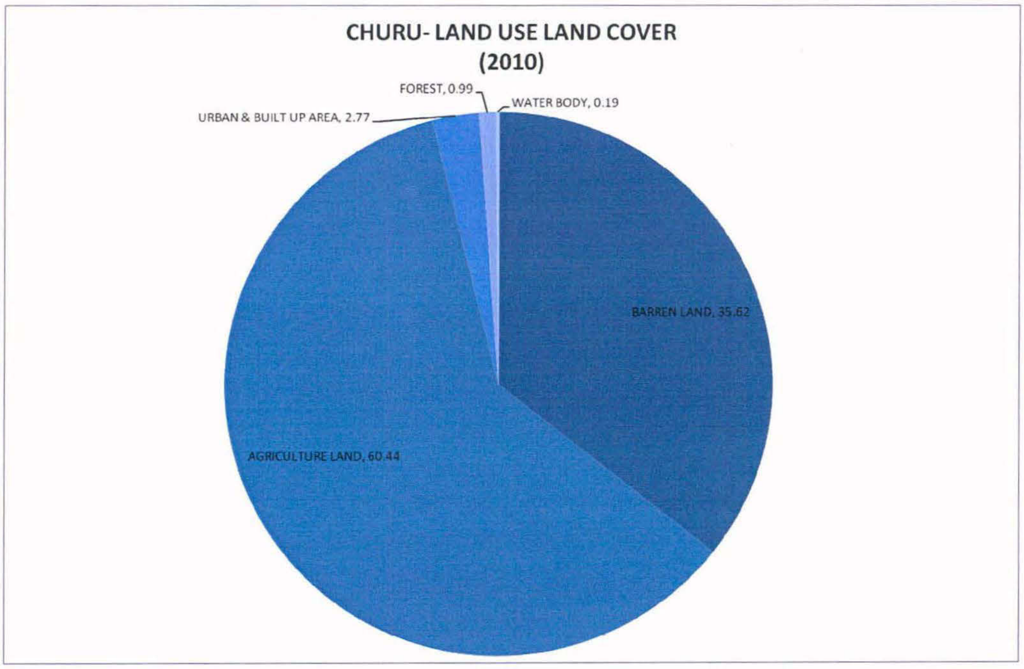


Figure: 2.3: Churu- Land Use Land Cover (Area in %) (2010)

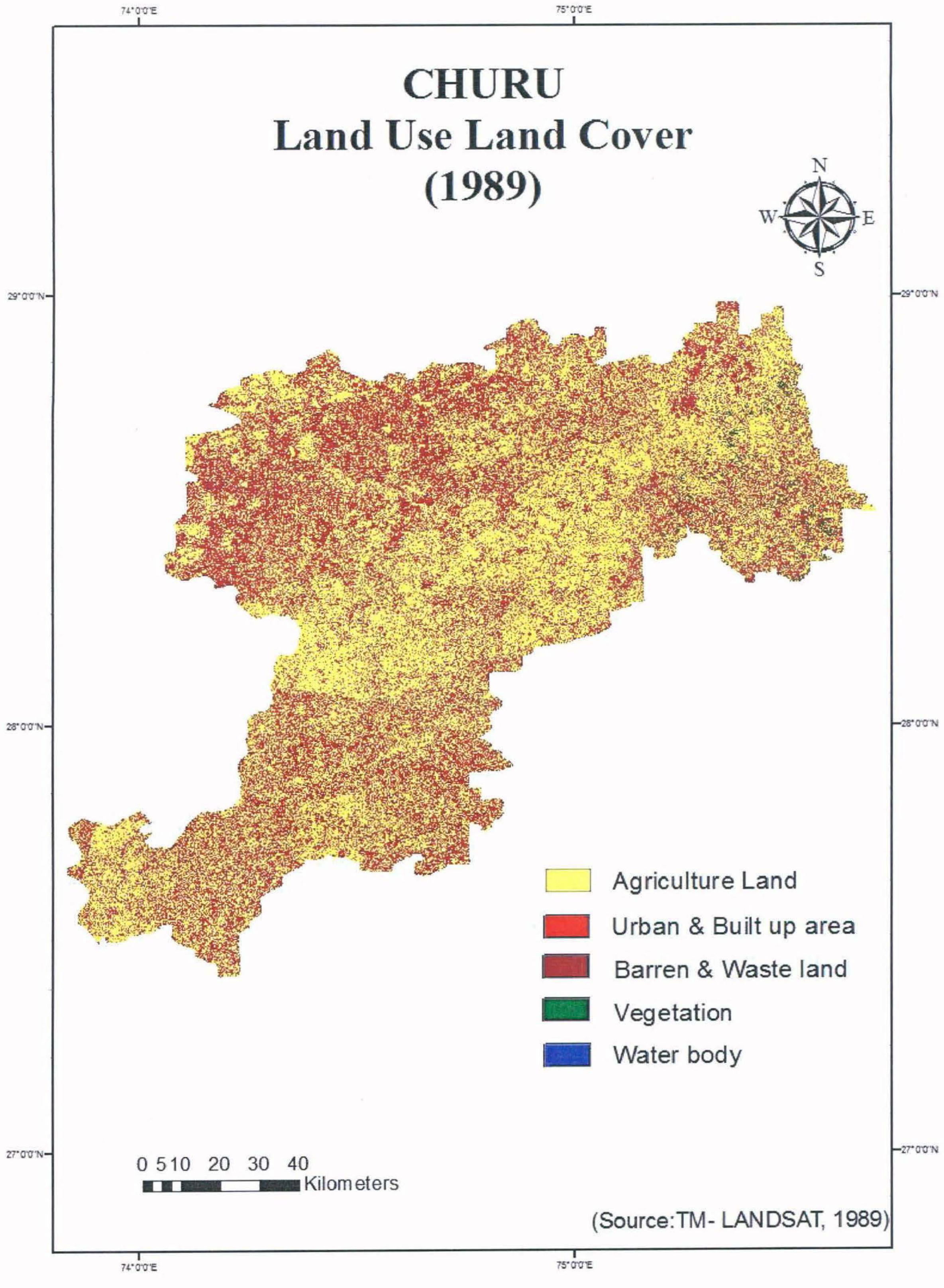


Figure 2.4: Churu- Land Use Land Cover (1989)

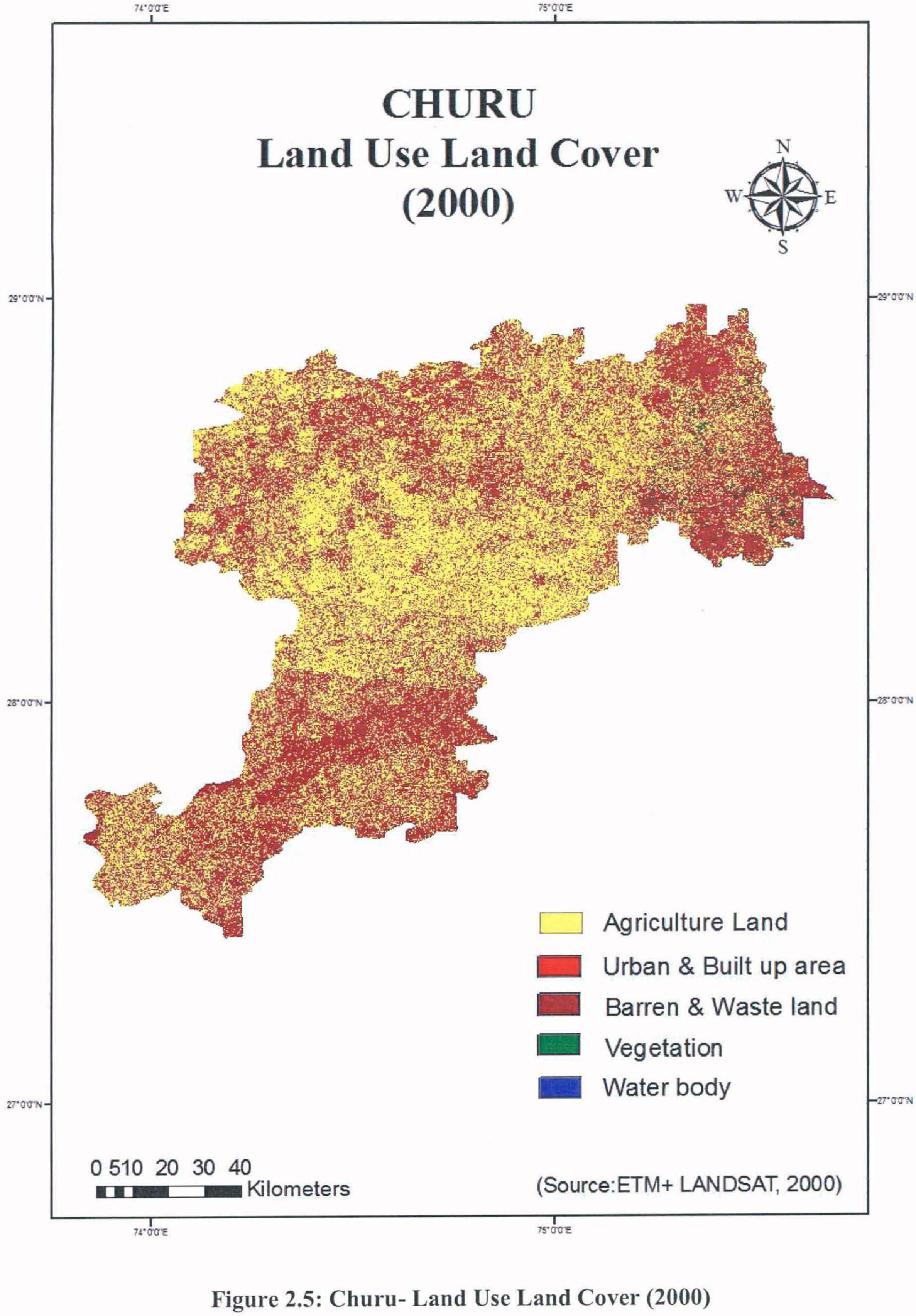


Figure 2.5: Churu- Land Use Land Cover (2000)

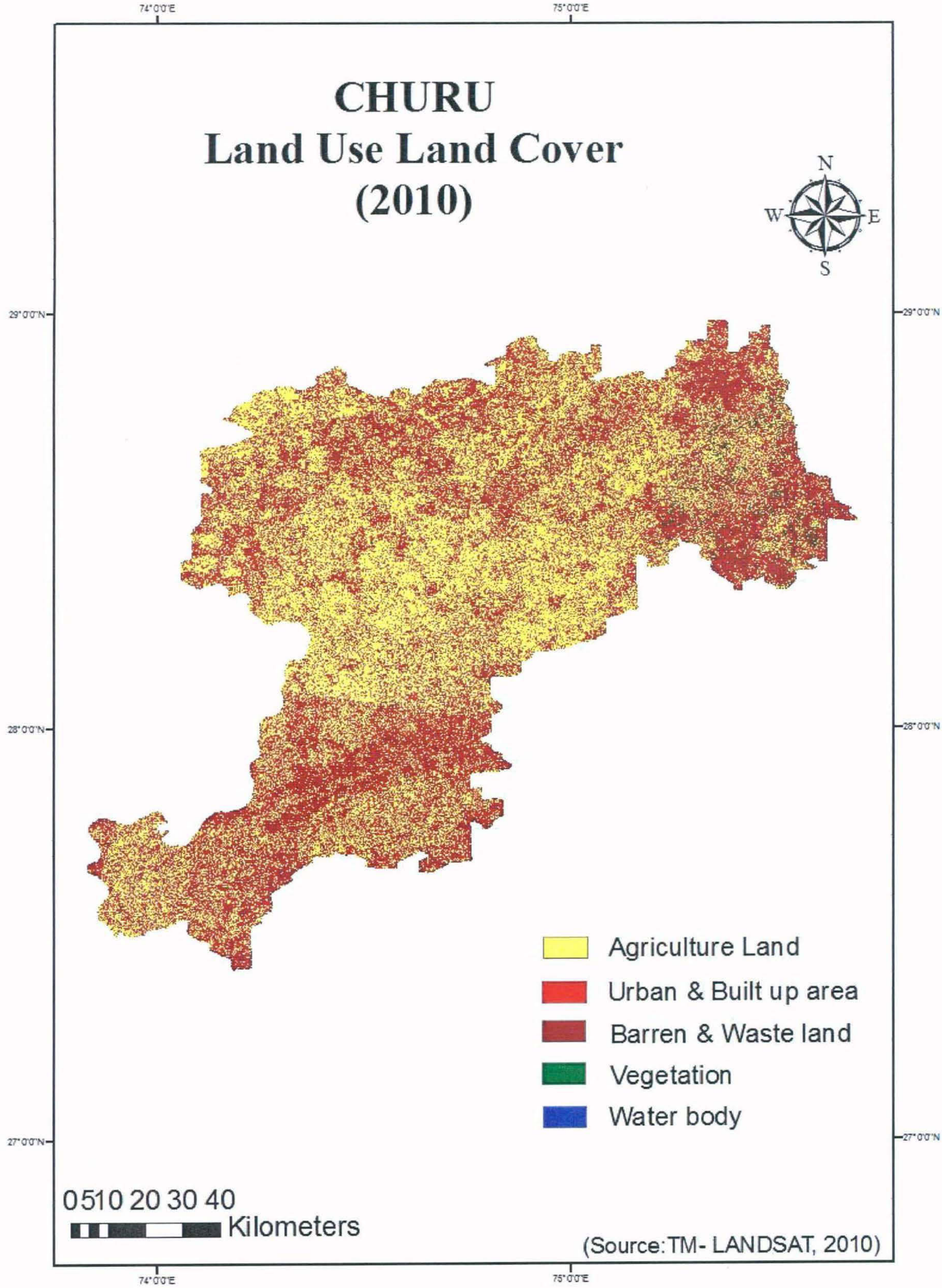


Figure 2.6: Churu- Land Use Land Cover (2010)

2.2.2 JHUNJHUNU DISTRICT: Jhunjhunu is located between 28°08'N 75°24'E and 28°13'N 75°40'E.It has an average elevation of 323 metres (1059 feet). Jhunjhunu primarily lies in the semi-arid Rajasthan. Scattered Aravali hills constitute major portion of the city and nearby towns like Khetri, Udaipurwati, Sakambhari etc. Climate is harsh and subjected to frequent drought and sandstorms. Sand dunes are common phenomena in this district.

Land use & land cover of Jhunjhunu has been shown by using unsupervised classification. Change has been studied for the period from 1989 to 2010. The change has been shown by difference in percentage of total area of each land use land cover class during 1989-2010.

Table 2.3: Jhunjhunu- Land Use Land Cover (Area in hectare)

JHUNJHUNU- LAND USE LAND COVER(Area in hectare)			
YEAR			
CATEGORY	1989	2000	2010
BARREN LAND	162842	160254	166571.7
AGRICULTURE LAND	366507.9	364845.9	356730.3
URBAN & BUILT UP AREA	35964	38246	41227
FOREST	6924	8425	8012.876
WATER BODY	1425	1892	1121
TOTAL	573662.9	573662.9	573662.9

Agriculture area in Jhunjhunu was 63.89 % in 1989, which is highest for the period from 1989 to 2010. It declined slightly by 1.71 % to reach at 62.18 % in 2010. Barren land shows increase during 2000-2010 which is the result of the problem of land degradation in the district.

Table 2.4: Jhunjhunu- Land Use Land Cover (Area in %)

JHUNJHUNU- LAND USE LAND COVER(Area in %)			
YEAR			
CATEGORY	1989	2000	2010
BARREN LAND	28.39	27.94	29.04
AGRICULTURE LAND	63.89	63.60	62.18
URBAN & BUILT UP AREA	6.27	6.67	7.19
FOREST	1.21	1.47	1.40
WATER BODY	0.25	0.33	0.20

Urban and built up area has shown a continuous increase during 1989-2010. Forest area in Jhunjhunu is very low but it is more than Churu district. In 1989, only

1.21 % geographical area was under forest, it increased very slightly to 1.40 % over a time period of 20 years. Water bodies constitute a very small fraction of total geographical area in the district and did not vary much during 1989-2010.

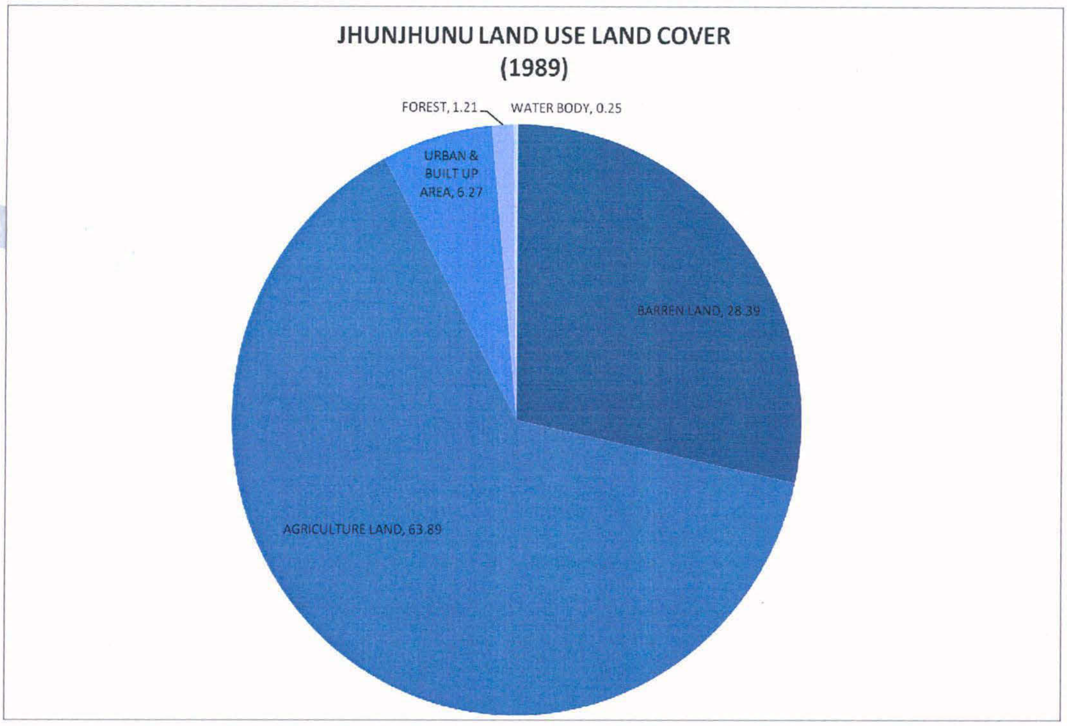


Figure 2.7: Jhunjhunu-Land Use Land Cover (Area in %) (1989)

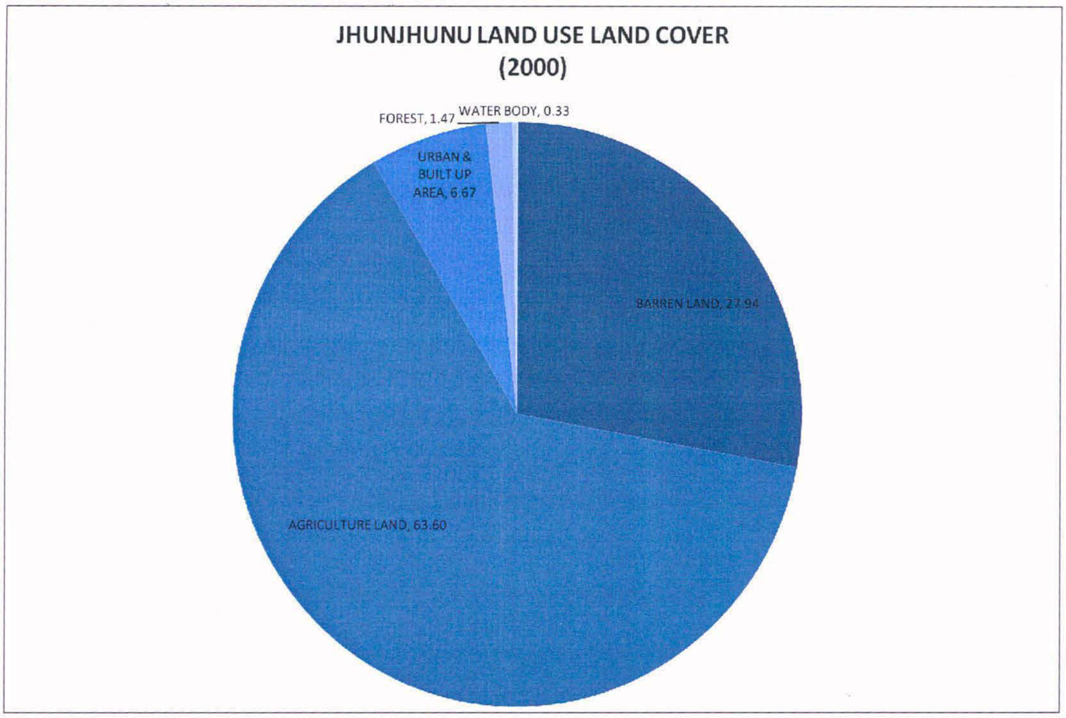


Figure 2.8: Jhunjhunu-Land Use Land Cover (Area in %) (2000)

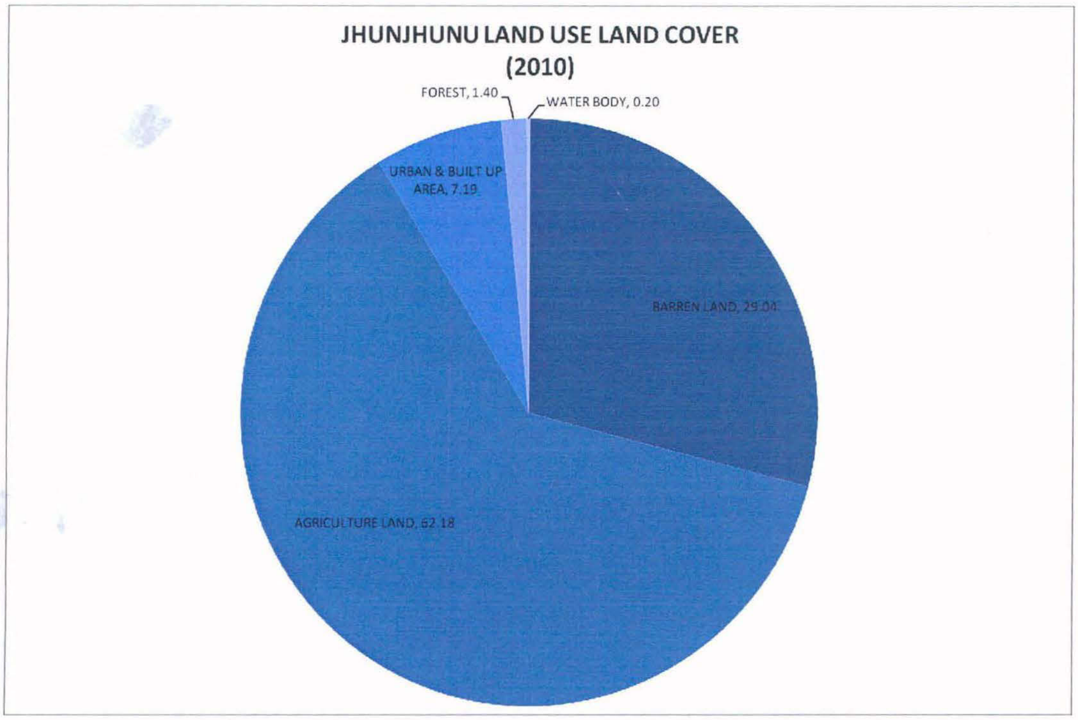


Figure 2.9: Jhunjhunu-Land Use Land Cover (Area in %) (2010)

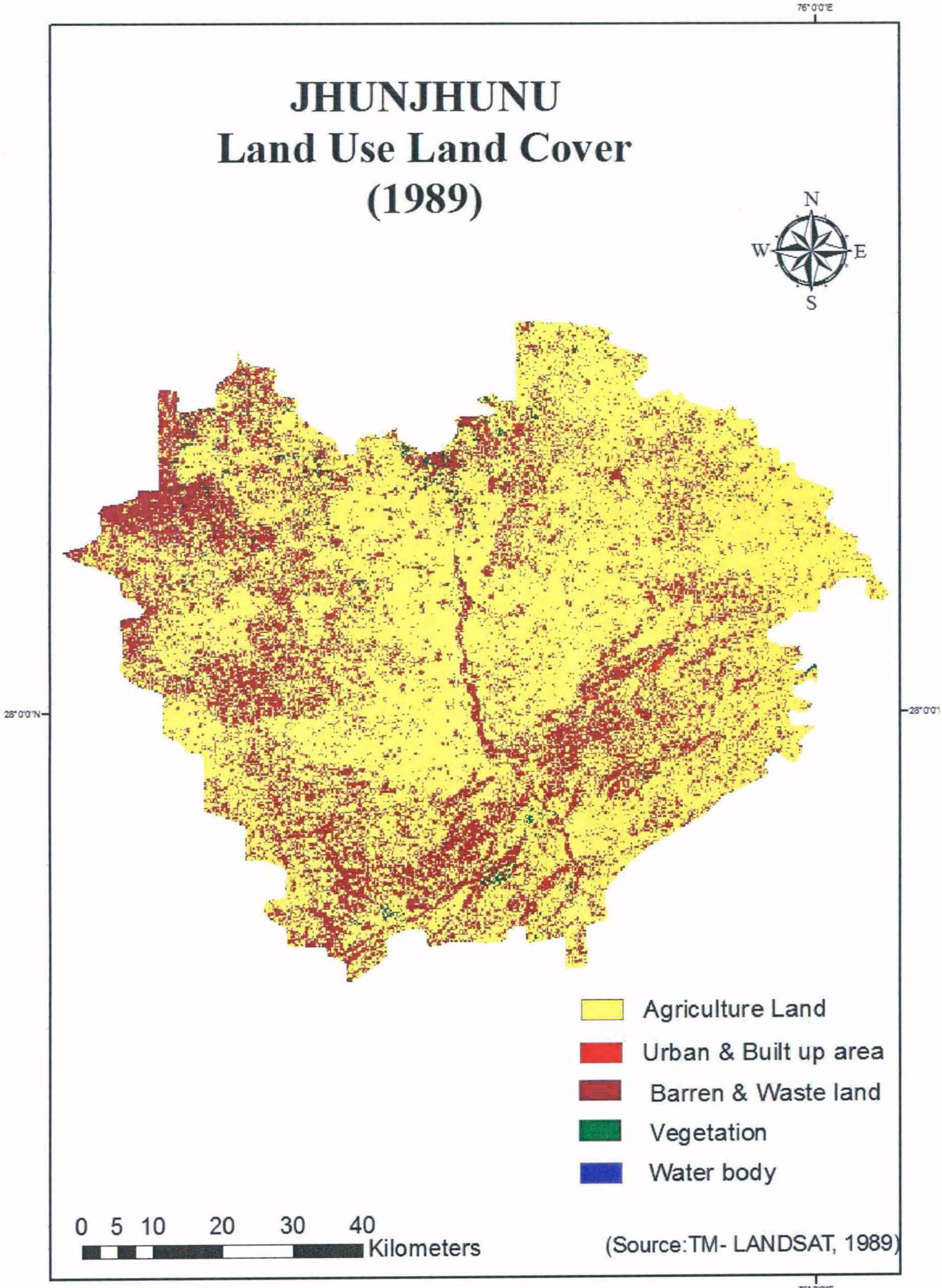


Figure 2.10: Jhunjhunu- Land Use Land Cover (1989)

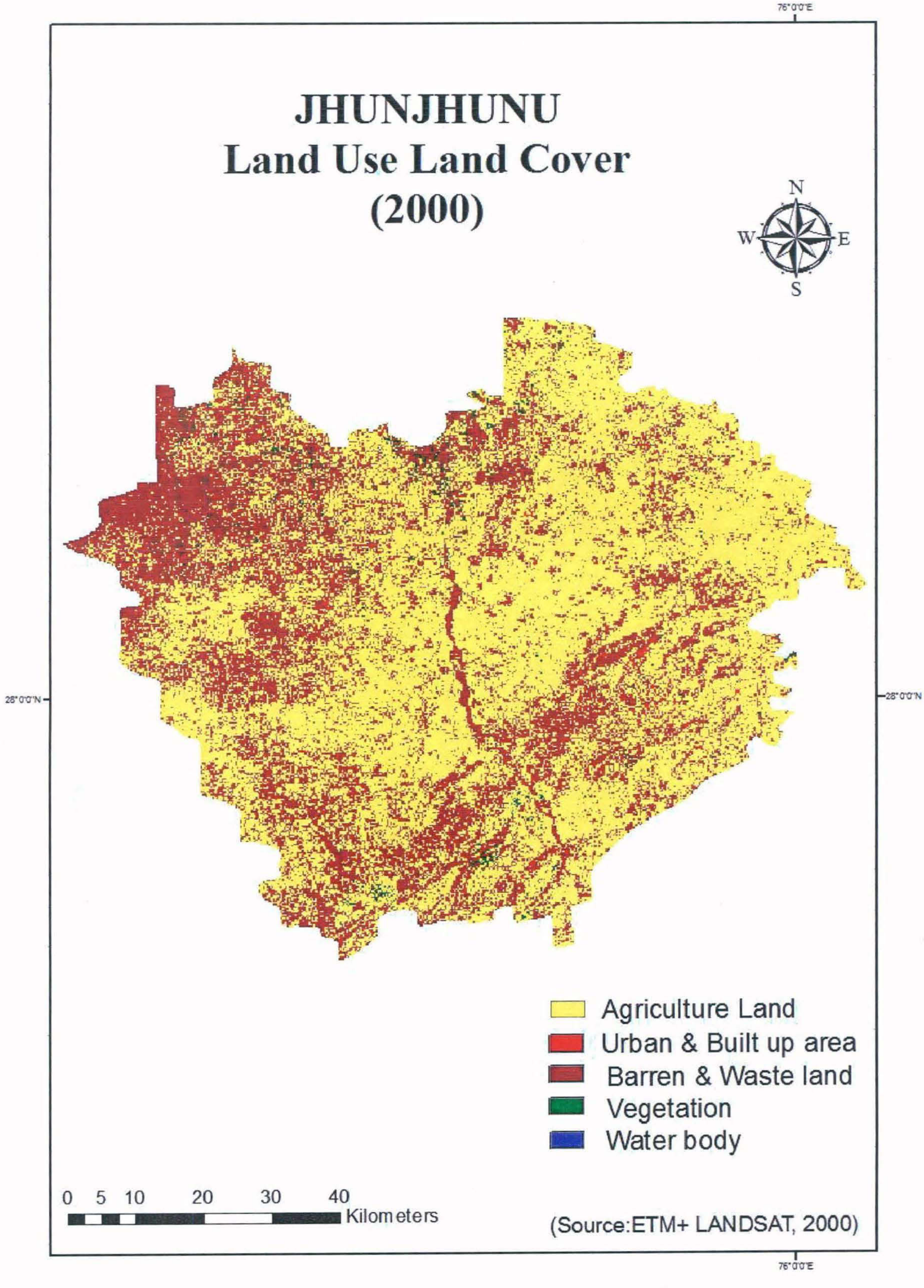


Figure 2.11: Jhunjhunu- Land Use Land Cover (2000)

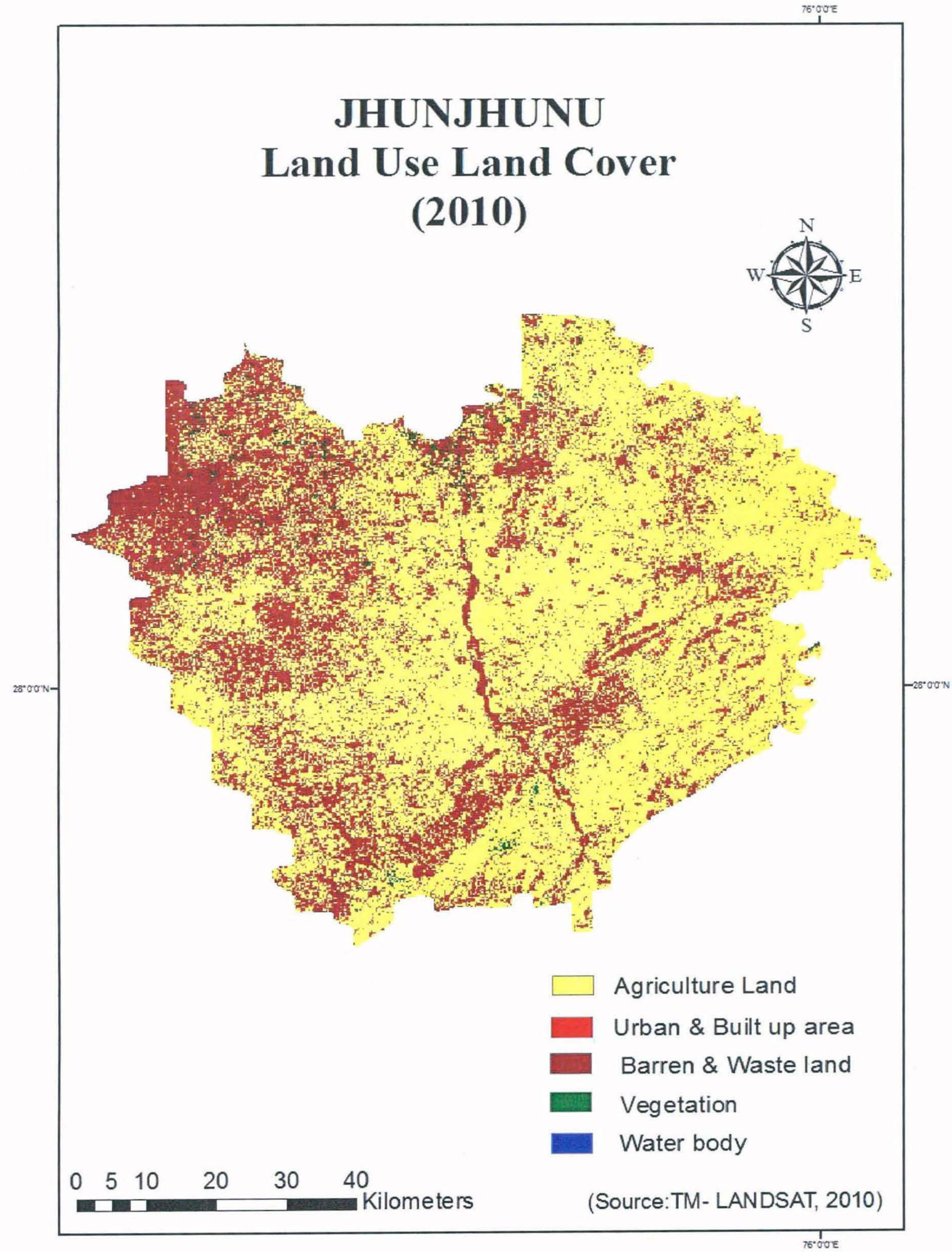


Figure 2.12: Jhunjhunu- Land Use Land Cover (2010)

2.3.3 NAGAUR DISTRICT: Nagaur is located between 27°12'N 73°44'E and 27°20'N 73°73'E. It has an average elevation of 302 metres (990 feet). It is situated amidst seven districts namely Bikaner, Churu, Sikar, Jaipur, Ajmer, Pali and Jodhpur. Nagaur is the fifth largest district in Rajasthan with a vast terrain spreading over 17,718 km². Its geographical spread is a good combine of plain, hills, sand mounds and it is a part of the great Indian Thar desert. Nagaur has a dry climate with a hot summer season. Sand storms are common in summer. The climate of the district is conspicuous by extreme dryness, large variations of temperature and highly variable rainfall. The mercury keeps on rising intensely from March till June. These are the hottest months. The district of Nagaur is poor in forest resources.

Land use & land cover of Nagaur has been shown by using unsupervised classification. Change has been studied for the period from 1989 to 2010. The change has been shown by difference in percentage of total area of each land use land cover class.

Table 2.5: Nagaur- Land Use Land Cover (Area in hectare)

NAGAUR- LAND USE LAND COVER(Area in hectare)			
	YEAR		
CATEGORY	1989	2000	2010
BARREN LAND	745581	724189	747160
AGRICULTURE LAND	984157	995560	961379
URBAN & BUILT UP AREA	37859	42651	49759
FOREST	24231	28485	32807
WATER BODY	4252	5195	4975
TOTAL	1796080	1796080	1796080

Nagaur land use land cover shows a distinctive trend. Change in land use & land cover during 1989-2010 is shown in table 4.5 and 4.6. In 1989 barren land occupied 41.51 % which decreased over time period. It was reduced to 40.32 % in 2000 and then it registered a slight increase and reached up to 41.60 % in 2010. It can be attributed to land degradation in the district and consequently to desertification.

Table 2.6: Nagaur- Land Use Land Cover (Area in %)

NAGAUR- LAND USE LAND COVER(Area in %)			
	YEAR		
CATEGORY	1989	2000	2010
BARREN LAND	41.51	40.32	41.60
AGRICULTURE LAND	54.79	55.43	53.53
URBAN & BUILT UP AREA	2.11	2.37	2.77
FOREST	1.35	1.59	1.83
WATER BODY	0.24	0.29	0.28

Urban and built up area increased during 1989-21010 from 2.11 % to 2.37 %. Forest area in Nagaur is very low. It was as low as 1.35 % in 1989. It slightly increased to 1.83 % in 2010. Paucity of potable water, harsh climatic conditions, lack of water bodies etc. are some of the causes responsible for low forest cover and built up area in the district. Land use land cover in Nagaur shows decline in agriculture area during 1989-2010. Though it increased slightly in 2000 but again decreased in 2010 to 53.53 % which almost 1% less than its value in 1989.

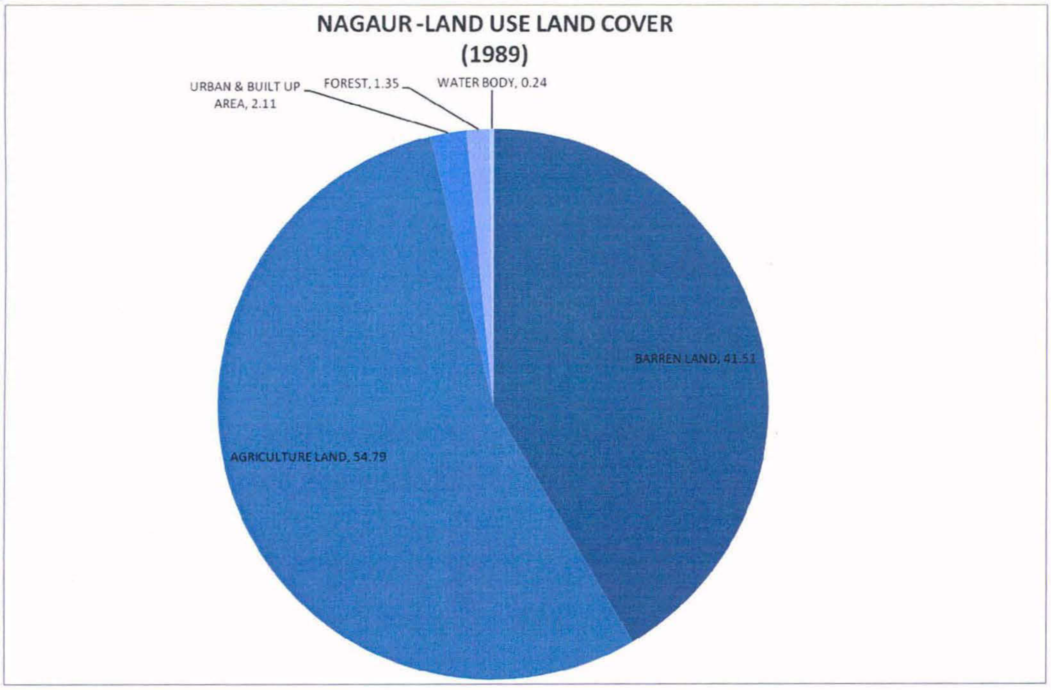


Figure 2.13: Nagaur-Land Use Land Cover (Area in %) (1989)

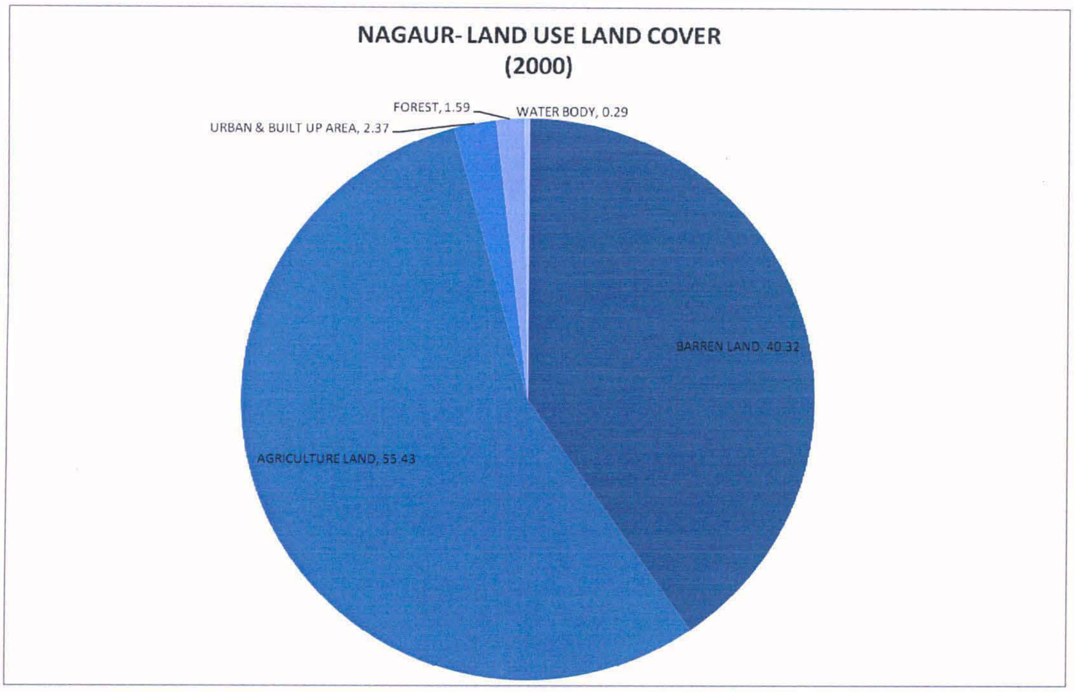


Figure 2.14: Nagaur-Land Use Land Cover (Area in %) (2000)

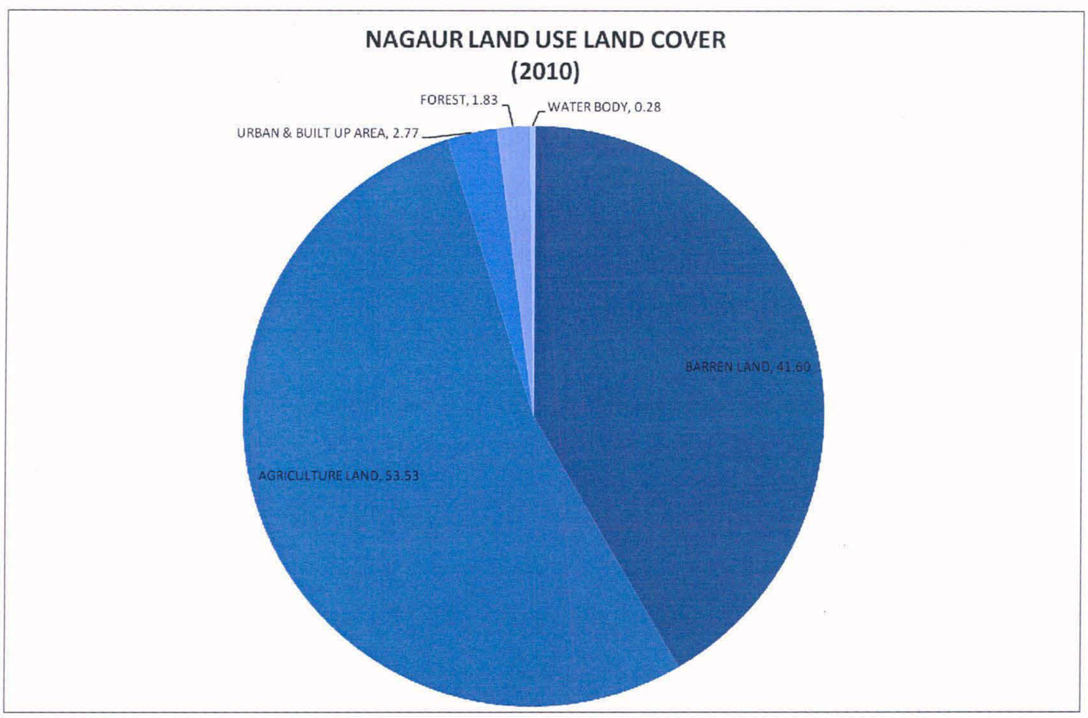


Figure 2.15: Nagaur-Land Use Land Cover (Area in %) (2010)

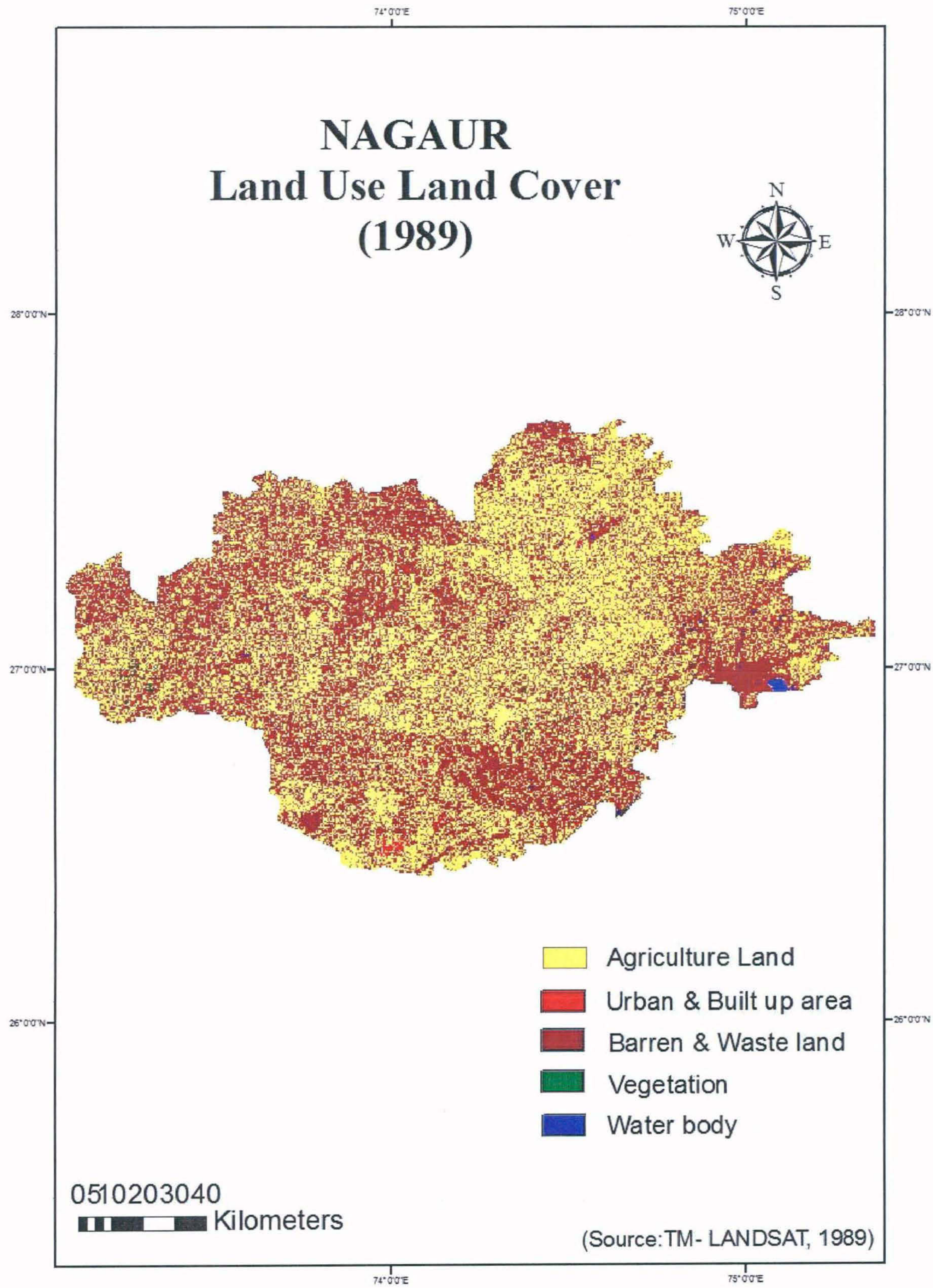


Figure: 2.16: Nagaur-Land Use Land Cover (1989)

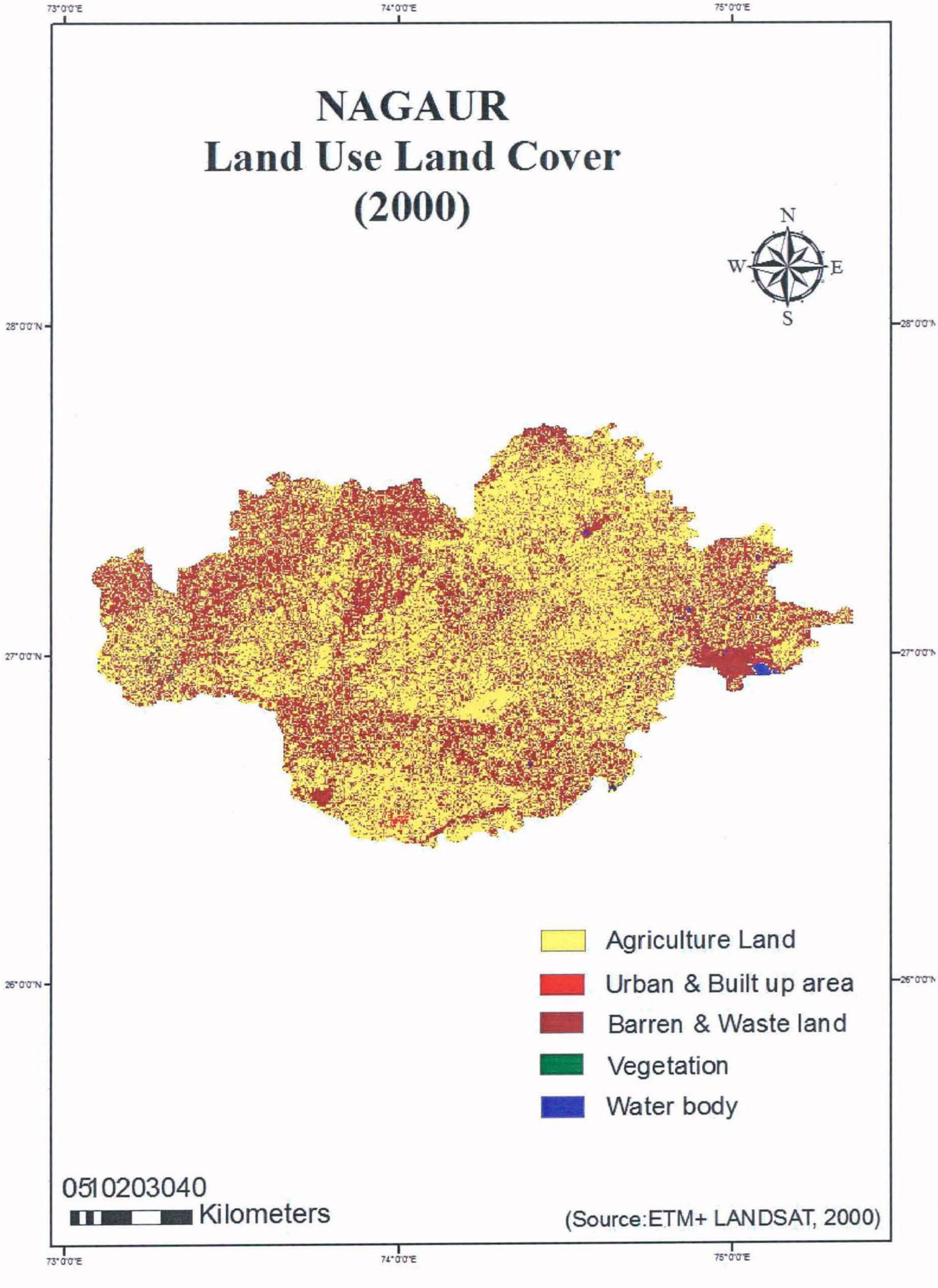


Figure: 2.17: Nagaur-Land Use Land Cover (2000)

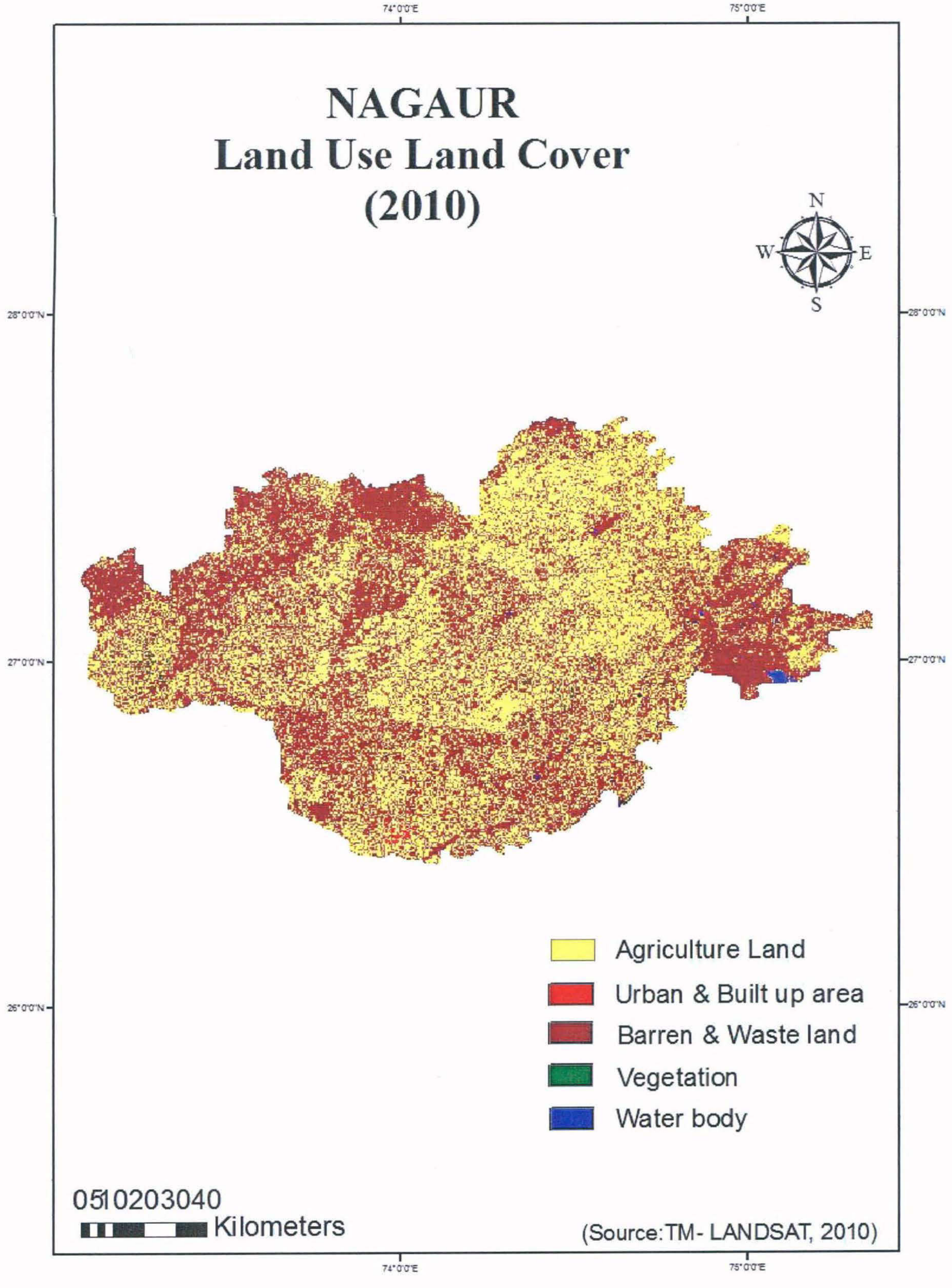


Figure: 2.18: Nagaur-Land Use Land Cover (2010)

2.3.4 SIKAR DISTRICT: Sikar is located between 27°37'N 75°09'E and 27°62'N 75°15'E.It has an average elevation of 427 metres (1400 feet). Physiography of Sikar is composed of dissected uplands of Aravali.

Land use & land cover of Sikar has been shown by using unsupervised classification. Change has been studied for the period from 1989 to 2010. The change has been shown by difference in percentage of total area of each land use land cover class.

Sikar land use land cover shows a distinctive trend. Change in land use & land cover during 1989-2010 is shown in table 2.7 and 2.8. In 1989 barren land occupied 24.05 % which decreased over time period. It was reduced to 22.94 % in 2000 and then it registered a slight increase and reached up to 24.87 % in 2010. It can be attributed to land degradation in the district and consequently to desertification.

Table 2.7: Sikar- Land Use Land Cover (Area in hectare)

SIKAR- LAND USE LAND COVER(Area in hectare)			
YEAR			
CATEGORY	1989	2000	2010
BARREN LAND	187567	178871	193971
AGRICULTURE LAND	529359	531599	510365
URBAN & BUILT UP AREA	42311	47324	50674
FOREST	18964	20224	23291
WATER BODY	1685	1868	1584
TOTAL	779886	779886	779886

Urban and built up area increased during 1989-21010 from 5.43 % to 6.50 %. Forest area in Sikar is low but it is higher than other three districts included in the study. It was 2.43 % in 1989. It slightly increased to 2.59 % in 2000 and further to 2.99 in 2010. Land use land cover in Sikar shows decline in agriculture area during 1989-2010. Though it increased slightly in 2000 but again decreased in 2010 to 65.44% which almost 2 % less than its value in 1989.

Table 2.8: Sikar- Land Use Land Cover (Area in %)

SIKAR- LAND USE LAND COVER(Area in %)			
YEAR			
CATEGORY	1989	2000	2010
BARREN LAND	24.05	22.94	24.87
AGRICULTURE LAND	67.88	68.16	65.44
URBAN & BUILT UP AREA	5.43	6.07	6.50
FOREST	2.43	2.59	2.99
WATER BODY	0.22	0.24	0.20

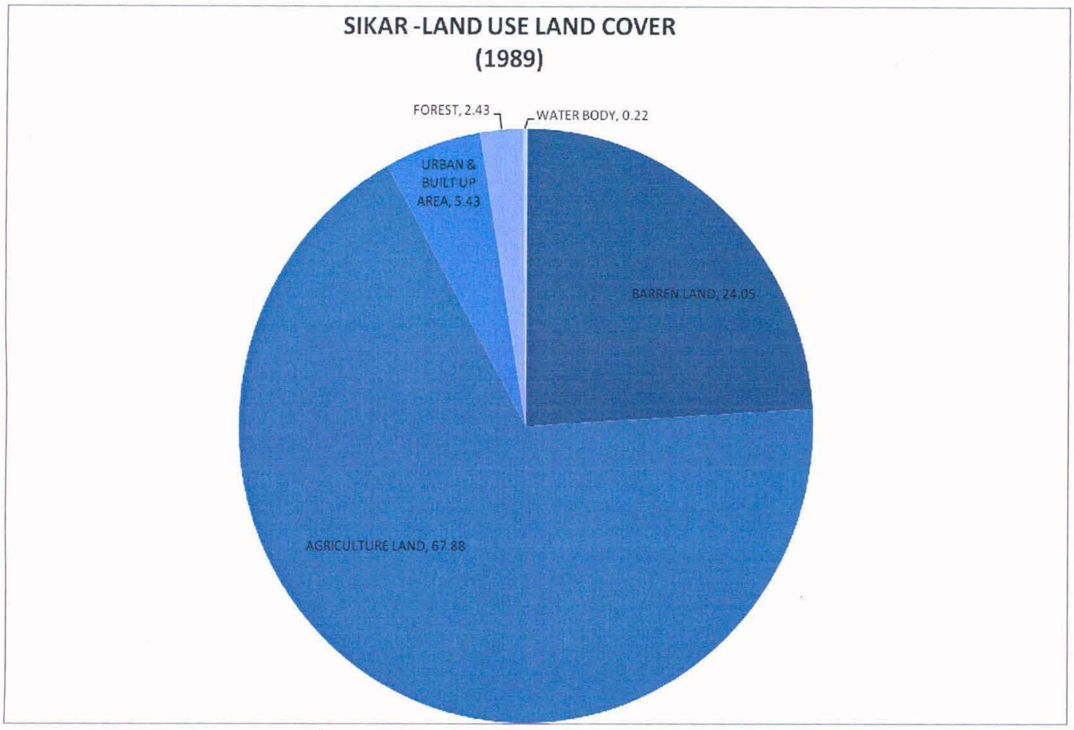


Figure 2.19: Sikar-Land Use Land Cover (Area in %) (1989)

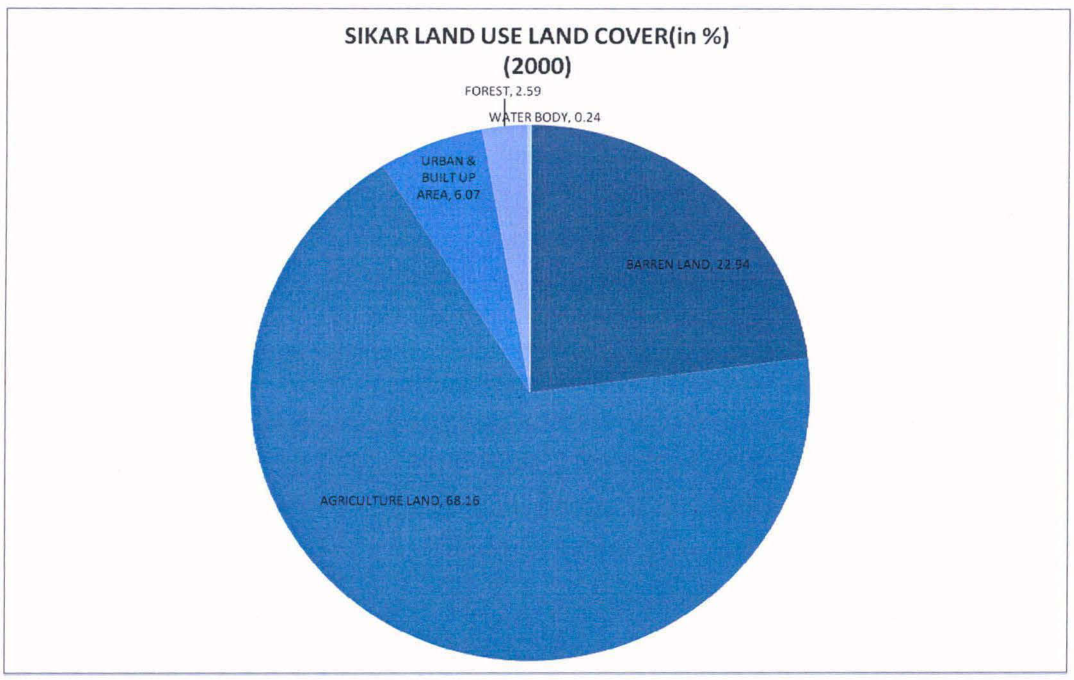


Figure: 2.20: Sikar-Land Use Land Cover (Area in %) (2000)

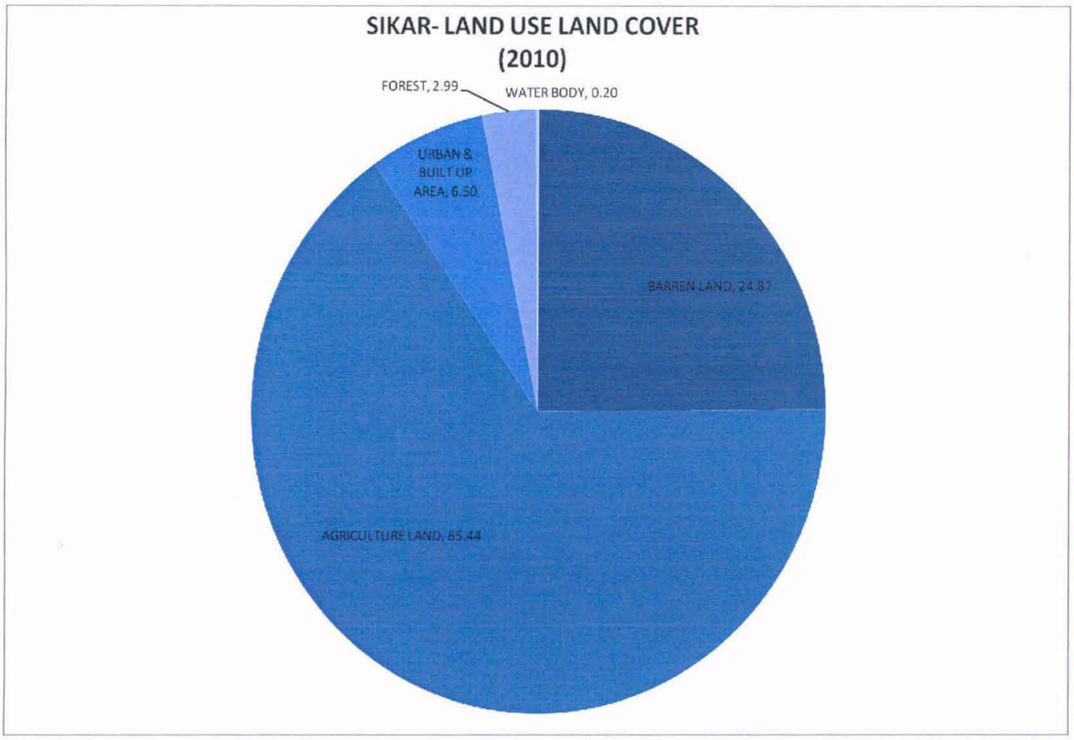


Figure: 2.21: Sikar-Land Use Land Cover (Area in %) (2010)

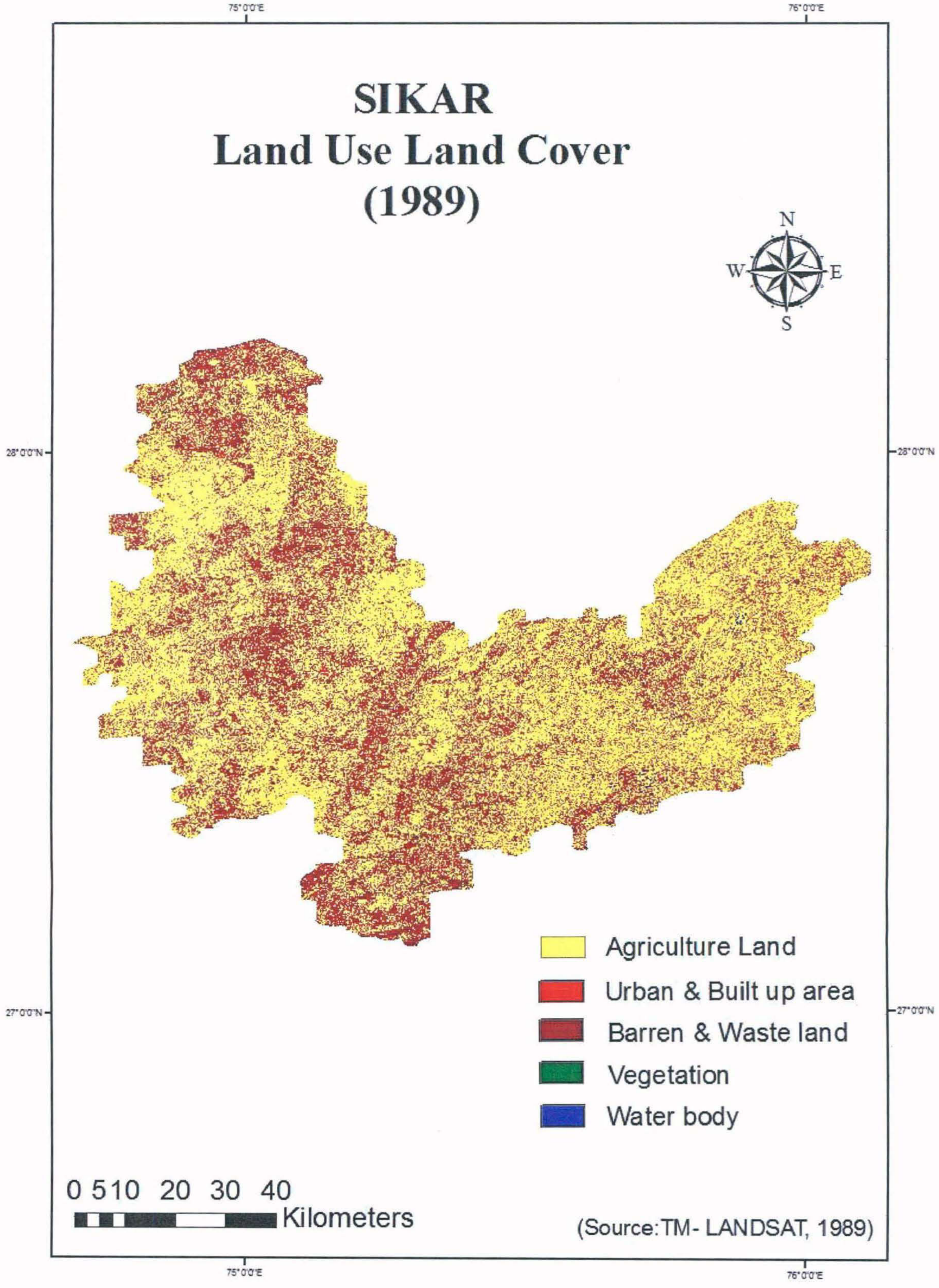


Figure: 2.22: Sikar-Land Use Land Cover (1989)

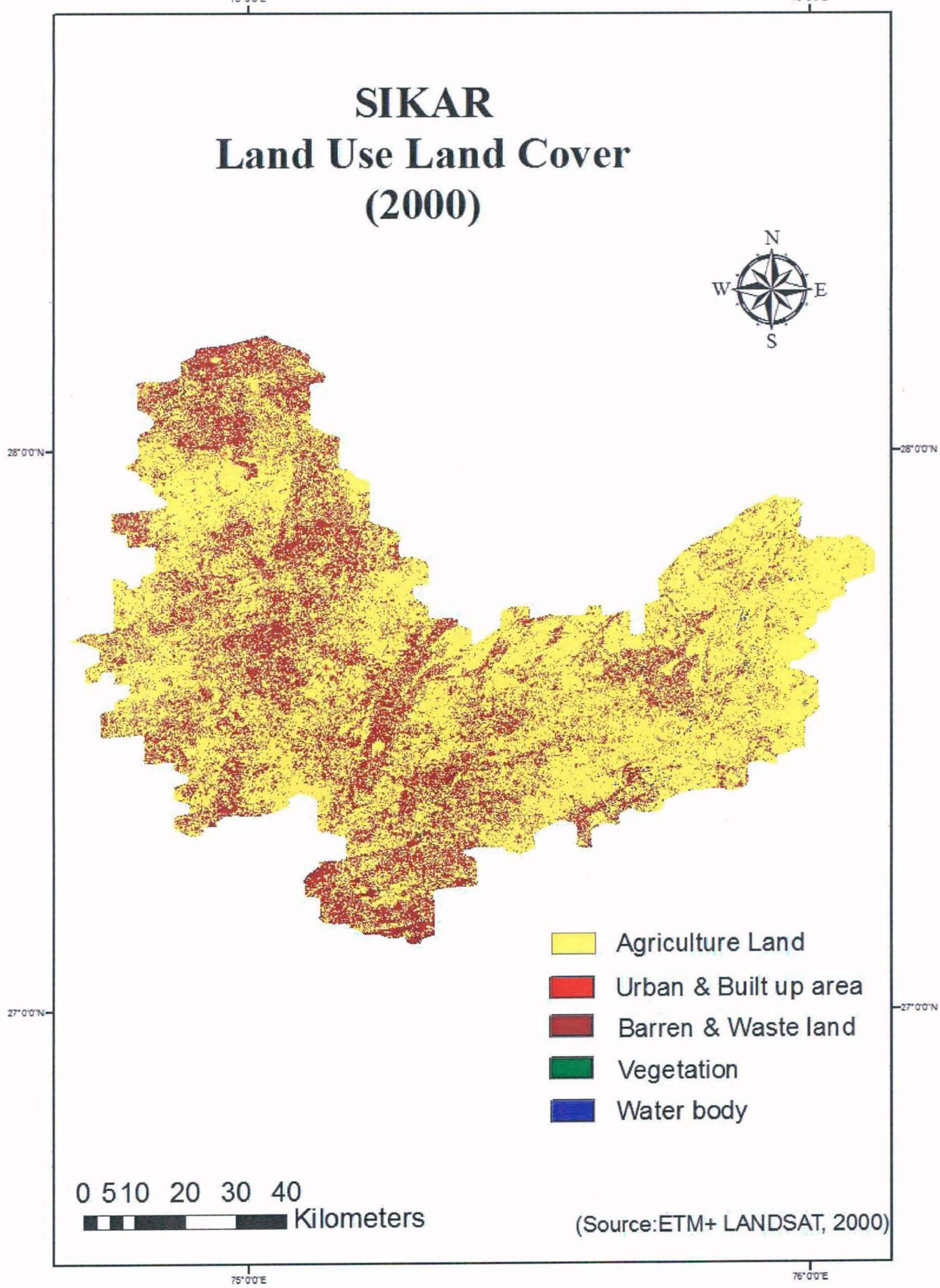


Figure: 2.23: Sikar-Land Use Land Cover (2000)

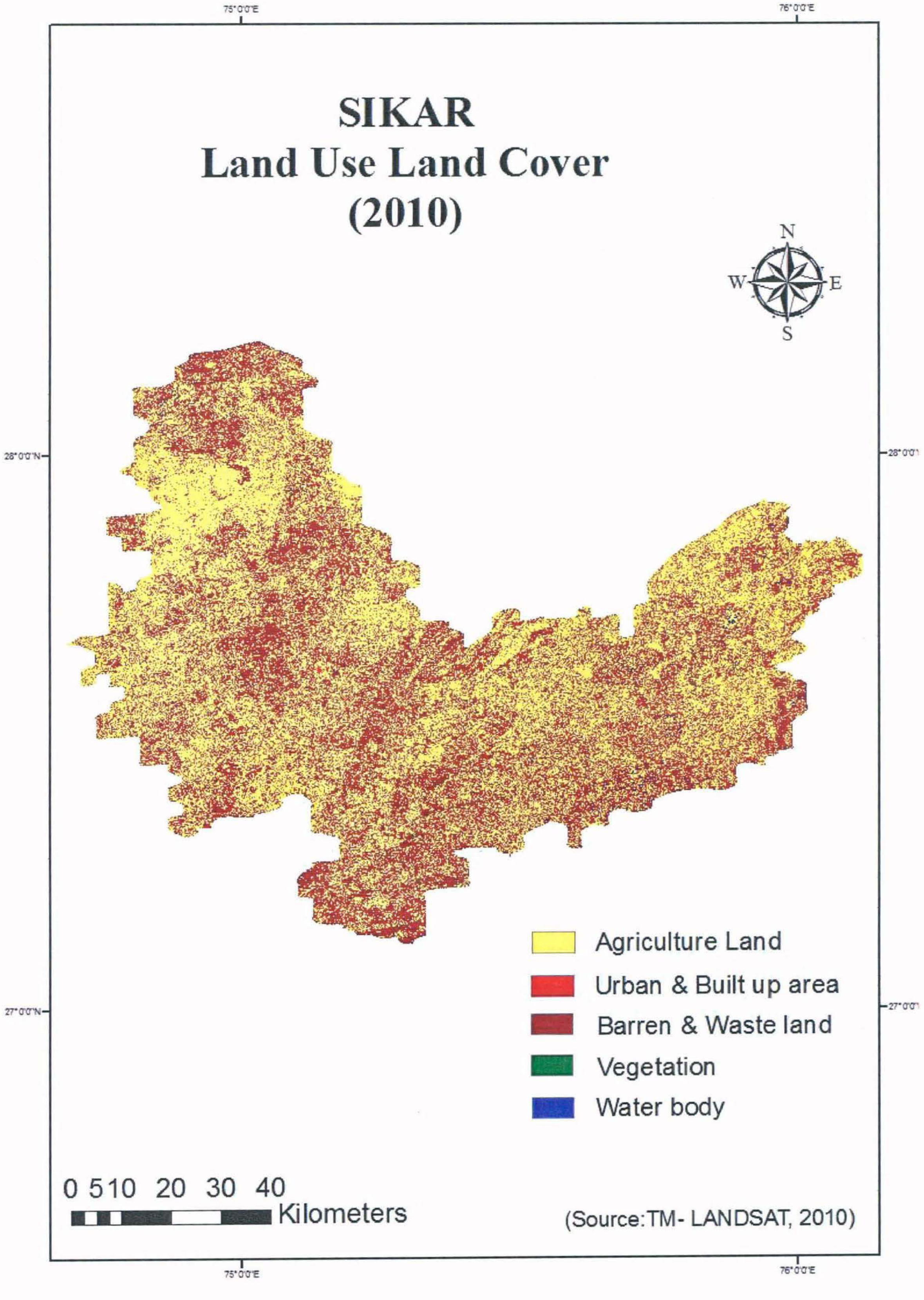


Figure: 2.24: Sikar-Land Use Land Cover (2010)

Chapter Three

Spatio-Temporal Analysis of Agricultural Area, Production and Yield in Churu, Jhunjhunu, Nagaur and Sikar Districts

(1956-2008)

3.1 INTRODUCTION:

The dependence of India's agriculture on the south-west monsoon and its consequent vulnerability has been recognised from the earliest times. Agriculture has always been the principal occupation of the vast majority of the people and successive governments from time to time have been directing their energies to improve the lot of the farmer, to give him protection against the failure of rains. Efforts were made to bring the waters to the field for irrigation. Early irrigation ventures were mostly concerned with storing rainwater in tanks and with leading canals from the tanks to farmers' field. Only a few plots in the Sujangarh and Reni in Bikaner district were watered from Kachcha wells in 1897. No irrigation from wells existed in Jaisalmer district as wells were too deep. Irrigation from rainwater by constructing kharins or khadeens existed in Jaisalmer district in the 18th century. Kharins are shallow depression into which the rainwater flows. They are basically used to harvest surface runoff from the surrounding area for raising crops during Rabi season. Where soil is harder and the surrounding hilly and rocky surface runoff is diverted to shallow depression.

Secondary data of Agricultural area, production and yield in four districts namely Churu, Jhunjhunu, Nagaur and Sikar during 1956 to 2008 has been used for this analysis. This secondary data of agricultural area, production and yield is divided into two main seasons:

1. Kharif season
2. Rabi season

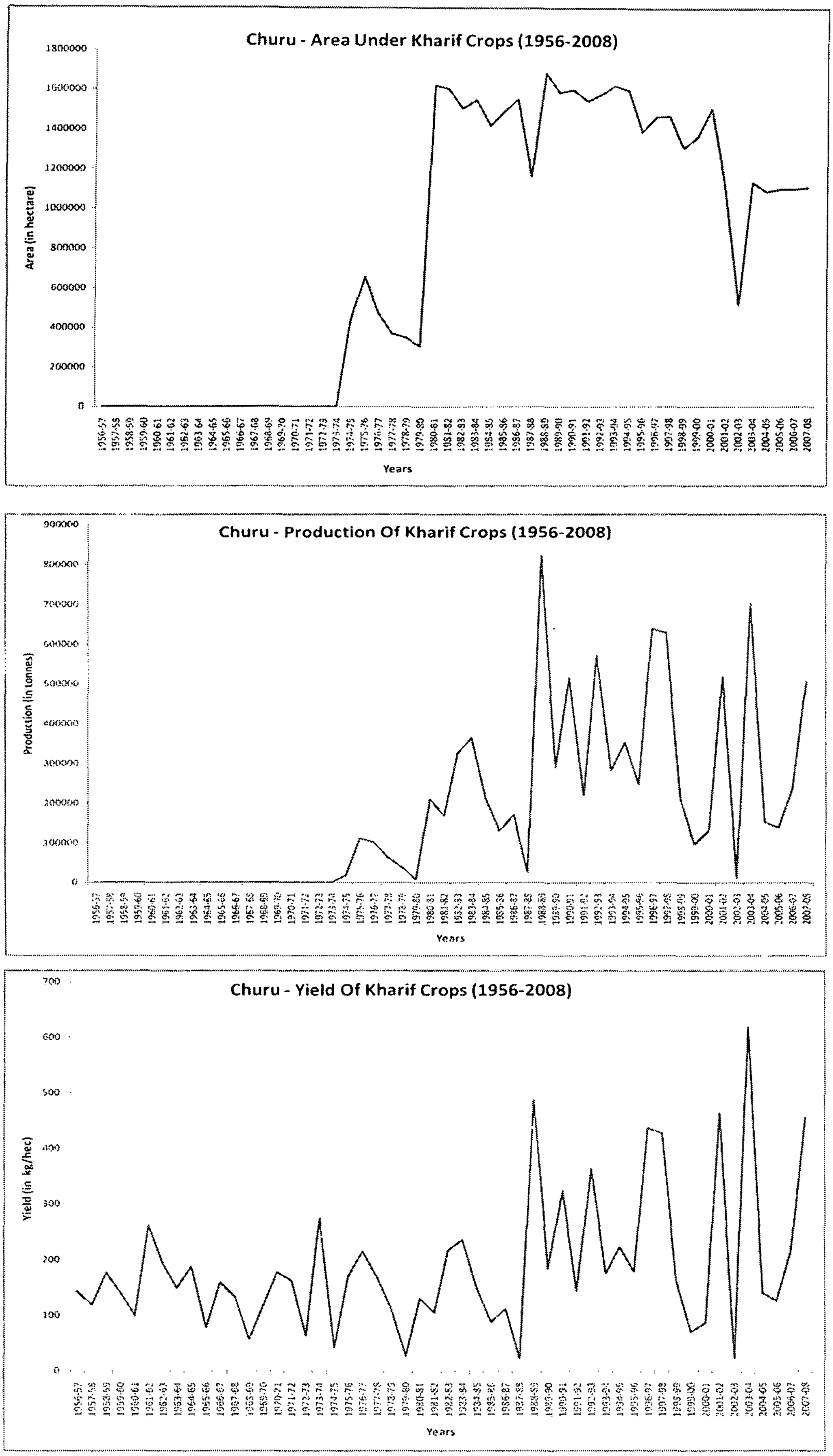


Figure 3.1: Area, Production and Yield of Kharif Crops in Churu

3.2 CHURU DISTRICT : As per given data, line diagram shows that area under Kharif crops remained stagnant from 1956 to 1973 in Churu district and same story is repeated in case of production. During 1973 to 1981 there was sharp rise in production. Till 2001, many peak points were reached in both Net Sown Area and production. Simultaneously there were lowest points primarily because of temporary variability of rainfall. After 2001 there is continuous decrease in Net Sown Area but production has been almost stagnant in its peak and bottom values. On the other hand yield has been continuously increasing in its peak and bottom value since 1956 to 2008. This anomaly in production and yield can be attributed to introduction of green revolution and consequent changes in agricultural production and yield.

Churu lies in western Rajasthan where rainfall is scanty and agriculture has been exclusively dependent on summer monsoon till benefit of green revolution reached to the district. Since 1970s irrigation wells started gaining momentum otherwise pulses used to be sown during rabi season placing exclusive reliance on mavath (rainfall by effects of Mediterranean cyclones during winter, popularly known as Western Disturbances). There has been slight increase in area under rabi crops but still there has been fluctuations on account of having poor development regarding assured irrigation. Churu has maximum variation of annual temperature and rainfall and faces most climatic uncertainties among four districts.

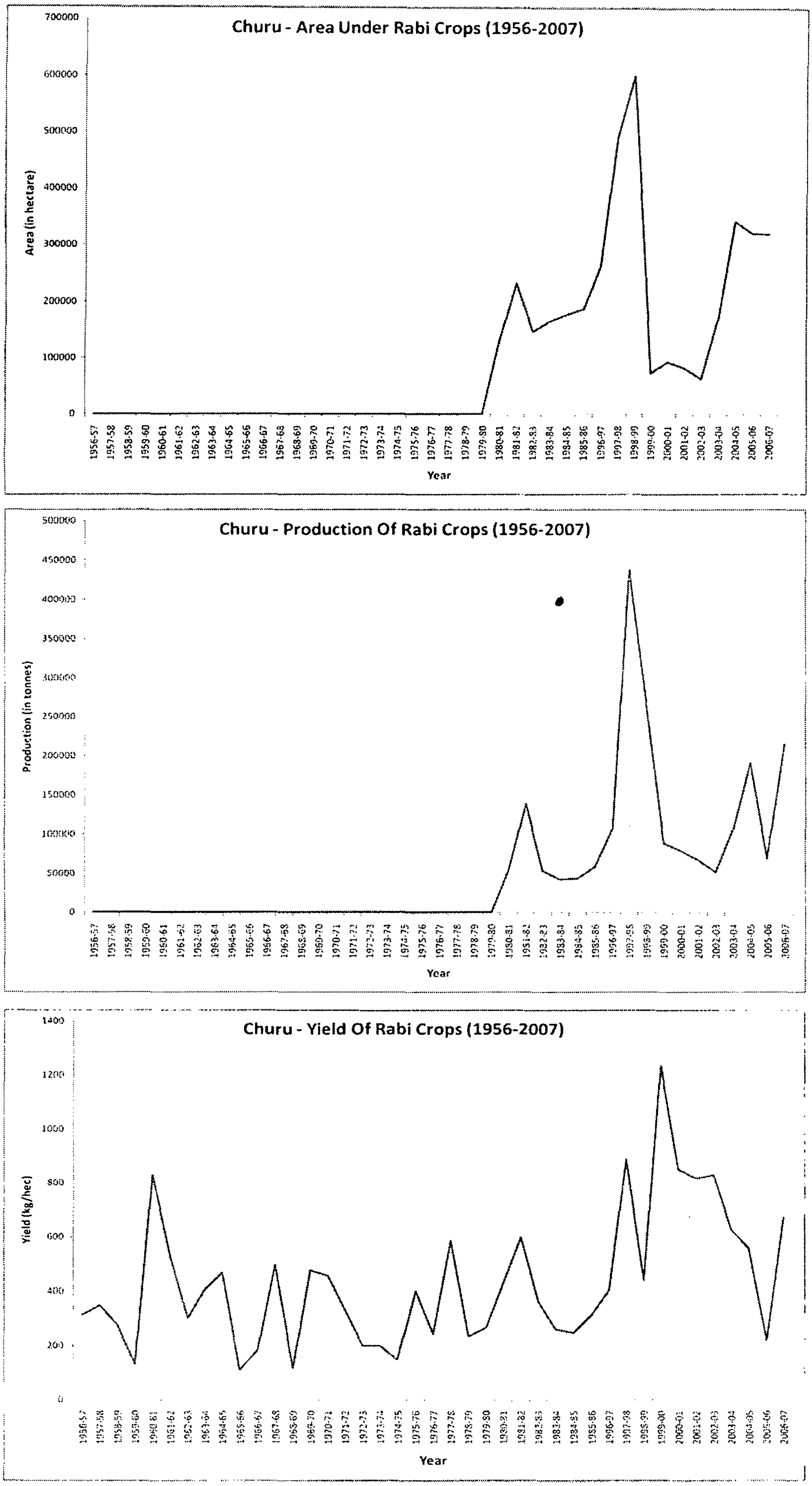


Figure 3.2: Area, Production and Yield of Rabi Crops in Churu

3.3 JHUNJHUNU DISTRICT: Jhunjhunu has relatively more area under crops since its command area is more. Means of assured irrigation has made it possible in Jhunjhunu to enhance Net Sown Area and moreover its continuation over a long time period. Area under kharif crops has been continuously increasing since 1973-74.Between 1981 -2002 there has been peak values of area under kharif crops. After it has been declining on account of two reasons, first land has been losing fertility so farmers have started leaving fallow land. Secondly ripening time of kharif crops and sowing time of rabi crops overlaps. To avoid overlapping farmers reduce area under kharif crops. Production of crops faces uncertainties because of long dry spell and scanty rainfall. There has not been any definite trend of yield but one thing is sure that both minimum and maximum value of yield has been upwardly increasing in Jhunjhunu.

In Jhunjhunu Rabi season has been more meaningful after introduction of means of assured irrigation especially tube wells. Area under rabi crops and production has been rising since 1980s. With less uncertainties compared to other three districts, fluctuations has been less contrasting which indicates that dependency on rainfall has been much less pronounced than other districts. When trends in yield of rabi crop is analysed than it was found that productivity of land has been continuously increasing on account of increasing use of chemical fertilisers and pesticide and better storage and thrashing facilities. Still drastic famine and drought has been influencing the yield, production and area. For example 1994-95 and 2002-03 has shown lowest values of yield and production as well as Net Sown Area. Fluctuations in rabi crop yield could be explained on the basis of frost, infestation etc. There has been continuous decline in area under rabi crops because most of irrigated area is dependent on tubewells. There are evidences of overexploitation of groundwater resources. Further short supply of electricity reduced scope of expansion of area under rabi crops.

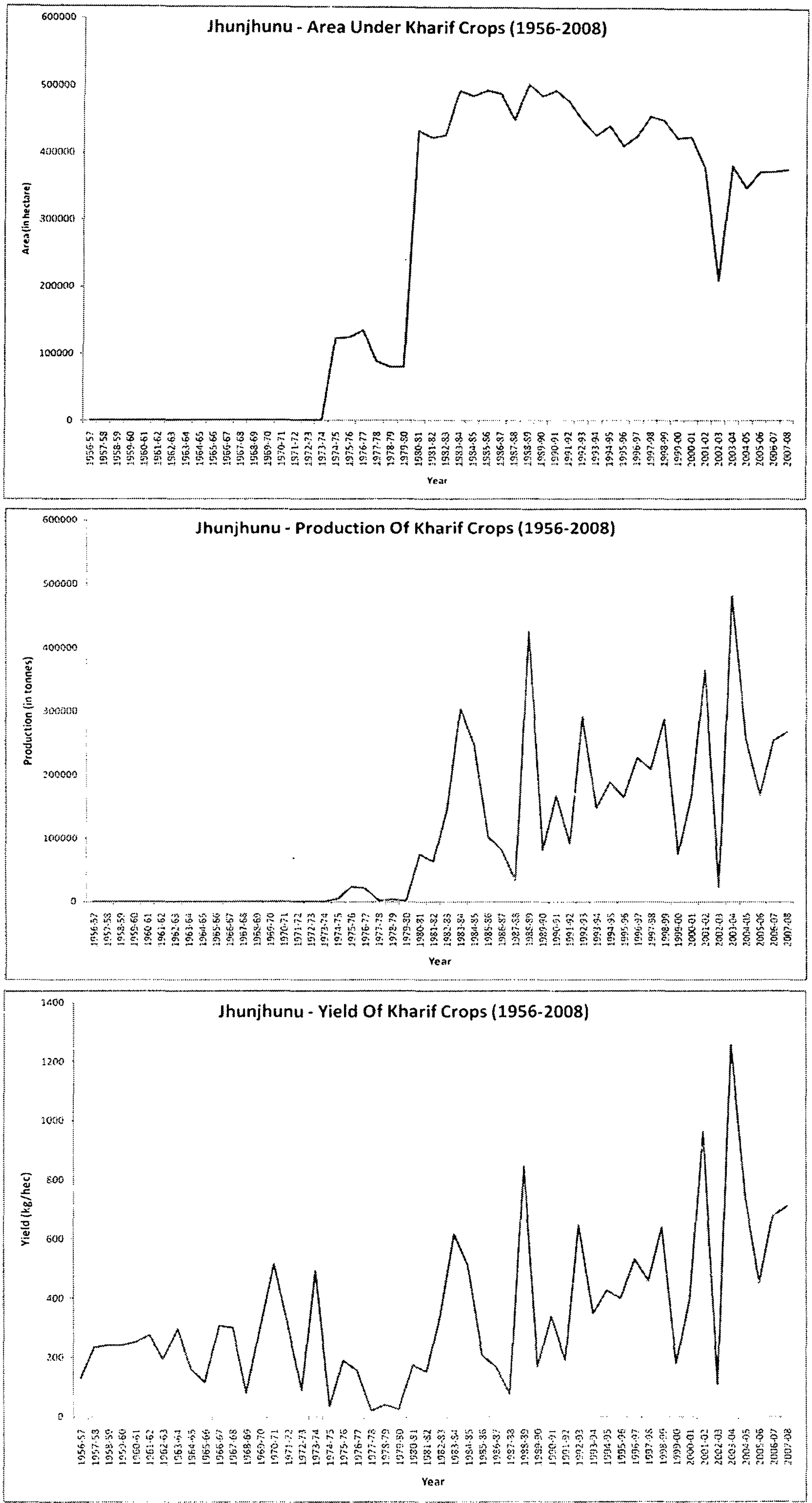


Figure 3.3: Area, Production and Yield of Rabi Crops in Jhunjhunu

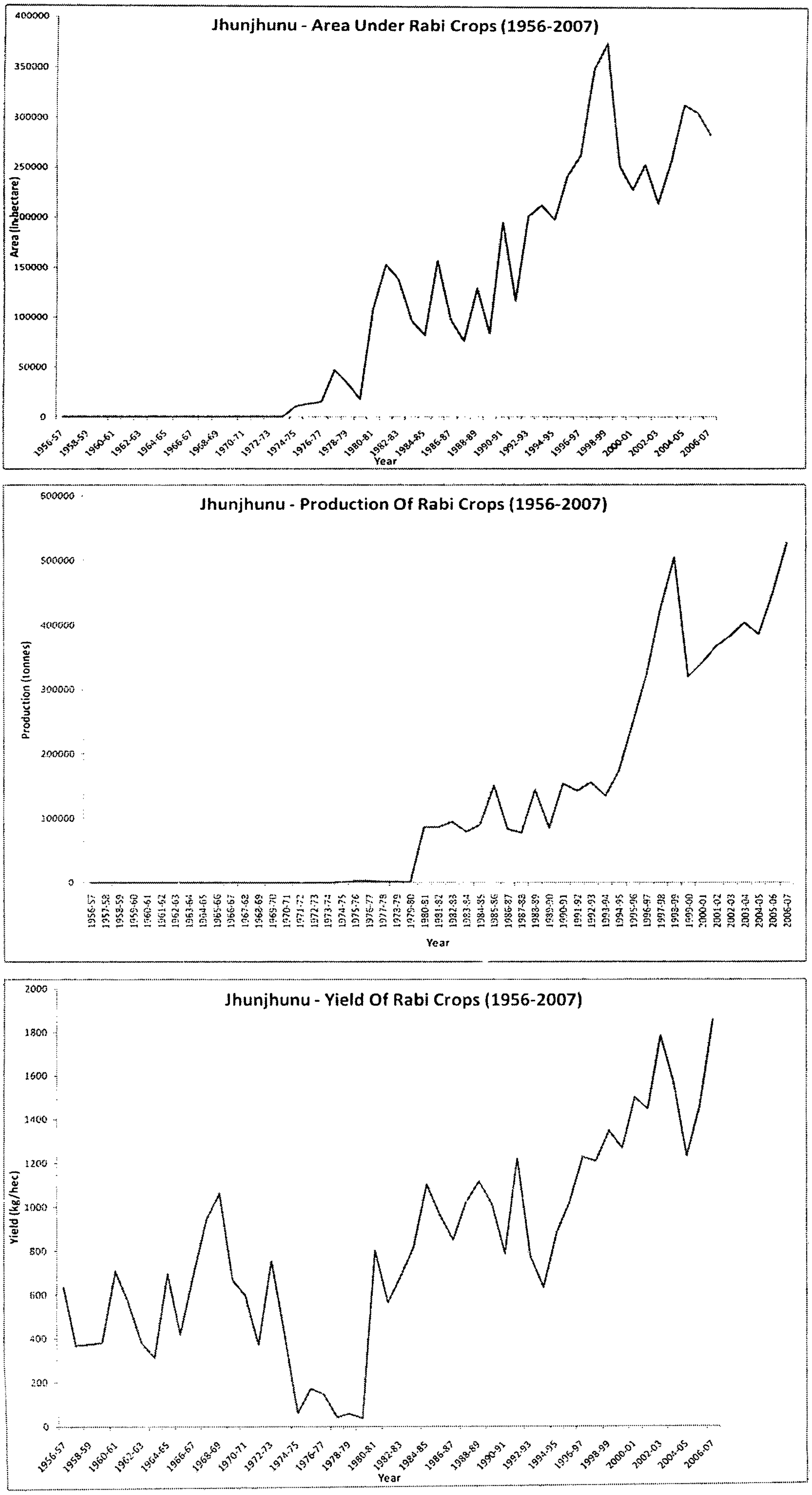


Figure 3.4: Area, Production and Yield of Rabi Crops in Jhunjhunu

3.4 NAGAUR DISTRICT: As visualised in figure 3.5 and 3.6, area under kharif in Nagaur has shown almost similar trend as shown in case of Jhunjhunu and Churu. Nagaur reached its peak in area under rabi and kharif crops between 1998-2002, time period which has fortune of good rainfall as well as mavath. In fact area under crops depends not only on amount of rainfall but also on the time at which occurs. Nagaur is an upland area. There are scattered ridges of Aravalli and patches of stony uplands and sand. Nagaur lies on eastern edge of acute desert .Nagauri soils are most suitable for pulses. That is why Nagaur despite of lacking assured water supply has more area under rabi crops. Nagaur has shown extreme downfall in value of yield during 1974-78. Drought was recorded in those years. It has been inferred from the same trend observed in all districts during same period. Nagaur is rich in animal resources. Having livestock in enough amounts it has been able to sustain fertility of soil. That is why Nagaur experienced stable growth in yield provided with sufficient amount of rainfall at appropriate time.

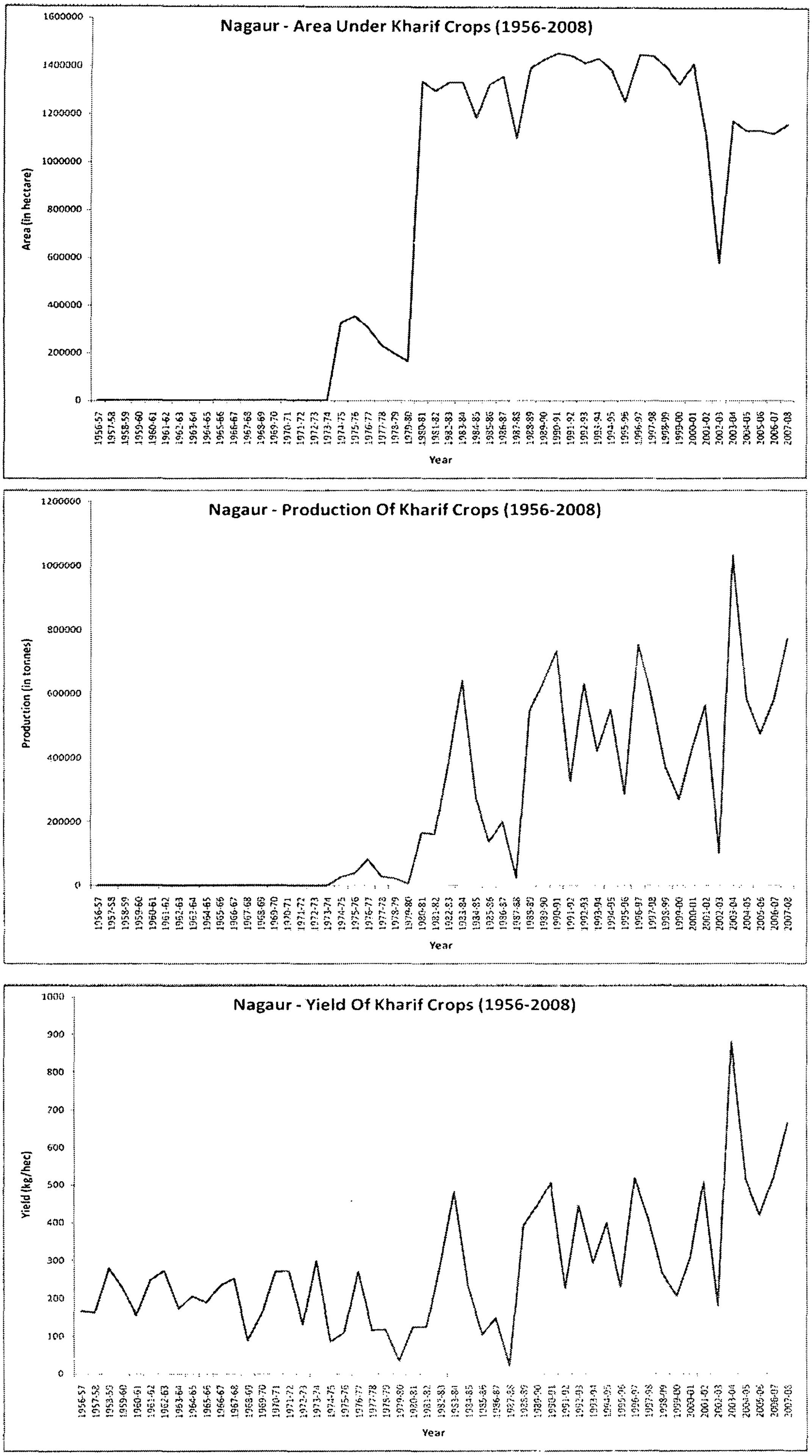


Figure 3.5: Area, Production and Yield of Rabi Crops in Nagaur

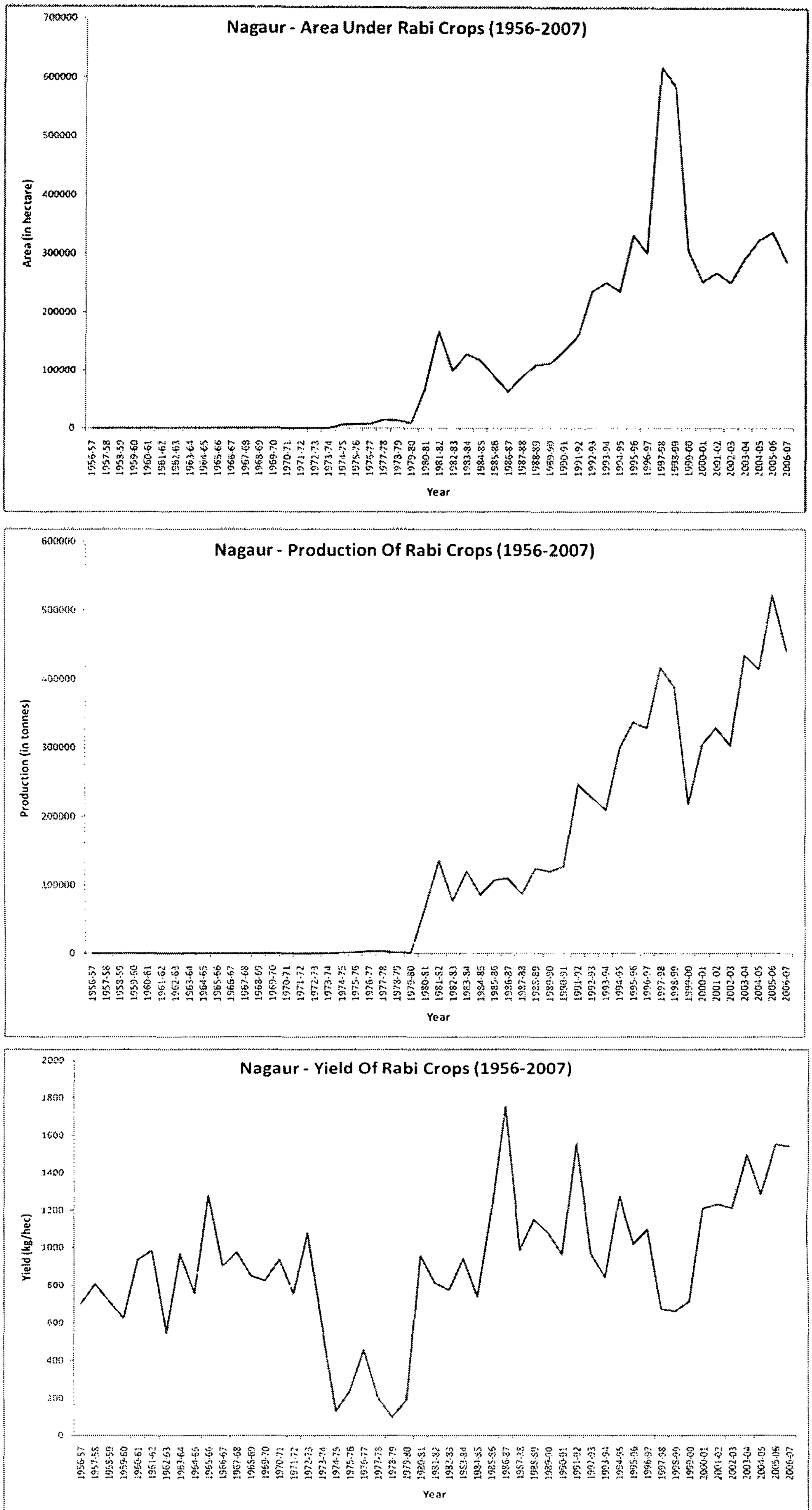


Figure 3.6: Area, Production and Yield of Rabi Crops in Nagaur

3.5 SIKAR DISTRICT: Sikar is among the good agriculturally productive districts of Rajasthan. Applying Von Thunen Model Sikar has intensive agriculture on account of nearness to Jaipur City. Sikar has shown stagnant area under kharif crops during 1980-2004 minus effect of rainfall regime. But production and yield has shown many fluctuations.

Sikar has shown steady increase under rabi crops contrary to other three districts. This is because rabi crops proved more remunerative .Keeping strategic location of Sikar in mind it can be said that guaranteed returns and commercial crops and means of assured irrigation has made possible for Sikar to achieve higher area under rabi crops. Sikar has shown same trend as other districts regarding yield and production fluctuations. However magnitude of fluctuations is less in comparison to other districts. The point to be noted is Sikar has experienced steady rise in growth of yield in rabi crops.

To conclude area under crops cannot not be strictly taken as indicator of desertification primarily because of two reasons. Firstly area under crops is a function of suitability of time of rainfall not that of advancement of desert. Secondly area under crops is subject to changes in land use. Moreover, fluctuations and their magnitude and directions do explain effects of desertification. But these fluctuations are not entirely because of desertification but partially because of lack of agricultural infrastructure and partially because of desertification.

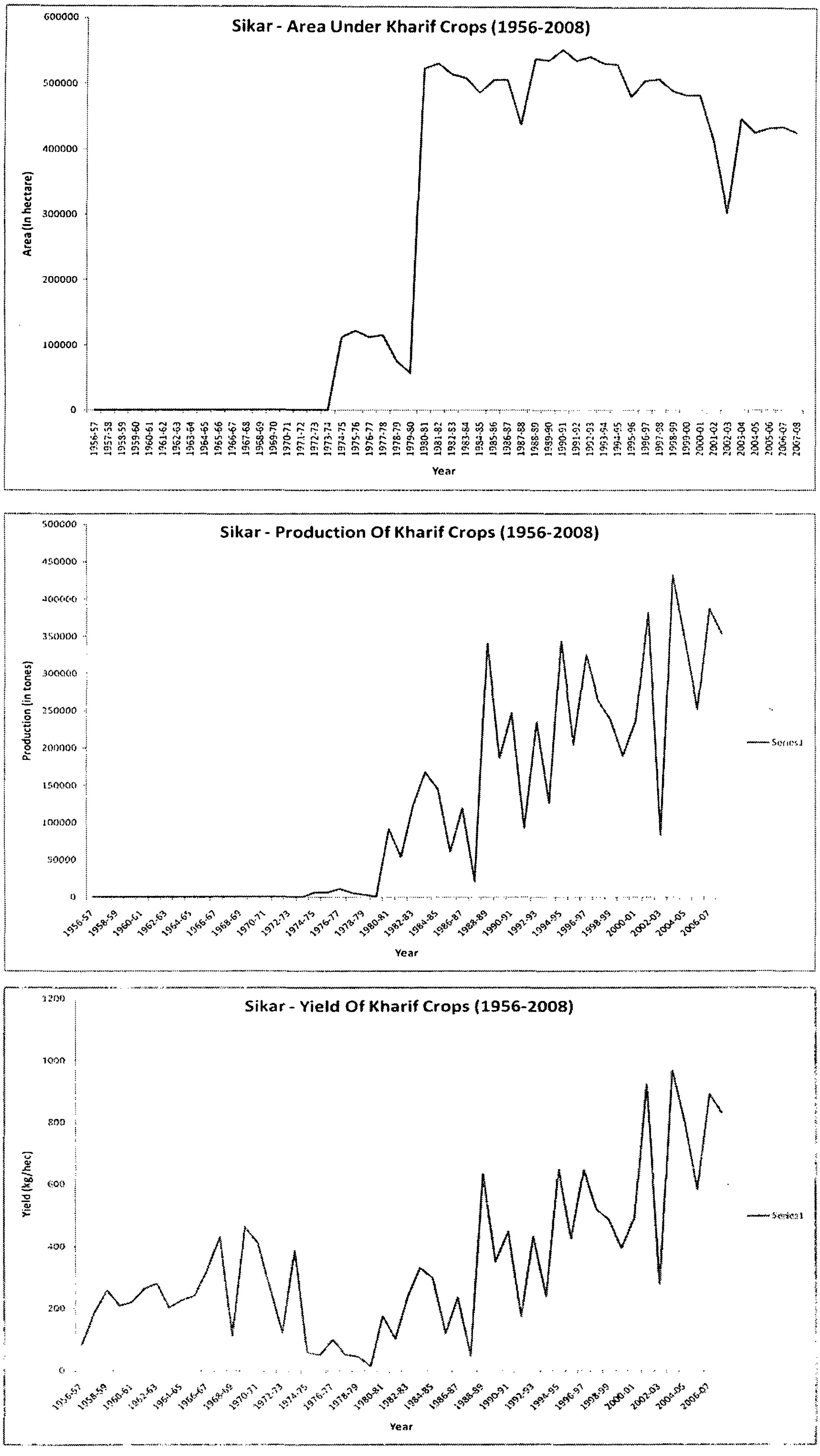


Figure 3.7: Area, Production and Yield of Kharif Crops in Sikar

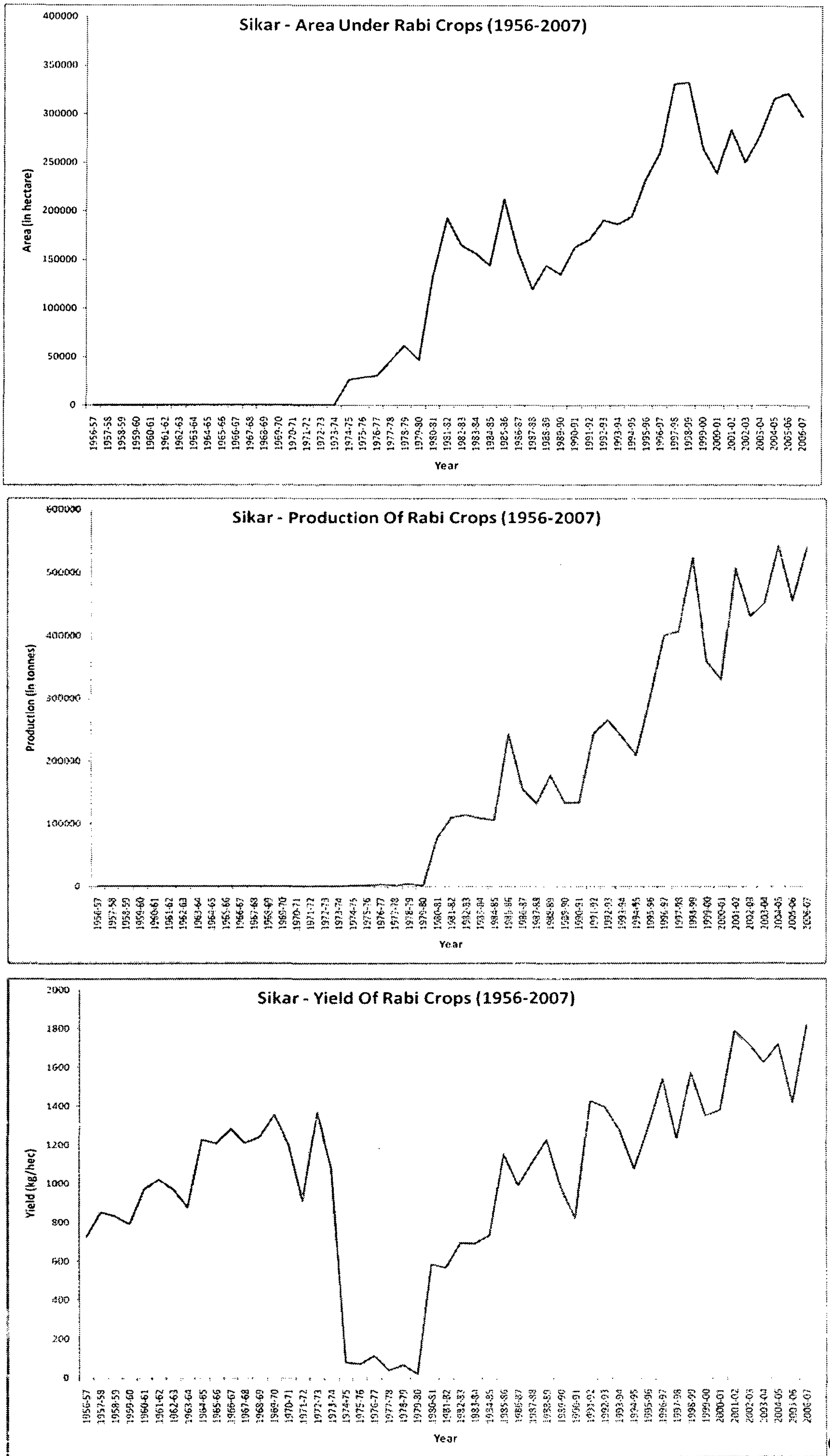


Figure 3.8: Area, Production and Yield of Rabi Crops in Sikar

Chapter Four

Temporal and Spatial Climatic Variation in Churu, Jhunjhunu, Nagaur and Sikar Districts

4.1 INTRODUCTION

The deserts such as the Thar, Sahara, Kalahari, Atacama, Namib etc. are ideal sites for the study of assessment of climatic variability and its impact on natural processes and anthropogenic activities. The wide areal extent of these regions amplifies variability in precipitation and temperature **(Liu and Chen 2000; Thompson *et al.*, 2000).** Besides being the source of mineral oil and solar energy, the Thar Desert acts as a zone of transition between Middle East and Indian sub continent and thus causes variation in meteorological and hydrological conditions of these two land masses. Even a minor change in its climate has a potential to cause disastrous consequences on the socio-economic condition of millions of people inhabiting the Indo–Gangetic plain. The longer period of existence and large spatial extent of the Thar Desert provides enormous opportunities for the climatic studies of the region. Main thrust of the current study is over the recent climatic conditions of selected districts namely Churu, Jhunjhunu, Nagaur and Sikar of Rajasthan and in this context study incorporated the instrumental data recorded at above mentioned meteorological stations. The temporal- seasonal as well as spatial variability in the climatic parameters i.e. temperature, rainfall and rainy days was analyzed.

Variation analysis is divided in two parts;-

- Temporal-Seasonal Climatic Variation analysis based on
    1. Moving Average method
    2. Normalized Accumulated Departure from Mean (NADM) method and
    3. Simple Average method.
- Spatial climatic variation analysis based on Coefficient of Variation (CV) method.

Also, on the basis of climatic parameters, the analysis is parted in two segments as,

1. Variation in temperature, rainfall and number of rainy days.
2. Variation in extreme events such as highest maximum, lowest minimum and heaviest rainfall.

4.2 TEMPORAL-SEASONAL CLIMATIC FLUCTUATION ANALYSIS USING MOVING AVERAGE METHOD

The accurate determination of trends of climate is dependent upon the availability of the reliable records over a long period of time._The moving average method is widely applied to study trend in temperature and rainfall data of a long period of time. This method smoothed out fluctuations in the curves that can be plotted on either a three, a five or ten year bases (**Monkhouse and Milkenson, 2003**). In this study 5 year base is applied to calculate the moving average/ running means on the data series of selected meteorological stations located in the study area. Table 4.1 denotes the meteorological stations included with respective properties and data span.

Table 4.1 Details of meteorological stations included in the moving average

Serial No.	Meteorological Station	Lat/Long	Data Span	Data Availability (Years)
1	Churu	28° 19' N 75° 01' E	1956-2010	54
2	Pilani (Jhunjhunu)	28° 06' N 75° 20' E	1958-2009	51
3	Nagaur	27° 00' N 73° 40' E	1958-1998	40
4	Sikar	27° 36' N 75° 15' E	1946-2003	57

4.2.1 TRENDS IN MEAN MONTHLY MAXIMUM TEMPERATURE

The seasonal variation in mean monthly maximum temperature of Churu, Jhunjhunu, Nagaur and Sikar is depicted in Figure 4.1.

- **Winter Mean Maximum Temperature**

This indicates almost uniform trend in the study area. Churu recorded increase in temperature during 1984-90 and 2004-08. Nagaur and Jhunjhunu does show more or less uniform trend for this parameter. Sikar recorded a sharp increase in temperature during 1974-80 but after that it also depicted a uniform trend.

- **Pre-Monsoon Mean Maximum Temperature**

This recorded decrease in temperature during 1978-82 in all districts except in Nagaur. Temperature in Churu, Jhunjhunu and Sikar showed uniform trend up to 1984 and thereafter it recorded increase up to 1988 and thereafter it declined once again.

- **Monsoon Mean Maximum Temperature**

It can be observed from the figure that fluctuations in Pre-Monsoon Mean Maximum Temperature were preceded by fluctuations in Monsoon Mean Maximum temperature in Churu and Jhunjhunu. Both recorded a decline in temperature between 1974 and 1978. Thereafter temperature increased up to 1982 in these districts and then it showed uniform trend. Nagaur has shown uniform trend over the entire time period. Interestingly Sikar showed declining trend between 1978-1982 and recorded increase during 1984-1988 which is simultaneous with fluctuations in Pre Monsoon Mean Maximum temperature.

- **Post-Monsoon Mean Maximum Temperature**

In Post-monsoon season variation in mean maximum temperature is similar to the winter. Sikar recorded decrease in temperature during 1972-78 and 1992-98 respectively.

- **Annual Mean Maximum Temperature**

It didn't experience so much variation. Sikar recorded decrease in temperature during 1972-78 and 1992-98 respectively while Churu, Jhunjhunu and Nagaur reflected uniform trend of temperature.

4.2.2 TRENDS IN MEAN MONTHLY MINIMUM TEMPERATURE

The seasonal variation in mean monthly maximum temperature of Churu, Jhunjhunu, Nagaur and Sikar is depicted in Figure 4.2.

- **Winter Mean Minimum Temperature**

Mean minimum temperature recorded high fluctuations at Churu. An increase in temperature was recorded during 1976-82 and 1984-88 while decrease was recorded during 1972-76 and 1982-84. Sikar recorded a sharp increase in temperature during 1974-80 and then it declined again. All districts recorded an increasing trend from 1994 onwards..

- **Pre-Monsoon Mean Minimum Temperature**

Here except Sikar all other districts recorded uniform temperature trend. Sikar recorded a sharp increase in temperature during 1974-80 and then it declined again. Sikar and Jhunjhunu recorded an increasing trend from 1994 onwards.

- **Monsoon Mean Minimum Temperature**

Here except Sikar all other districts recorded uniform temperature trend. Sikar recorded a sharp decrease in temperature during 1974-80 and then it increased again. Sikar recorded an increasing trend from 1994 onwards.

- **Post-Monsoon Mean Minimum Temperature**

Here except Sikar and Nagaur the other two districts recorded uniform temperature trend. Sikar recorded an increasing trend during 1982-88 and the again from 1994 onwards. Nagaur experienced increase in temperature during 1972-80.

- **Annual Mean Minimum Temperature**

Here except Sikar all other districts recorded uniform temperature trend. Sikar recorded an increasing trend from 1994 onwards.

Overall, all districts recorded variations in the minimum temperature during the fourth quarter of the last century.

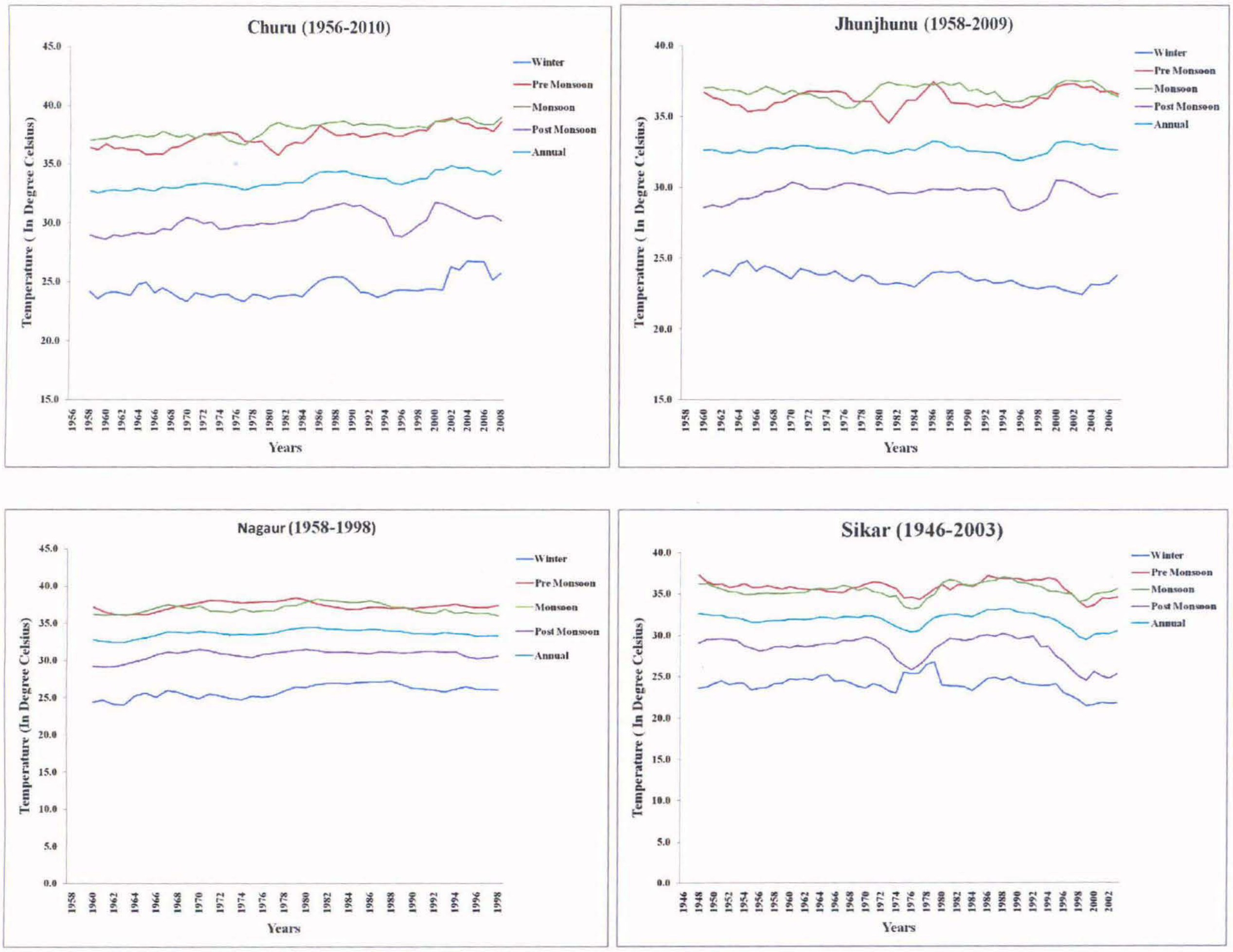


Figure 4.1: Seasonal fluctuation in Mean Monthly Maximum Temperature

Source: National Data Centre, IMD, Pune

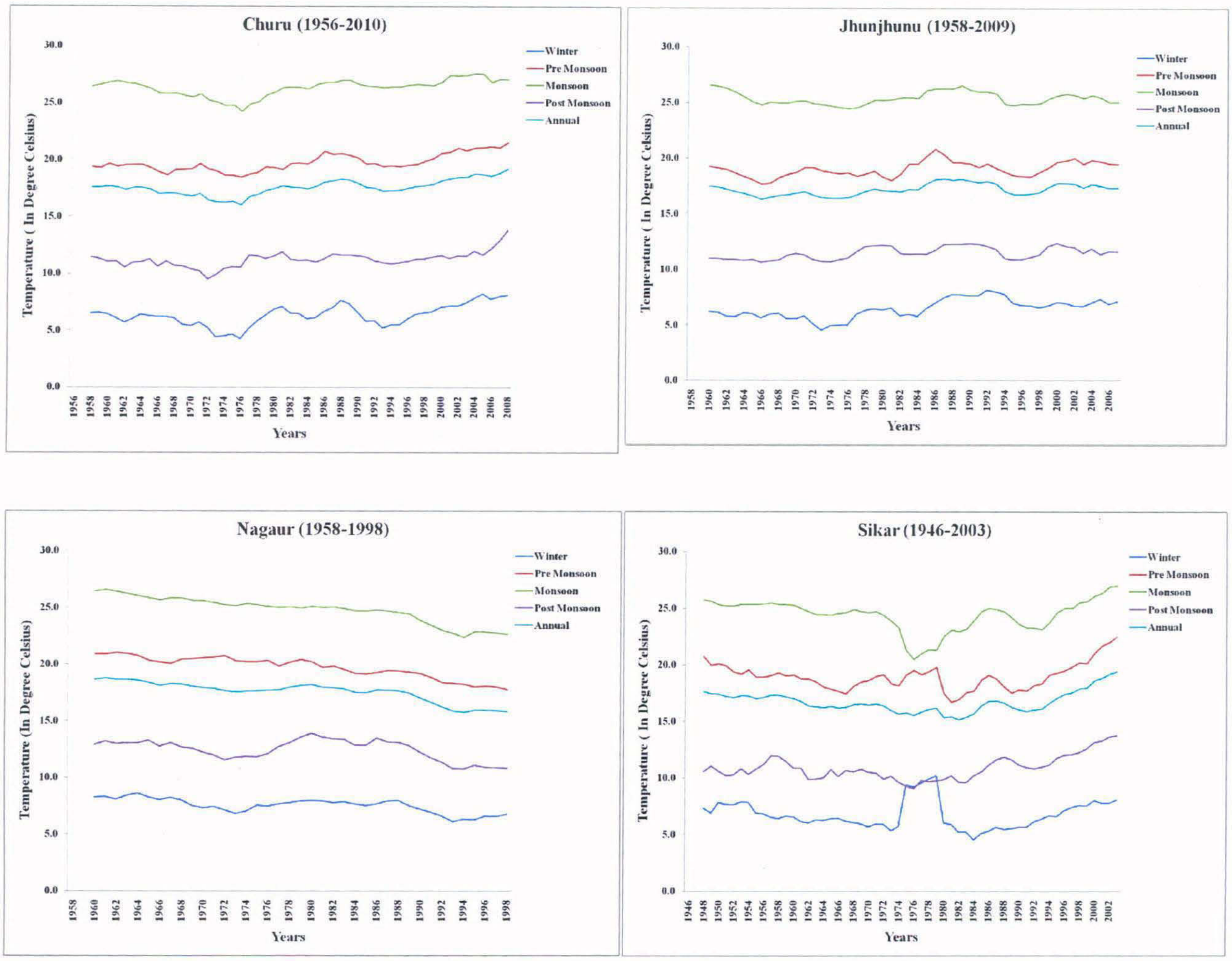


Figure 4.2: Seasonal fluctuation in Mean Monthly Minimum Temperature

Source: National Data Centre, IMD, Pune

4.2.3 TRENDS IN MEAN MONTHLY TEMPERATURE

The seasonal variation in mean monthly average temperature of Churu, Jhunjhunu, Nagaur and Sikar is depicted in Figure 4.3.

The mean monthly average temperature did not show any observable trend during all seasons namely winter, pre-monsoon, monsoon and monsoon in Churu, Jhunjhunu and Nagaur districts. But winter temperature in Sikar recorded a sharp increase during 1974 -80 and thereafter it declined and depicted uniform trend. Monsoon temperature trend was just opposite to winter temperature trend in Sikar. It recorded a sharp decrease during 1974 -80 and thereafter it increased and depicted uniform trend.

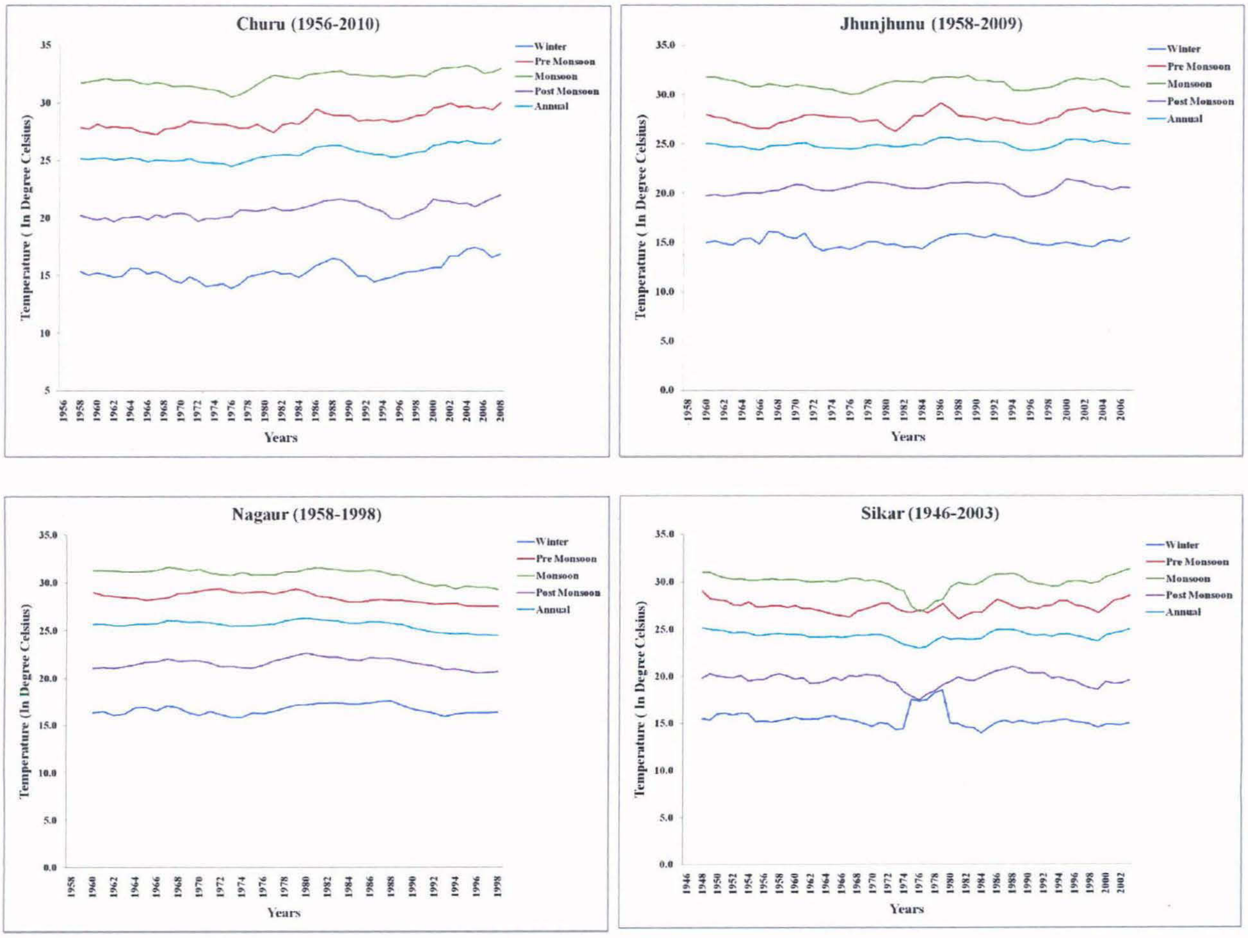


Figure 4.3: Seasonal fluctuation in Mean Monthly Temperature

Source: National Data Centre, IMD, Pune

4.2.4 TRENDS IN MEAN MONTHLY RAINFALL

The state of Rajasthan receives more than 80 per cent of rainfall in monsoon season. The variations recorded in the amount of monthly rainfall are the consequences of many local physical factors and their interactions such as local topography, physical barriers to obstacle the monsoon etc. That's why variation in rainfall is more complex than variation in the temperature. Local factors affect the monsoonal rainfall at a large extent. Figure 4.4 shows the variation in the monthly rainfall regime of the four selected districts of the state.

- **Winter Rainfall**

All the four districts recorded uniform trends in winter rainfall. Churu experienced two peak times of the winter rainfall, one during 1974-80 and other during 1990-96. Sikar experienced single peak of the winter rainfall during 1974-80.

- **Pre-Monsoon Rainfall**

Here also Sikar experienced single peak of the rainfall during 1974-80 whereas other districts experienced the same more or less uniform trend of rainfall.

- **Monsoon Rainfall**

An overview of the figure 4.4 suggests that Churu experienced two peak times of the monsoon rainfall, one during 1974-80 and other during 1990-96. Nagaur recorded increasing trend during 1968-78 and then from 1982 onwards. Jhunjhunu also experienced two peak times of the monsoon rainfall, one during 1974-80 and other during 1990-96. Sikar recorded uniform trend with a peak in 1978 and then observed declining trend from 1996 onwards.

- **Post-Monsoon Rainfall**

Here Churu experienced increasing trend during 1972-76, 1982-84 and 1992-96 whereas all other districts did experience more or less uniform trend.

- **Annual Rainfall**

An overview of the figure 4.4 suggests that Churu experienced two peak times of the annual rainfall, one during 1974-80 and other during 1990-96. Nagaur recorded increasing trend during 1968-78 and then from 1982 onwards. Jhunjhunu also experienced two peak times of the annual rainfall, one during 1974-80 and other during 1990-96. Sikar recorded uniform trend with a peak in 1978 and then observed declining trend from 1996 onwards.

Figure 4.4: Seasonal fluctuation in Mean Monthly Rainfall

Source: National Data Centre, IMD, Pune

4.2.5 TRENDS IN MEAN MONTHLY NUMBER OF RAINY DAYS

Number of rainy days suggests about the wet spells of a year and also represents the intensity and performance of the monsoon. Figure 4.5 depicts trend in number of rainy days.

- **Number of Rainy Days in Winter**

All the four districts recorded uniform trends in number of rainy days. Churu experienced increasing trend in number of rainy days twice, one during 1974-80 and other during 1990-96. Sikar experienced increasing trend in number of rainy days during 1974-80.

- **Number of Rainy Days in Pre-Monsoon**

Here also Sikar experienced increasing trend in number of rainy days during 1974-80 whereas other districts experienced increasing trend in number of rainy days during 1980-86.

- **Number of Rainy Days in Monsoon**

An overview of the figure 4.5 suggests that Churu experienced increasing trend in number of rainy days twice, one during 1974-80 and other during 1990-96. Nagaur recorded increasing trend during 1968-78 and then from 1982 onwards. Jhunjhunu also experienced increasing trend in number of rainy days twice, one during 1974-80 and other during 1990-96. Sikar recorded uniform trend with a peak in 1978 and then observed declining trend from 1996 onwards.

- **Number of Rainy Days in Post-Monsoon**

Here Churu experienced increasing trend during 1972-76, 1982-84 and 1992-96 whereas all other districts did experience more or less uniform trend.

- **Number of Rainy Days Annual**

An overview of the figure 4.5 suggests that Churu experienced increasing trend in number of rainy days twice, one during 1974-80 and other during 1990-

1996. Nagaur recorded increasing trend during 1968-78 and then from 1982 onwards. Jhunjhunu also experienced increasing trend in number of rainy days twice, one during 1974-80 and other during 1990-96. Sikar recorded uniform trend with a peak in 1978 and then observed declining trend from 1996 onwards.

Figure 4.5: Seasonal fluctuation in Mean Monthly Number of Rainy Days

Source: National Data Centre, IMD, Pune

4.2.6 TEMPORAL-SEASONAL VARIATION IN EXTREME EVENTS

Along with the basic climatic elements maximum and minimum temperature and rainfall, some of the extreme events such as highest maximum temperature, lowest minimum temperature and highest total monthly rainfall were also included in the study, as they present variation in the extremity of basic elements. These events have been presented graphically as the figures themselves are self explanatory.

4.2.6.1 Trends in Mean Monthly Highest Maximum Temperature

Figure 4.6 depicts the variation in the mean monthly highest maximum temperature in Churu, Jhunjhunu, Nagaur and Sikar districts.

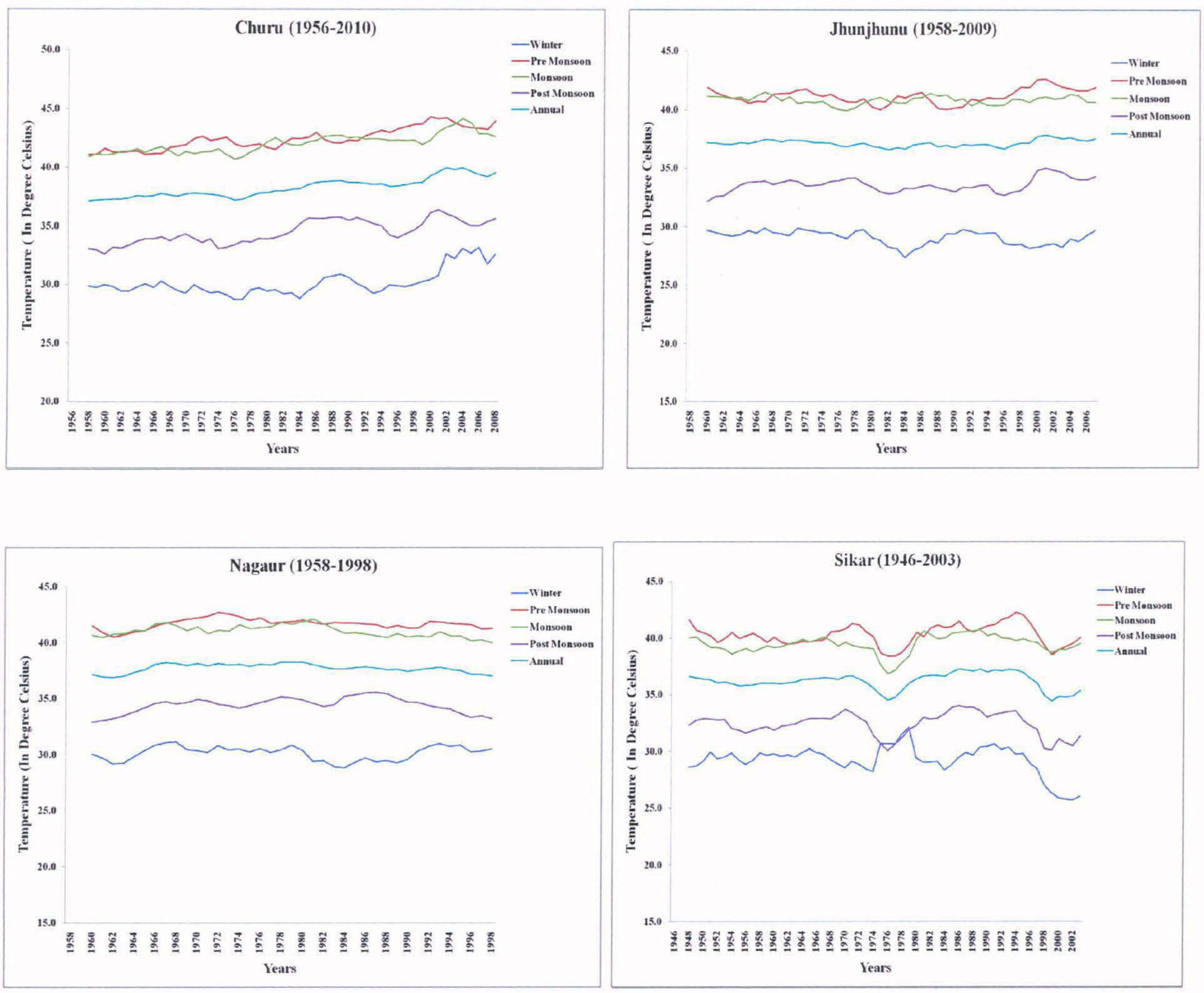


Figure 4.6: Seasonal fluctuation in Mean Monthly Highest Maximum Temperature

Source: National Data Centre, IMD, Pune

4.2.6.2 Trends in Mean Monthly Lowest Minimum Temperature

Figure 4.7 depicts the variation in the mean monthly lowest minimum temperature in Churu, Jhunjhunu, Nagaur and Sikar districts.

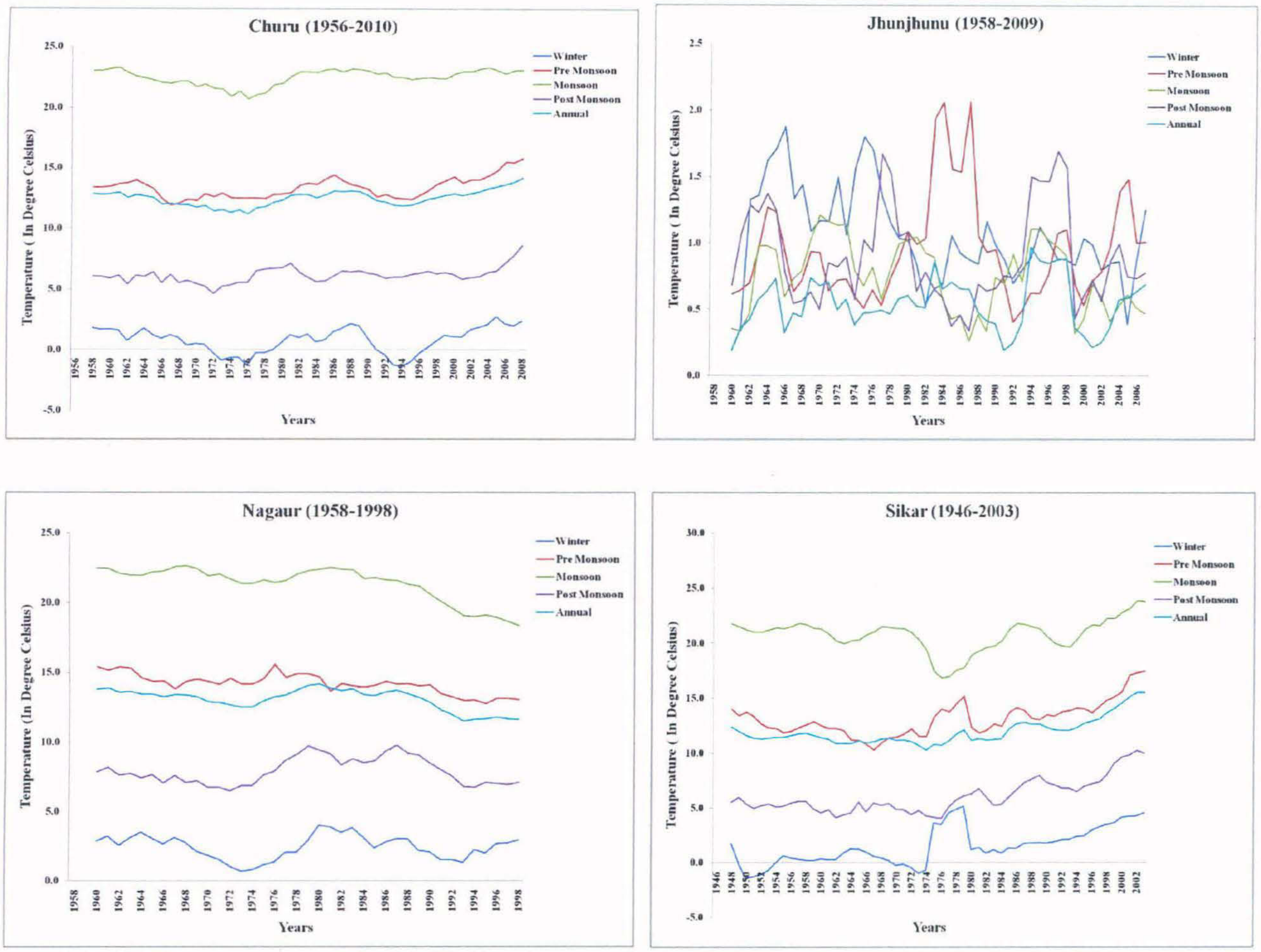


Figure 4.7: Seasonal fluctuation in Mean Monthly Lowest Minimum Temperature

Source: National Data Centre, IMD, Pune

4.2.6.3 Trends in Mean Monthly Heaviest Rainfall

Figure 4.8 represents the seasonal variation in mean monthly heaviest rainfall in Churu, Jhunjhunu, Nagaur and Sikar districts.

Figure 4.8: Seasonal fluctuation in Mean Monthly Heaviest Rainfall

Source: National Data Centre, IMD, Pune

4.3 TEMPORAL-SEASONAL CLIMATIC FLUCTUATION ANALYSIS USING NORMALIZED ACCUMULATED DEPARTURE FROM MEAN (NADM) METHOD

Since the time span of rainfall and temperature data record at Churu, Jhunjhunu, Nagaur and Sikar districts is short. Therefore, the normalized accumulated departure from mean (NADM) is a suitable method to analyze the temporal fluctuations and trends in temperature and rainfall. NADM permits visual as well as statistical comparison of unlike data periods characterized by above average (below average) conditions are indicated by positive (negative) slopes of the graph. Unlike other methods, such as moving average, the NADM permits the distinction between periods of high and low values by clearly defining the limits.

Due to specific requirements and demand of the study, only three variables i.e. mean monthly temperature, total monthly rainfall and number of rainy days were included in the study and annual data series was used, as the inclusion of all the seasons' data made the interpretation difficult. Table 4.2 depicting the information about the different meteorological stations included in the study.

Table 4.2 Information about the meteorological stations included in NADM analysis

Searial No.	Meteorological Station	Data Span	Data Availability (Years)	Variables	Seasons
1	Churu	1956-2010	54	Mean Monthly Temperature	
2	Pilani (Jhunjhunu)	1958-2009	51		
3	Nagaur	1958-1998	40	Total Monthly Rainfall	Annual
4	Sikar	1946-2003	57		
				Number of Rainy Days	
Note:- Variables and Seasons are common to all the stations.					

4.3.1 TRENDS IN MEAN MONTHLY TEMPERATURE

Figure 4.9 shows the annual trends in mean monthly temperature for the selected meteorological stations of Churu, Jhunjhunu, Nagaur and Sikar districts. The mean monthly temperature experienced positive NADM during 1984-92 and from 1998 onwards at Churu while negative value of NADM was recorded during 1956-82. Nagaur recorded positive departure of mean temperature during the entire period except during 1962, 1975 and from 1990 onwards where it recorded negative departure. The station experienced static trend in mean temperature during 1964-66. A sharp increasing trend in mean temperature was recorded at Jhunjhunu during 1984-94 and 1998-2004. The station experienced negative departure of mean monthly temperature during 1964-68 and 1970-79. Sikar recorded positive departure of mean temperature during 1952-54 and 1984-91 and negative departure during 1972-78 and 1996-2000. The station experienced increasing trends after 2001.

. 4.3.2 TRENDS IN MEAN MONTHLY RAINFALL

Figure 4.10 represents the trends and departure from mean monthly rainfall of selected meteorological stations of Churu, Jhunjhunu, Nagaur and Sikar districts. The mean monthly rainfall experienced positive NADM during 1964, 1974, 1978 and 1996-98 at Churu while negative value of NADM was recorded from 1998 onwards except in 2008. Nagaur recorded positive departure of mean rainfall during almost entire period except during 1966-69 and 1978-84 where it recorded negative departure. A sharp increasing trend in mean monthly rainfall was recorded at Jhunjhunu during 1974-79 and 1994-98. The station experienced negative departure of mean monthly rainfall during 1970-74 and 1998-04. Sikar recorded positive departure of mean rainfall during 1954-58 and 1973-79 and negative departure during 1988-91 and from 1997 onwards. The station experienced decreasing trends after 1997.

4.3.3 TRENDS IN MEAN MONTHLY NUMBER OF RAINY DAYS

Figure 4.11 shows the annual trends in mean monthly number of rainy days for the selected meteorological stations of Churu, Jhunjhunu, Nagaur and Sikar districts. The mean monthly number of rainy days experienced positive NADM during 1960-64 and 1993-98 at Churu while negative value of NADM was recorded during 1972-74 and 2000-04. Nagaur recorded positive departure of mean monthly number of rainy days during the entire period except during 1963,1965,1968,1988 and 1994 where it recorded negative departure. The station experienced static trend in mean temperature during 1968-86. A sharp increasing trend in mean monthly number of rainy days was recorded at Pilani during 1974-78. The station represented negative departure of mean monthly number of rainy days during 1998-2004 and positive departure during 1990-94 and 1996-98. Sikar recorded positive departure of mean monthly number of rainy days during 1954-60 and 1976-78 and negative departure during 1964-66. The station experienced negative trend in mean monthly number of rainy days during 1984-91 but experienced increasing trends after 1991. The station also experienced persistent negative trend in mean monthly number of rainy days from 1996 onwards.

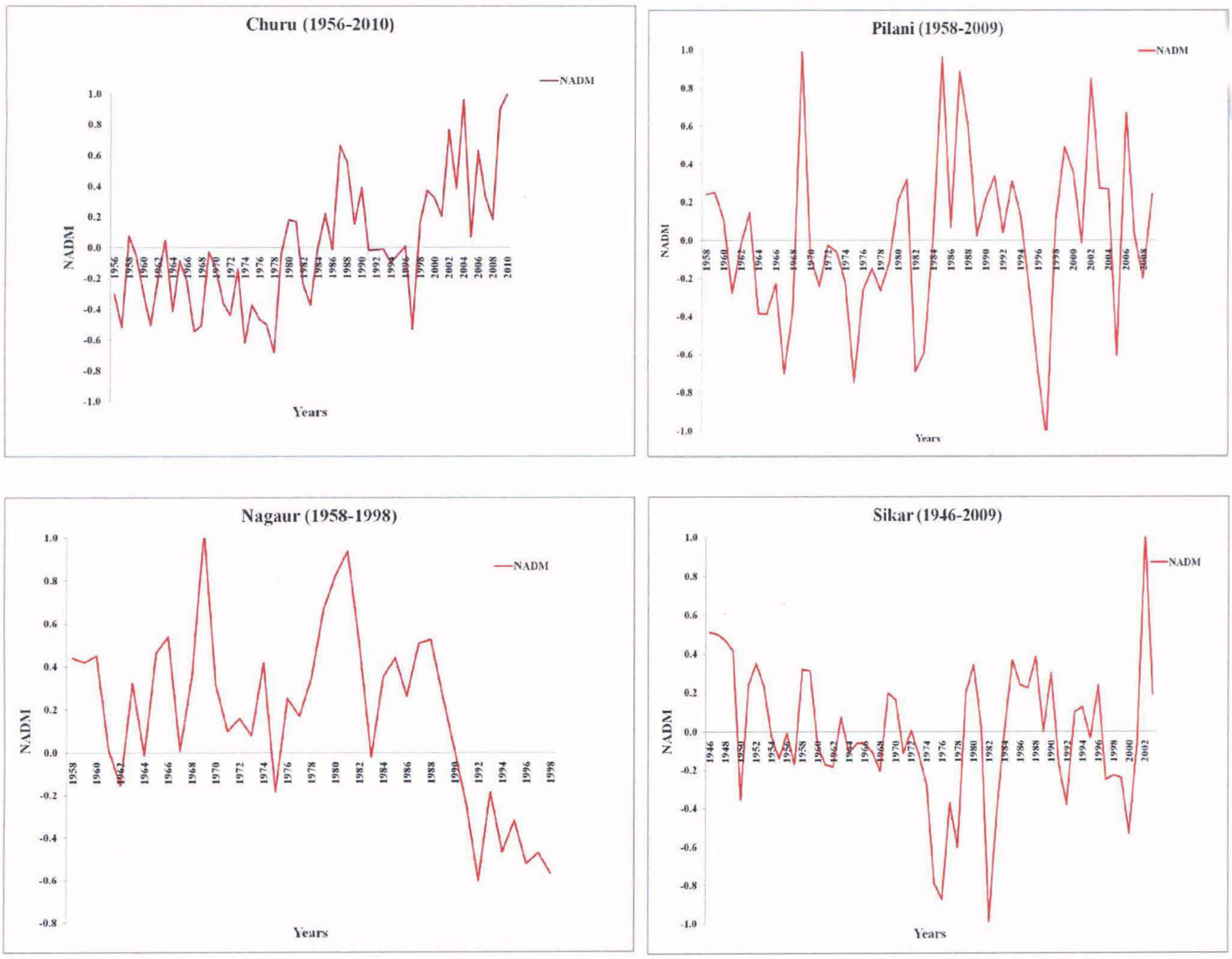


Figure 4.9: Seasonal fluctuation in Mean Monthly Temperature (NADM method)

Source: National Data Centre, IMD, Pune

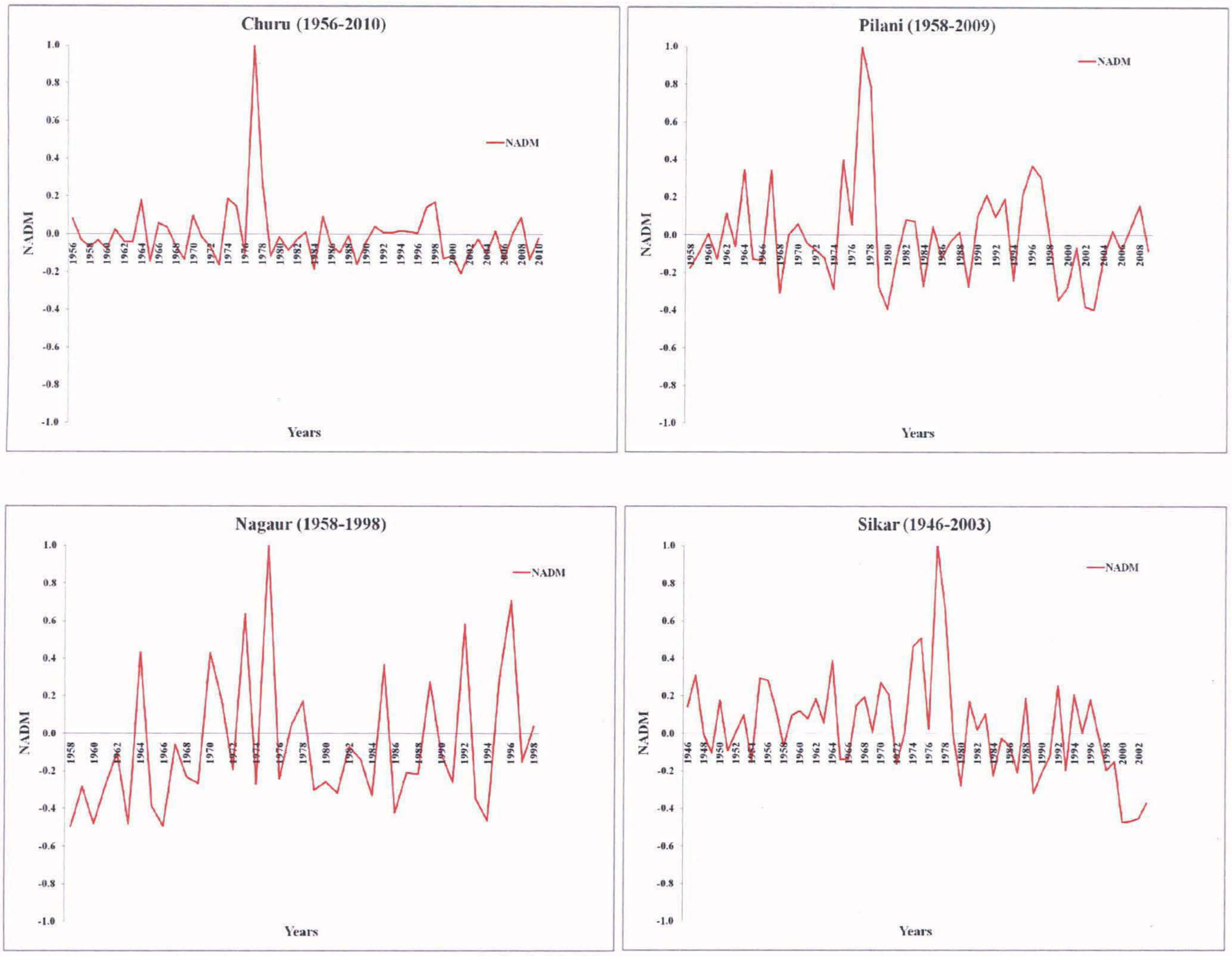


Figure 4.10: Seasonal fluctuation in Mean Monthly Rainfall (NADM method)

Source: National Data Centre, IMD, Pune

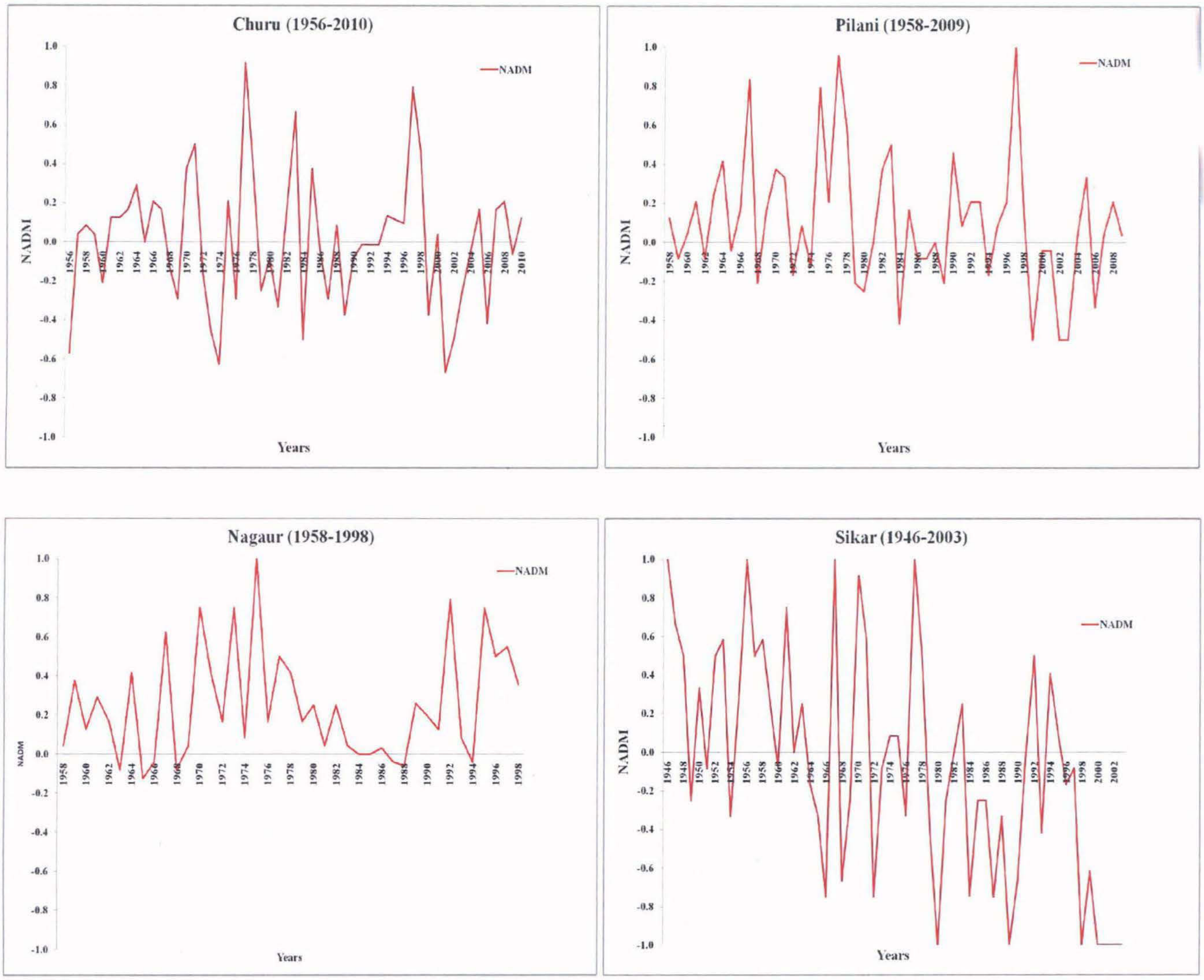


Figure 4.11: Seasonal fluctuation in Mean Monthly Number of Rainy Days (NADM method)

Source: National Data Centre, IMD, Pune

4.4 TEMPORAL-SEASONAL CLIMATIC VARIATION ANALYSIS USING SIMPLE AVERAGE METHOD

Simple average method facilitate the comparison of two climatic or base line periods and identify the variation occurred in the second period over the first one. As the 31 years period is generally regarded as one climatic period or base line period. But none of the meteorological stations viz. Churu, Jhunjhunu, Nagaur and Sikar had data for such a long period. Therefore, 25 years period was taken as one base line period. The detailed information about the stations, variables and seasons used in this analysis is given in table 4.3. The basic climatic variables, such as maximum, minimum and mean temperature, rainfall and number of rainy days were used in the analysis.

25 years base-line periods or climatic periods were calculated for Churu, Jhunjhunu, Nagaur and Sikar.

Table 4.3 Information about the meteorological stations used in the Simple Average Analysis

Serial No.	Station	Data Span	Base Line Periods	BP Codes	Variable	Season
1	Churu	1956-2010	1958-1983	BP-I	Mean Monthly Temperature	Winter
			1984-2008	BP-II	Mean Monthly Rainfall	Monsoon
					Number of Rainy Days	Annual
2	Pilani (Jhunjhunu	1958-2009	1958-1983	BP-I	Mean Monthly Temperature	Winter
			1984-2008	BP-II	Mean Monthly Rainfall	Monsoon
					Number of Rainy Days	Annual
3	Nagaur	1958-2009	1958-1983	BP-I	Mean Monthly Temperature	Winter
			1984-2008	BP-II	Mean Monthly Rainfall	Monsoon
					Number of Rainy Days	Annual
4	Sikar	1946-2009	1958-1983	BP-I	Mean Monthly Temperature	Winter
			1984-2008	BP-II	Mean Monthly Rainfall	Monsoon
					Number of Rainy Days	Annual

Table 4.4 Seasonal climatic variation analysis using Simple Average Method

	Variation in Meam Monthly Maximum Temperature (In Degree Celsius)									
Station	Base Line Periods	Winter			Monsoon			Annual		
		CV (in percent)	Simple Average	Variation	CV (in per cent)	Simple Average	Variation	CV (in per cent)	Simple Average	Variation
Churu	1958-1983	5.7	24.0		3.1	37.5		1.8	33.0	
	1984-2008	9.4	24.9	1.0	2.0	38.4	0.9	2.4	34.1	1.1
Nagaur	1958-1983	6.6	25.4		3.1	36.9		2.5	33.5	
	1984-2008	3.2	26.1	0.8	2.8	36.5	-0.4	1.4	33.7	0.2
Pilani (Jhunjhunu)	1958-1983	5.3	23.8		2.7	36.7		1.5	32.6	
	1984-2008	5.6	23.3	-0.5	2.6	36.9	0.2	2.2	32.7	0.1
Sikar	1958-1983	11.3	24.6		4.7	35.3		3.2	31.9	
	1984-2008	8.8	22.9	-1.7	4.0	35.6	0.3	5.7	31.3	-0.5

	Variation in Meam Monthly Minimum Temperature (In Degree Celsius)									
Station	Base Line Periods	Winter			Monsoon			Annual		
		CV (in percent)	Simple Average	Variation	CV (in per cent)	Simple Average	Variation	CV (in per cent)	Simple Average	Variation
Churu	1958-1983	26.6	5.9		4.2	25.8		5.3	17.1	
	1984-2008	23.1	6.7	0.8	3.0	26.8	1.0	3.9	18.0	0.9
Nagaur	1958-1983	11.8	7.9		3.0	25.6		3.4	18.1	
	1984-2008	12.4	6.8	-1.1	5.9	22.9	-2.7	7.3	16.0	-2.1
Pilani (Jhunjhunu)	1958-1983	22.0	5.9		3.6	25.3		3.6	16.9	
	1984-2008	19.6	7.1	1.2	4.0	25.6	0.3	5.2	17.5	0.7
Sikar	1958-1983	54.5	6.7		10.5	23.6		6.5	16.1	
	1984-2008	23.0	6.9	0.2	6.9	25.4	1.8	8.8	17.7	1.6

	Variation in Meam Monthly Temperature (In Degree Celsius)									
Station	Base Line Periods	Winter			Monsoon			Annual		
		CV (in percent)	Simple Average	Variation	CV (in per cent)	Simple Average	Variation	CV (in per cent)	Simple Average	Variation
Churu	1958-1983	6.2	16.0		2.1	31.6		1.7	25.7	
	1984-2008	4.2	16.3	0.3	1.6	31.8	0.2	1.7	26.0	0.4
Nagaur	1958-1983	6.1	17.4		1.9	30.7		1.7	26.0	
	1984-2008	4.0	17.6	0.2	1.8	31.0	0.3	1.8	26.4	0.4
Pilani (Jhunjhunu)	1958-1983	6.0	15.6		2.3	30.3		1.8	24.8	
	1984-2008	3.9	15.8	0.2	1.8	30.5	0.2	1.6	25.1	0.3
Sikar	1958-1983	6.2	16.2		2.1	30.3		1.8	25.2	
	1984-2008	4.0	16.4	0.2	1.7	30.6	0.3	1.7	25.5	0.4

Variation in Meam Monthly Rainfall (In mm)

Station	Base Line Periods	Winter			Monsoon			Annual		
		CV (in percent)	Simple Average	Variation	CV (in per cent)	Simple Average	Variation	CV (in per cent)	Simple Average	Variation
Churu	1958-1983	386.7	28.0		51.7	84.9		71.1	39.1	
	1984-2008	123.0	11.0	-17.0	36.4	68.1	-16.8	38.5	31.5	-7.6
Nagaur	1958-1983	174.2	4.2		63.7	75.7		58.4	28.9	
	1984-2008	93.2	7.8	3.7	44.5	95.4	19.7	38.5	37.0	8.1
Pilani (Jhunjhunu)	1958-1983	125.8	8.1		57.3	96.2		47.8	37.9	
	1984-2008	95.5	9.6	1.5	43.0	80.6	-15.7	36.3	33.9	-4.0
Sikar	1958-1983	269.9	11.1		47.7	99.5		42.6	42.2	
	1984-2008	142.9	5.2	-5.9	87.2	50.3	-49.2	73.5	20.2	-21.9

Variation in Meam Monthly Number of Rainy Days

Station	Base Line Periods	Winter			Monsoon			Annual		
		CV (in percent)	Simple Average	Variation	CV (in per cent)	Simple Average	Variation	CV (in per cent)	Simple Average	Variation
Churu	1958-1983	90	1		38	5		33	2	
	1984-2008	83	1	0.1	33	4	-0.6	35	2	-0.2
Nagaur	1958-1983	131	0.3		44	4		40	2	
	1984-2008	106	0.4	0.1	40	3	-0.8	37	1	-0.2
Pilani (Jhunjhunu)	1958-1983	104	1		36	5		28	2	
	1984-2008	81	1	0.0	34	4	-1.0	35	2	-0.4
Sikar	1958-1983	154	0.6		36	5		29	2	
	1984-2008	144	0.4	-0.2	67	3	-1.8	65	1	-0.9

Source : National Data Centre, IMD, Pune

4.4.1 MEAN MONTHLY MAXIMUM TEMPERATURE

Figure 4.12 represents the temporal variability in mean monthly maximum temperature at Churu, Jhunjhunu, Nagaur and Sikar. Maximum variation was experienced in the winter season. Base-line Period II (BP- II) recorded 1^0C and 0.8^0C increase over BP- I in Churu and Nagaur respectively in mean maximum temperature of this season. Whereas Base-line Period II (BP- II) recorded -0.5^0C and -1.7^0C decrease over BP- I in Jhunjhunu and Sikar respectively in mean maximum temperature of winter season. Monsoon and annual maximum temperature didn't show greater variations for these districts.

4.4.2 MEAN MONTHLY MINIMUM TEMPERATURE

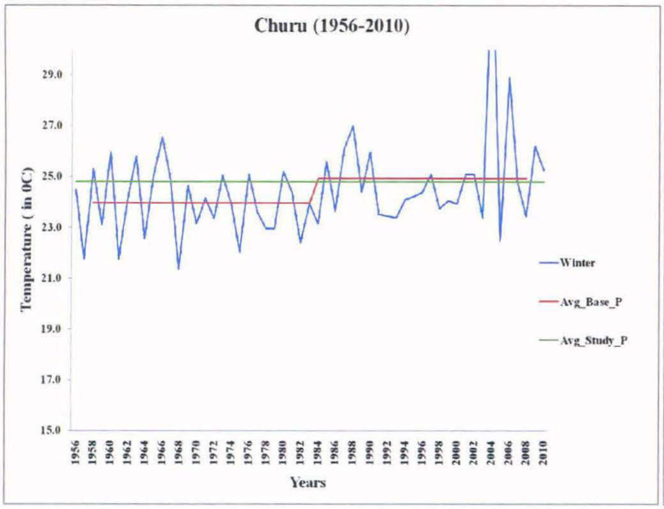
Over the period, minimum temperature decreased for Nagaur and increased by small values for Churu,Jhunjhunu and Sikar. Sikar experienced more increase in the minimum temperature than Churu and Jhunjhunu (Figure 4.13). From BP-I to BP-II, the minimum temperature increased by 0.8 ^{0}C in winter and 1 ^{0}C in monsoon season at Churu. Annual minimum temperature also recorded increase of 0.9 ^{0}C. Nagaur experienced decrease in the minimum tempearture for the second period. It is quite obvious that after 1980s minimum temperature increased for all stations except Nagaur and monsoon season experienced more incline in minimum temperature than winter in Churu and Sikar.

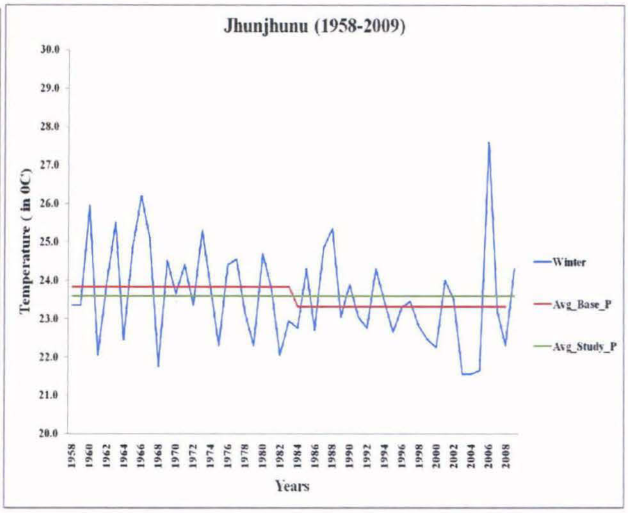
4.4.3 MEAN MONTHLY TEMPERATURE

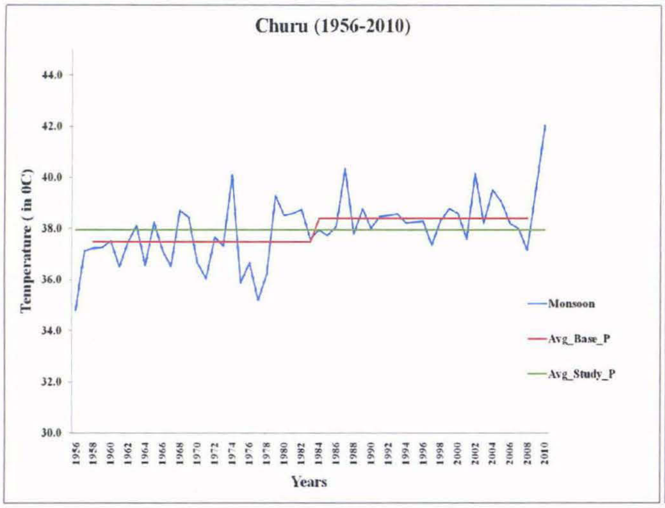
The mean monthly temperature increased from BP-I to BP-II at all the four districts in both winter and monsoon seasons (Figure 4.14). Again both winter and monsooon seasons experienced alost identical increase in mean temperature in the second period for all the four districts.

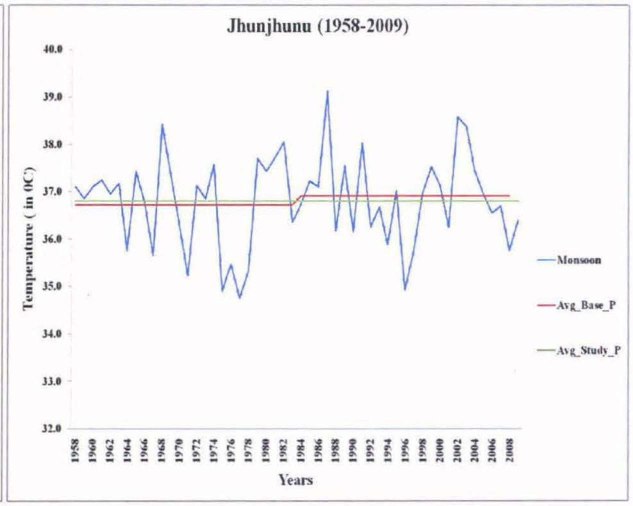
4.4.4 MEAN MONTHLY RAINFALL

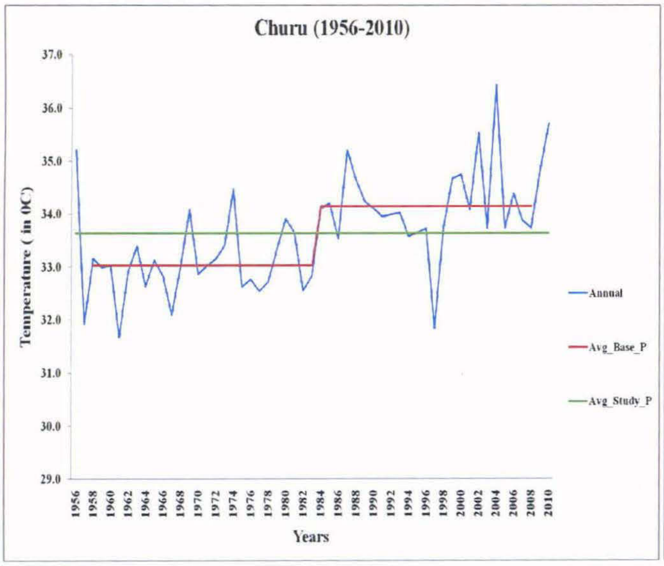
Winter rainfall recorded decline in second base-line period for Churu and Sikar whereas it recorded an increase for Nagaur and Jhunjhunu districts (Figure 4.15). Churu and Sikar recorded 17 mm and 5.9 decrease in rainfall for BP-II in winter season. Nagaur and Jhunjhunu experienced 3.7and 1.5 increase in mean monthly rainfall in the BP-II. Monsoon rainfall also reflected decline but Nagaur in the BP-II experienced increase in the rainfall. It experienced 19.7 mm increase in the rainfall. Annual rainfall recorded decrease at Churu (-7.6 mm), Jhunjhunu (-4.0 mm) and Sikar (-21.9 mm). But Nagaur recorded increase in annual rainfall (8.1 mm). The overall scenario is that Churu, Jhunjhunu and Sikar experienced decline in the monthly rainfall and Nagaur recorded increase in rainfall during BP-II.

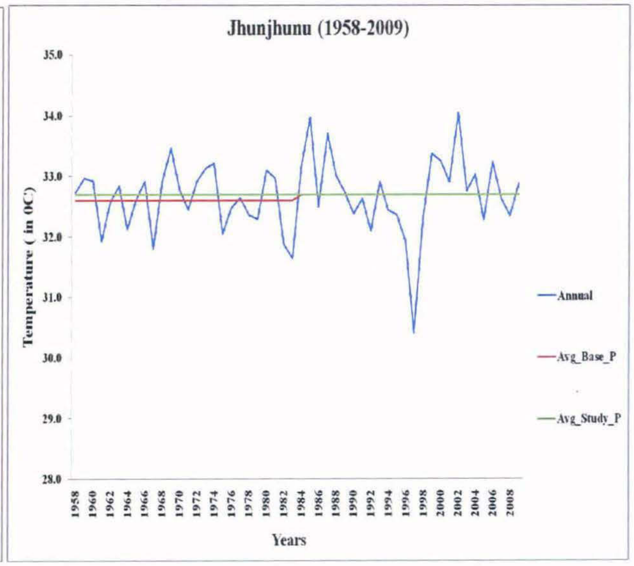

Churu (1956-2010)
Temperature (in 0C)
Years
Winter
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Temperature (in 0C)
Years
Winter
Avg_Base_P
Avg_Study_P


Churu (1956-2010)
Temperature (in 0C)
Years
Monsoon
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Temperature (in 0C)
Years
Monsoon
Avg_Base_P
Avg_Study_P


Churu (1956-2010)
Temperature (in 0C)
Years
Annual
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Temperature (in 0C)
Years
Annual
Avg_Base_P
Avg_Study_P

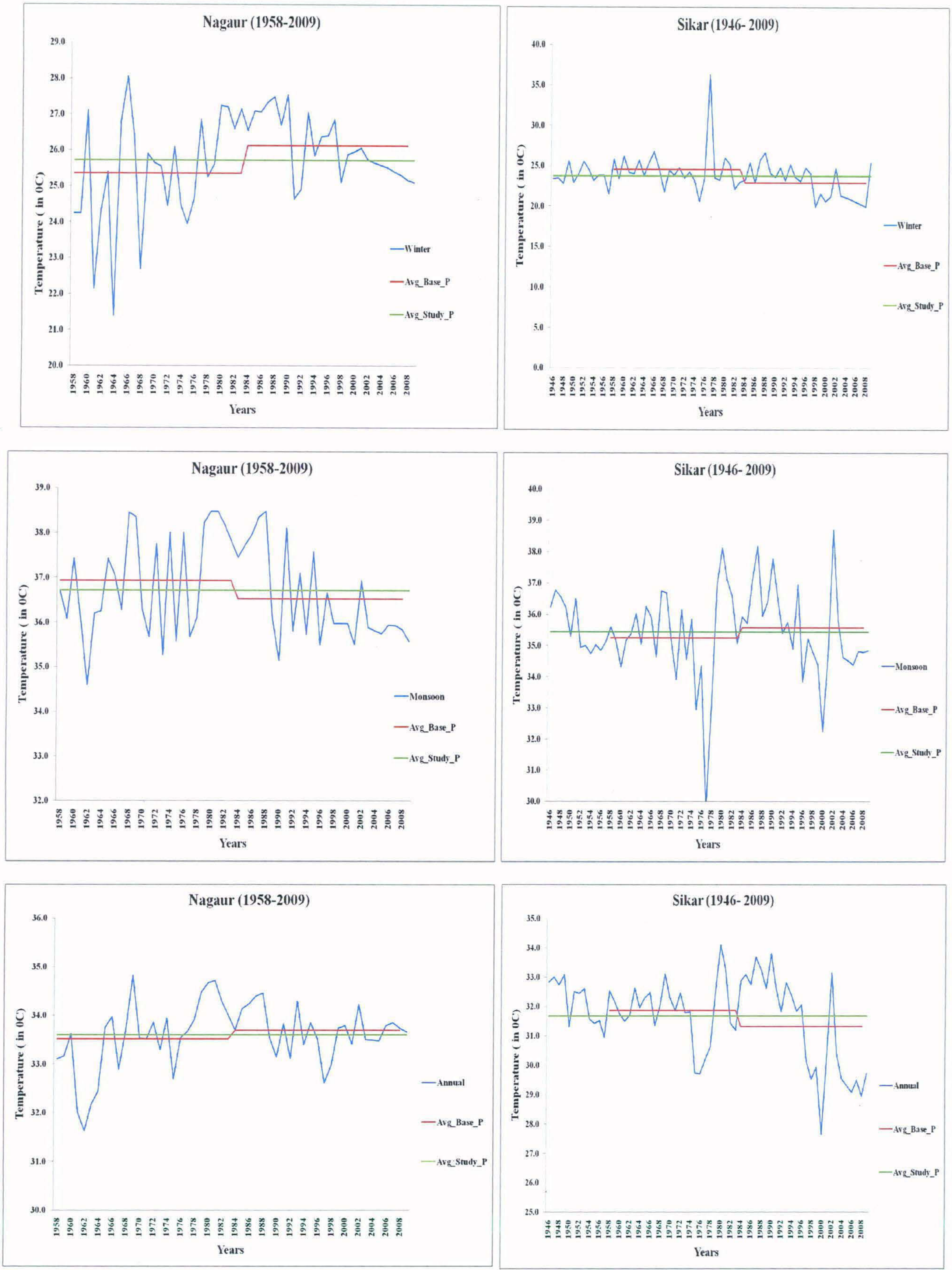
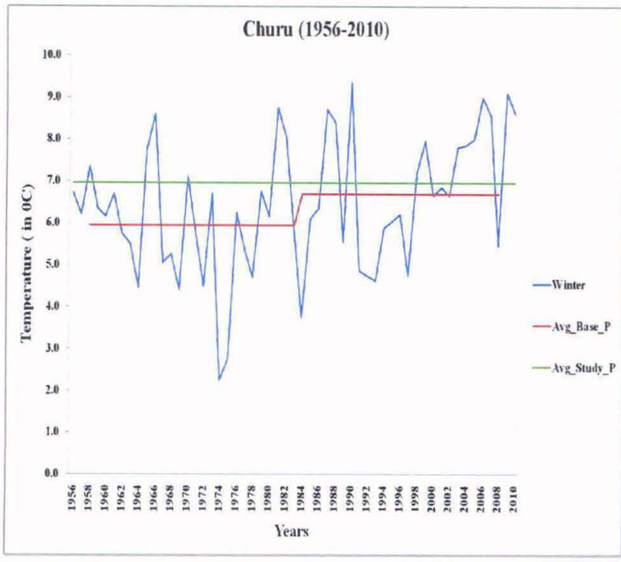
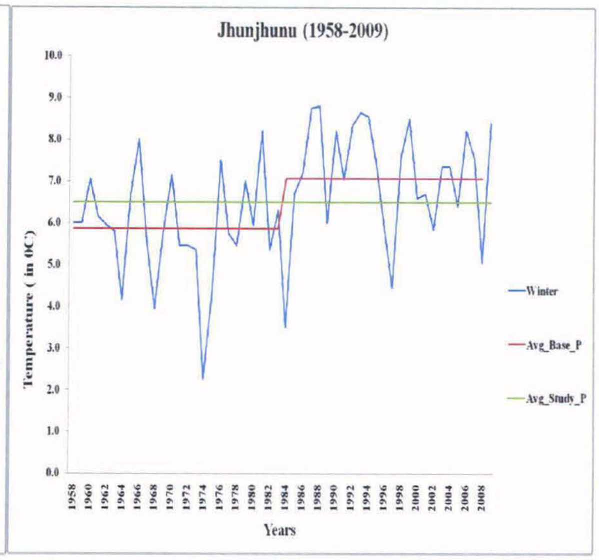
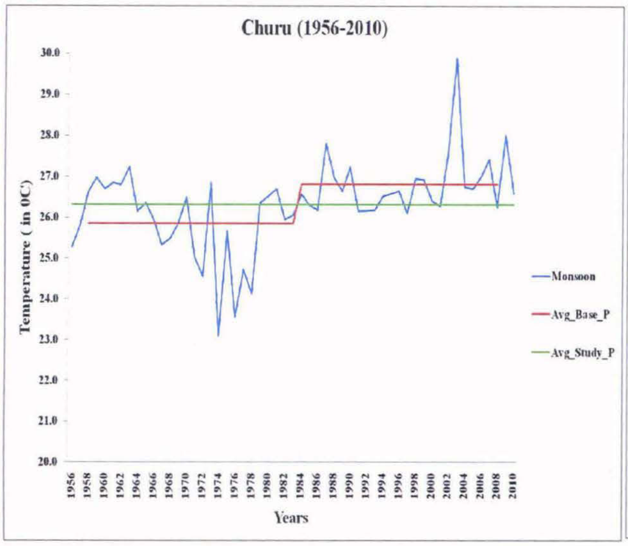


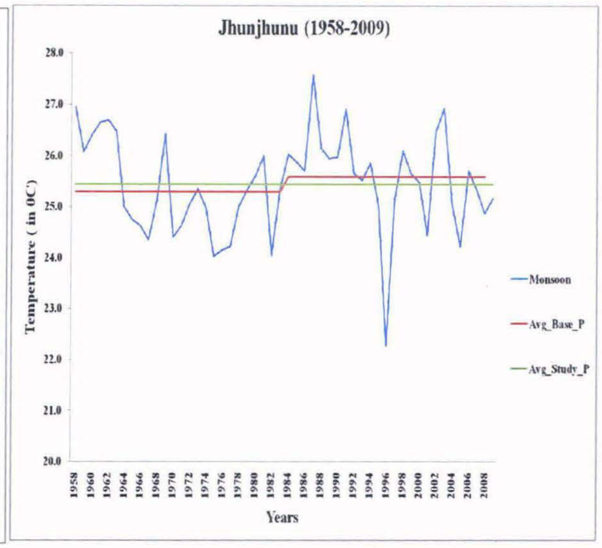
Figure 4.12: Analysis of seasonal variation in Mean Monthly Maximum Temperature

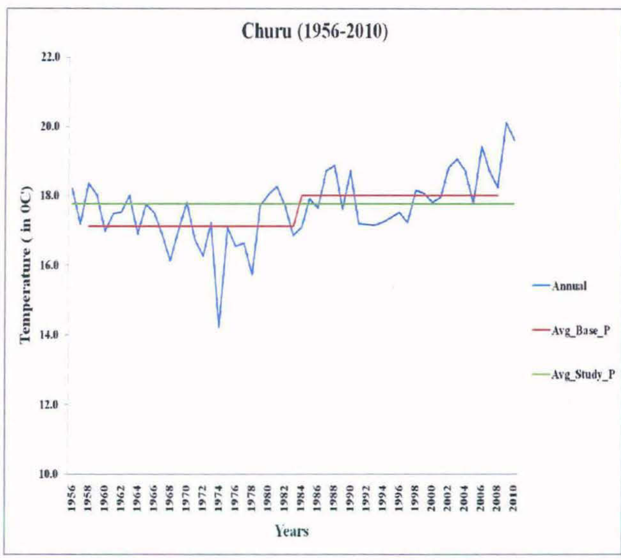
Source: National Data Centre, IMD, Pune

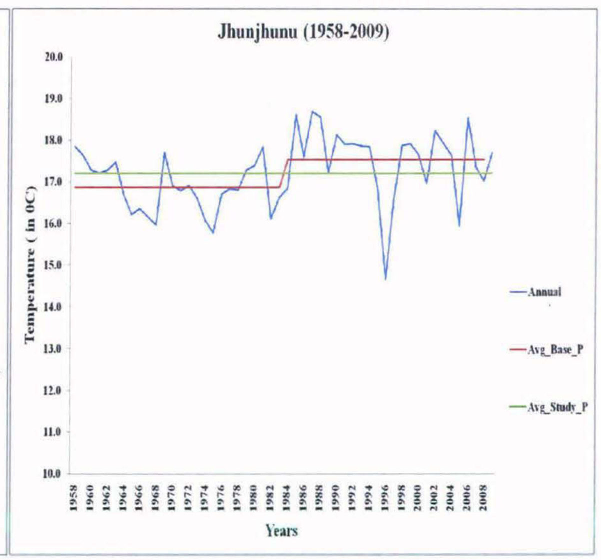

Churu (1956-2010)
Temperature (in 0C)
Years
Winter
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Temperature (in 0C)
Years
Winter
Avg_Base_P
Avg_Study_P


Churu (1956-2010)
Temperature (in 0C)
Years
Monsoon
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Temperature (in 0C)
Years
Monsoon
Avg_Base_P
Avg_Study_P


Churu (1956-2010)
Temperature (in 0C)
Years
Annual
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Temperature (in 0C)
Years
Annual
Avg_Base_P
Avg_Study_P

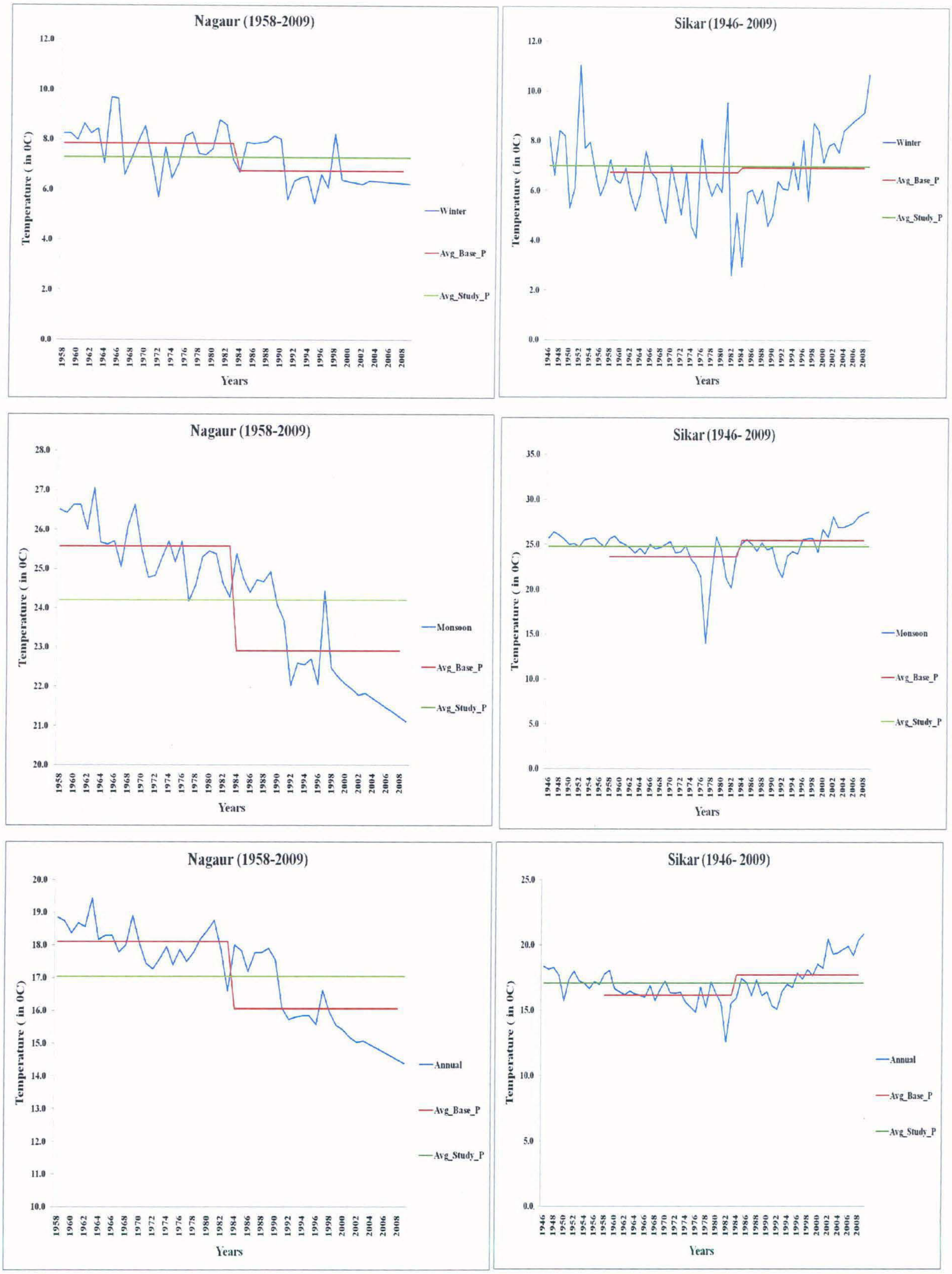
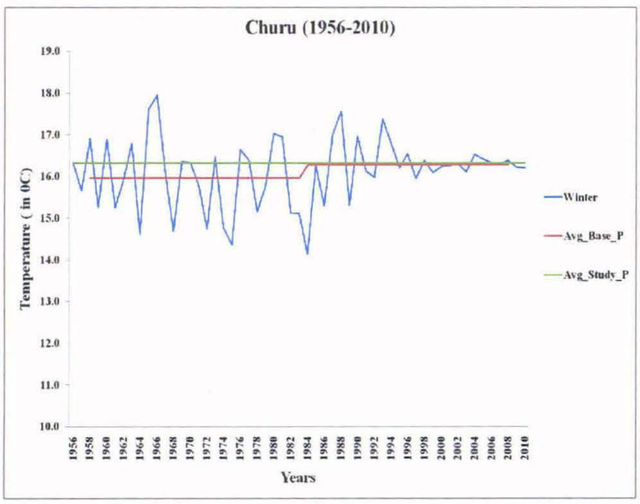


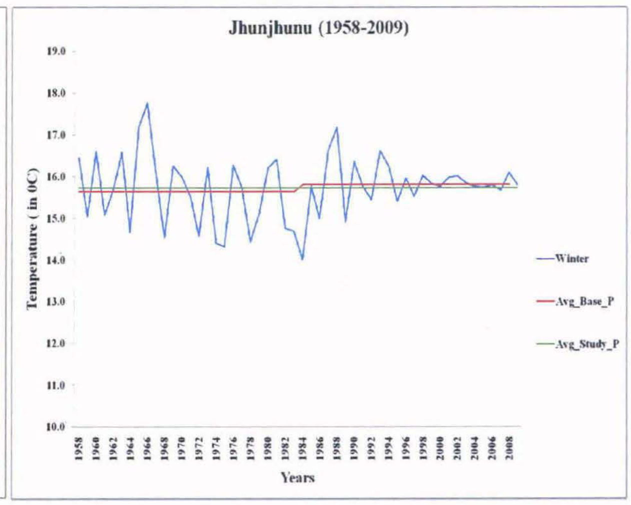
Figure 4.13: Analysis of seasonal variation in Mean Monthly Minimum Temperature

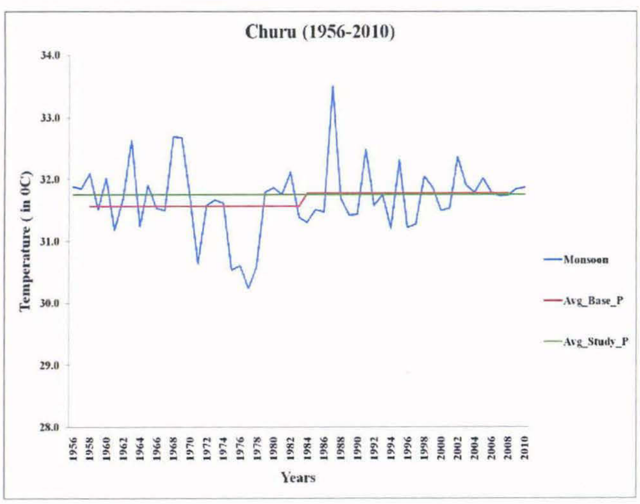
Source: National Data Centre, IMD, Pune

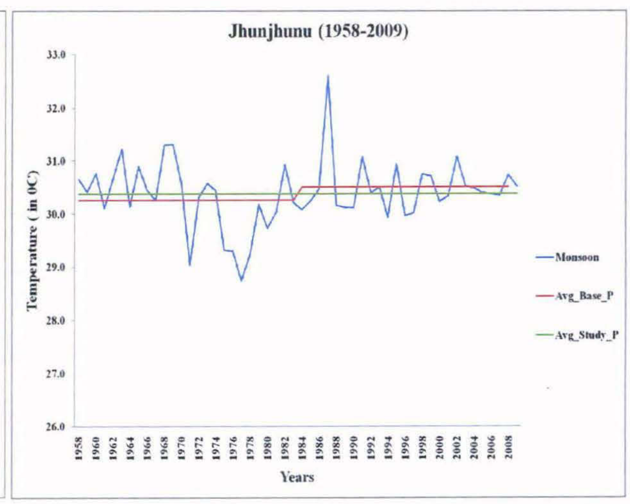
4.4.5 MONTHLY NUMBER OF RAINY DAYS

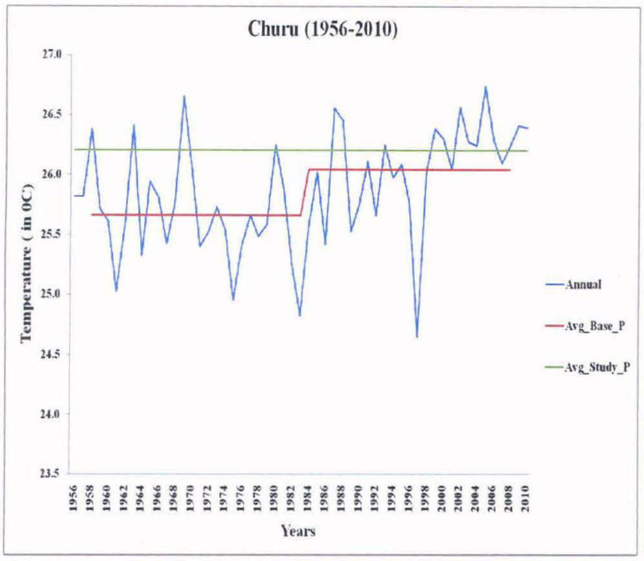
Number of rainy days didn't experience much variation at all the four districts. Sikar recorded decline in number of rainy days for the BP-II by -0.2 day in winter, -1.8 days in monsoon and -0.9 day in annual record. Number of rainy days decreased in monsoon season as well as annually for all four districts but Churu, Jhunjhunu and Nagaur recorded an increase in number of rainy days for BP-II during winter season.

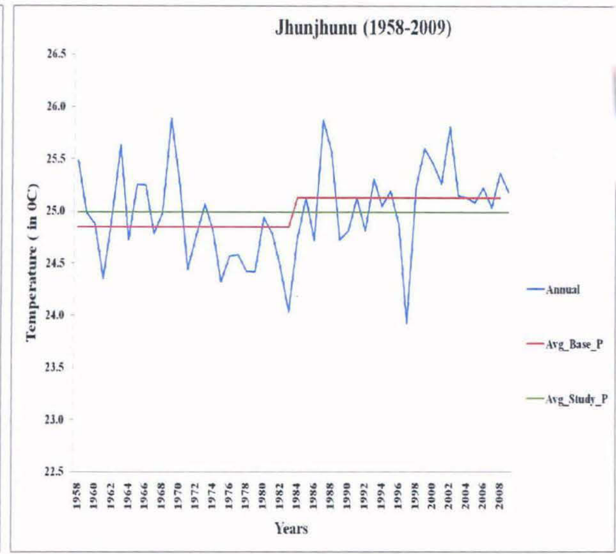


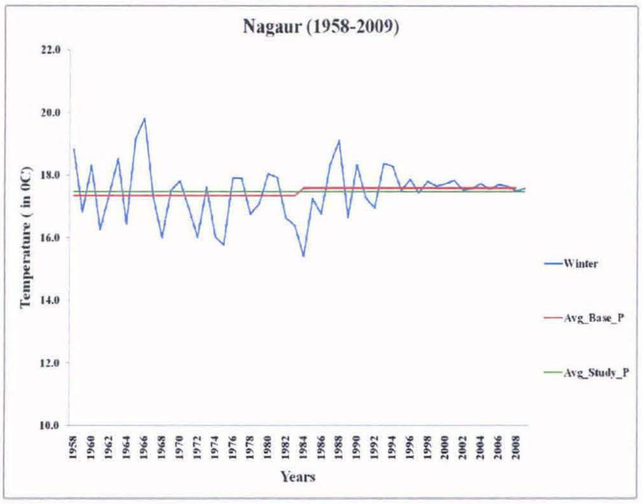


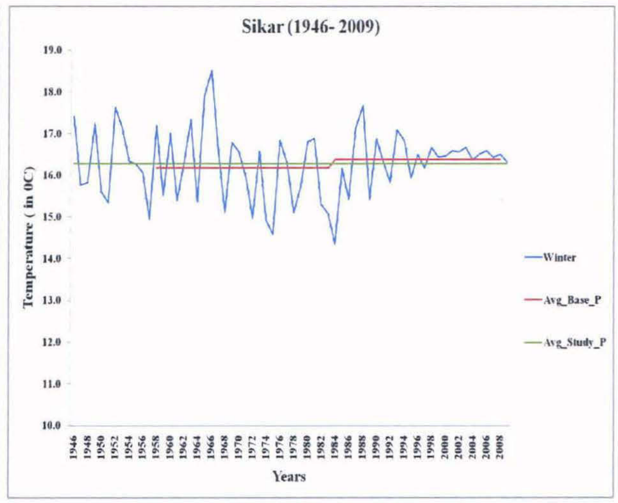


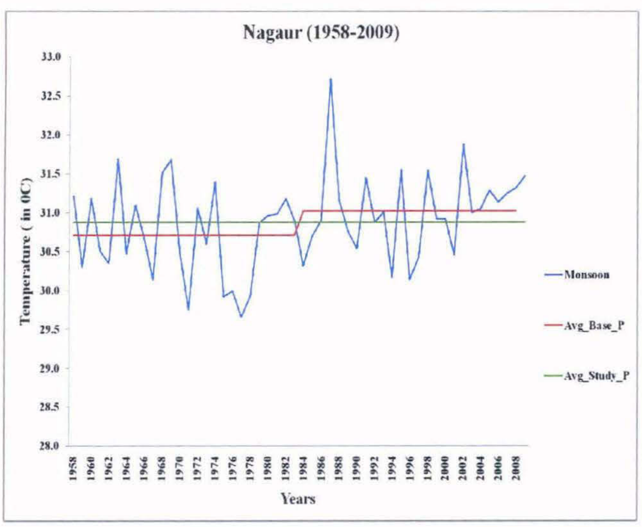


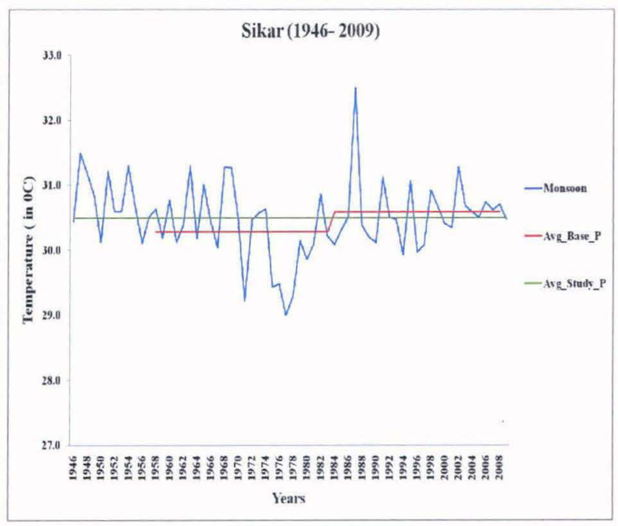

Churu (1956-2010)
Temperature (in 0C)
Years
Annual
Avg_Base_P
Avg_Study_P

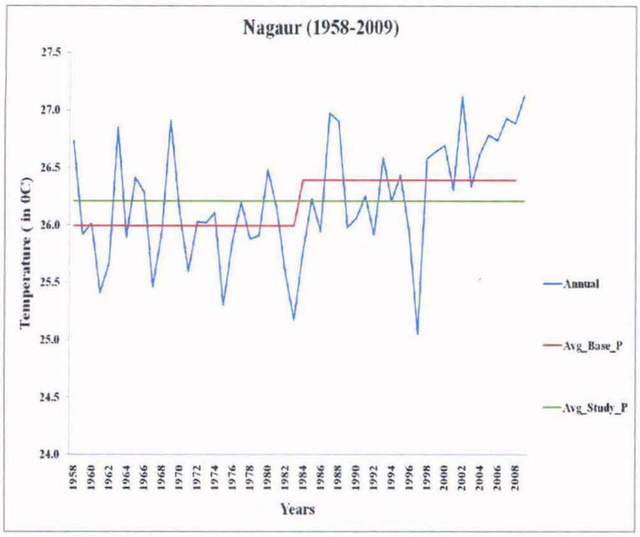

Jhunjhunu (1958-2009)
Temperature (in 0C)
Years
Annual
Avg_Base_P
Avg_Study_P


Nagaur (1958-2009)
Temperature (in 0C)
Years
Winter
Avg_Base_P
Avg_Study_P


Sikar (1946- 2009)
Temperature (in 0C)
Years
Winter
Avg_Base_P
Avg_Study_P


Nagaur (1958-2009)
Temperature (in 0C)
Years
Monsoon
Avg_Base_P
Avg_Study_P


Sikar (1946- 2009)
Temperature (in 0C)
Years
Monsoon
Avg_Base_P
Avg_Study_P



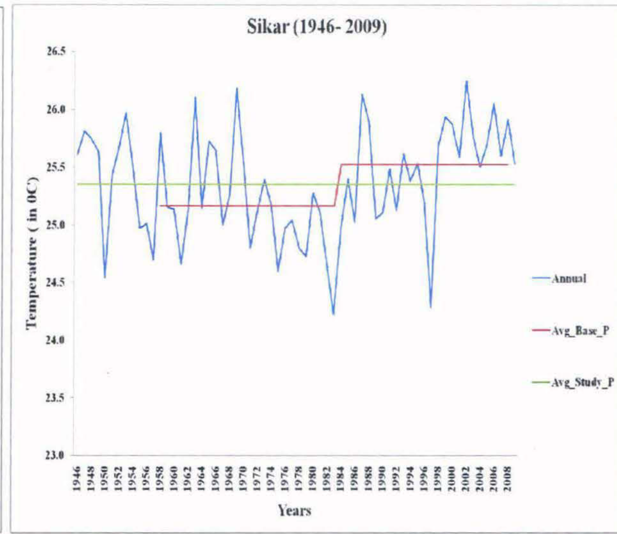
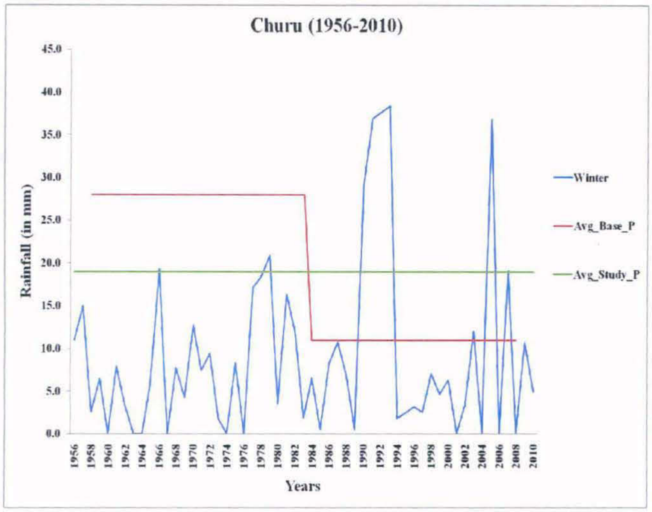
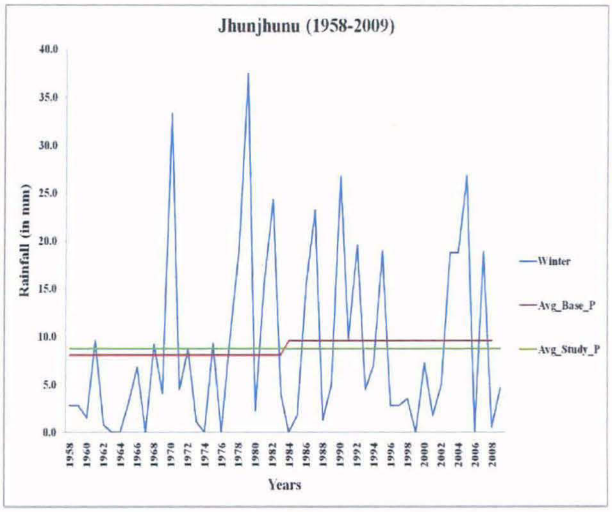
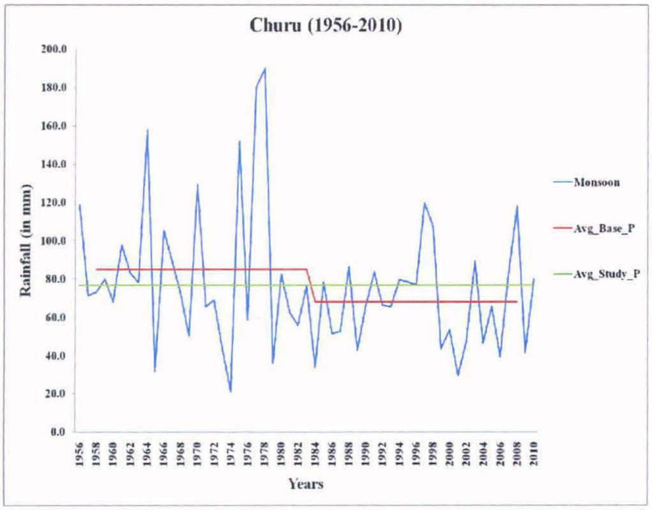


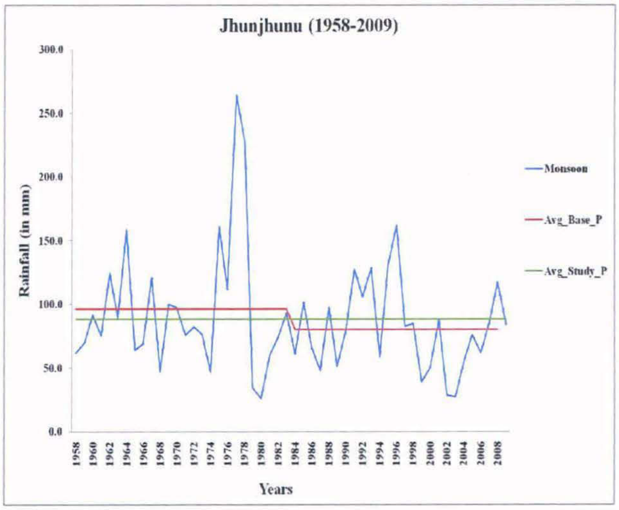
Figure 4.14: Analysis of seasonal variation in Mean Monthly Temperature

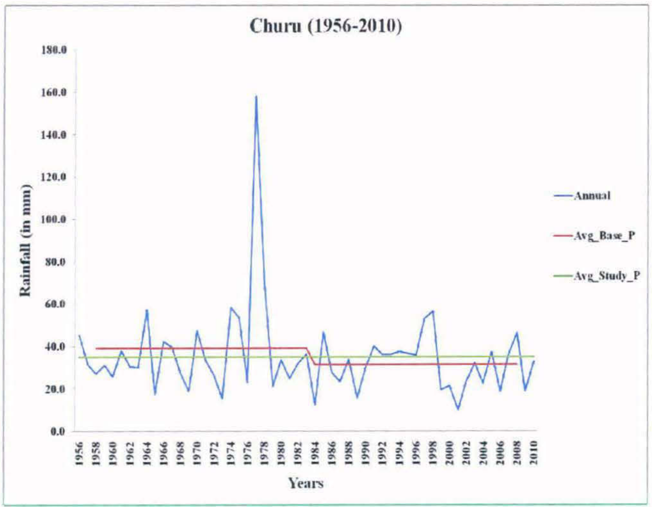
Source: National Data Centre, IMD, Pune

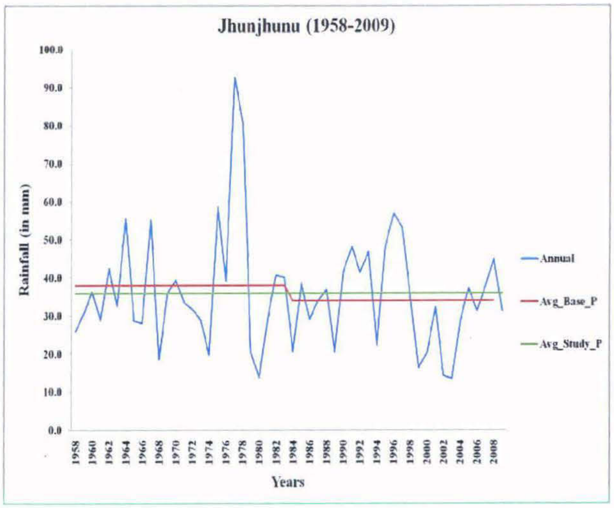

Churu (1956-2010)
Rainfall (in mm)
Years
Winter
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Rainfall (in mm)
Years
Winter
Avg_Base_P
Avg_Study_P


Churu (1956-2010)
Rainfall (in mm)
Years
Monsoon
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Rainfall (in mm)
Years
Monsoon
Avg_Base_P
Avg_Study_P


Churu (1956-2010)
Rainfall (in mm)
Years
Annual
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Rainfall (in mm)
Years
Annual
Avg_Base_P
Avg_Study_P

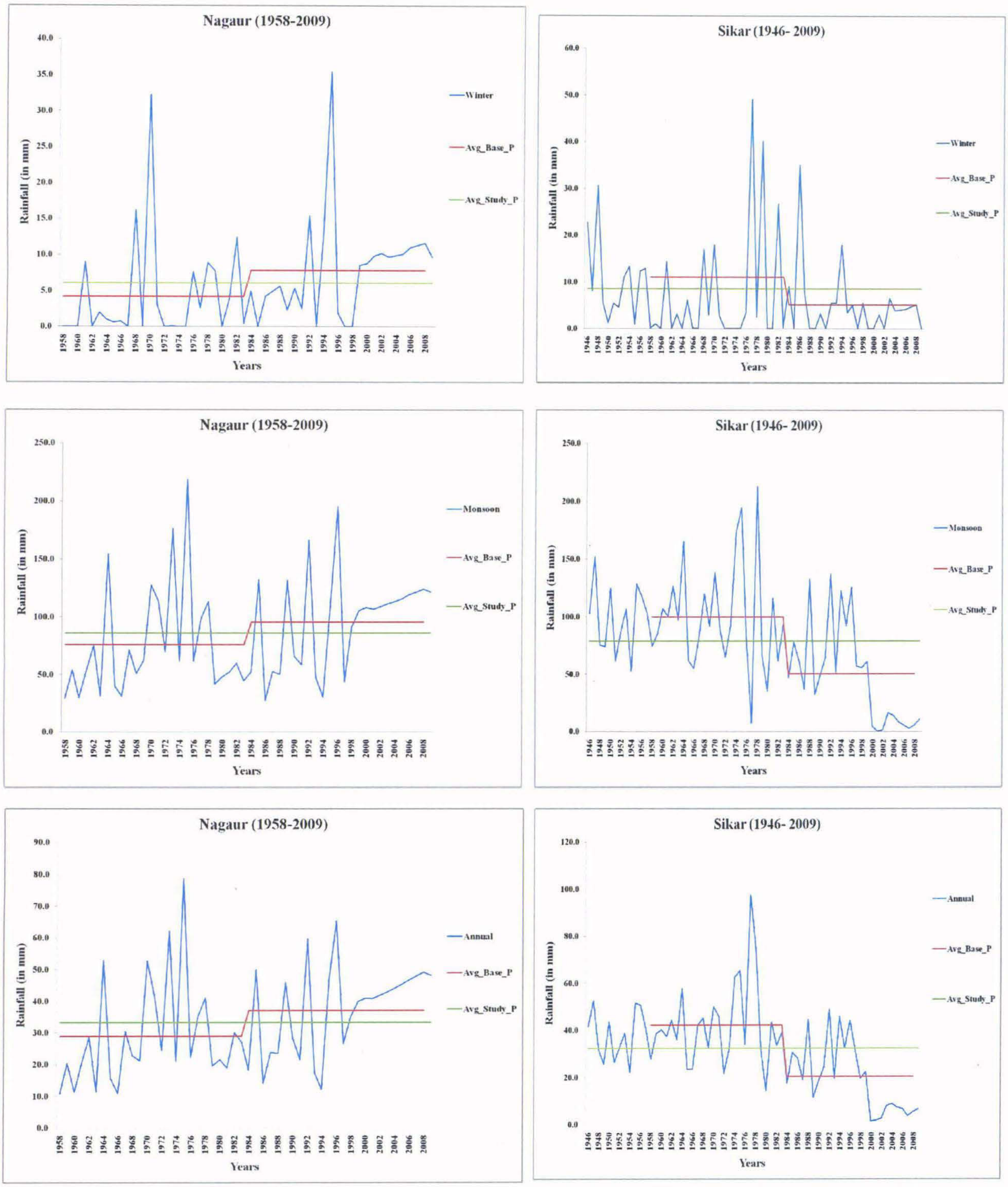
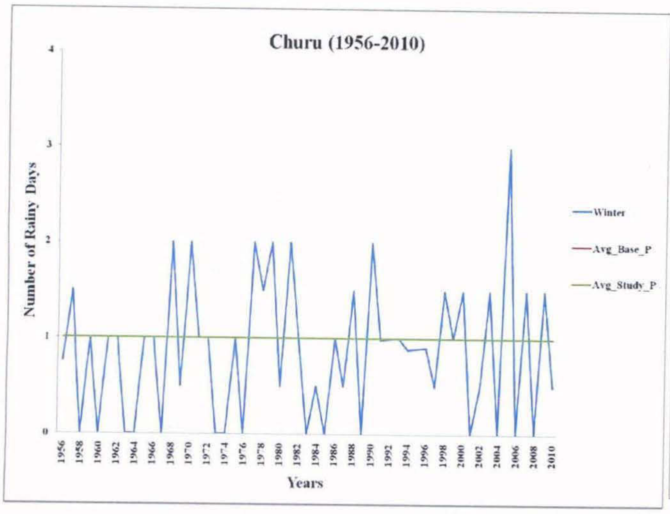
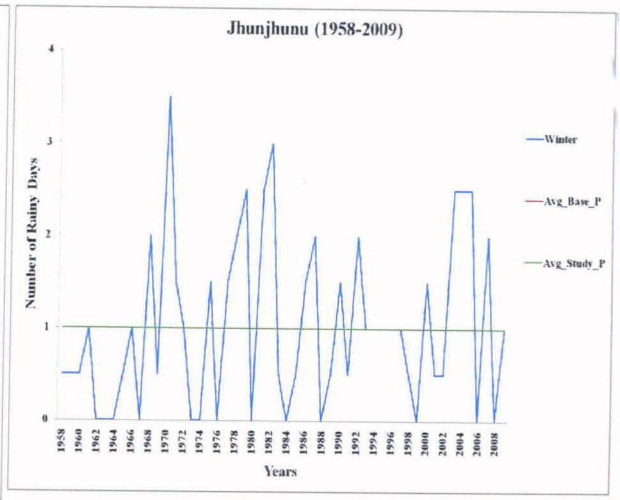
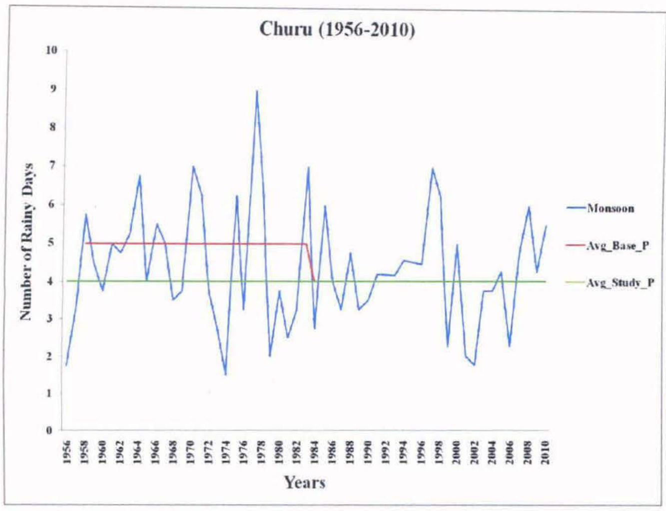


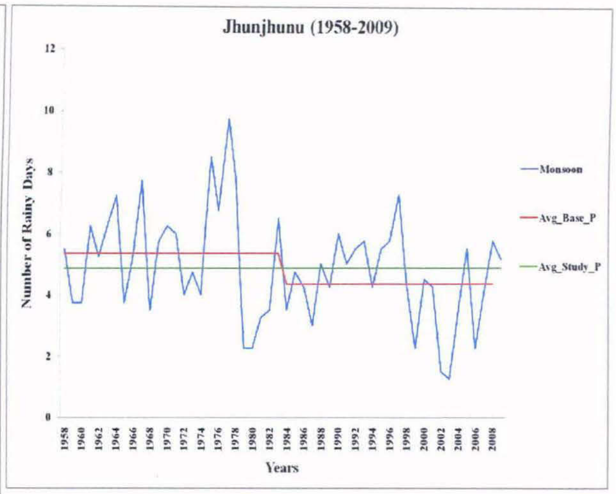
Figure 4.15: Analysis of seasonal variation in Mean Monthly rainfall

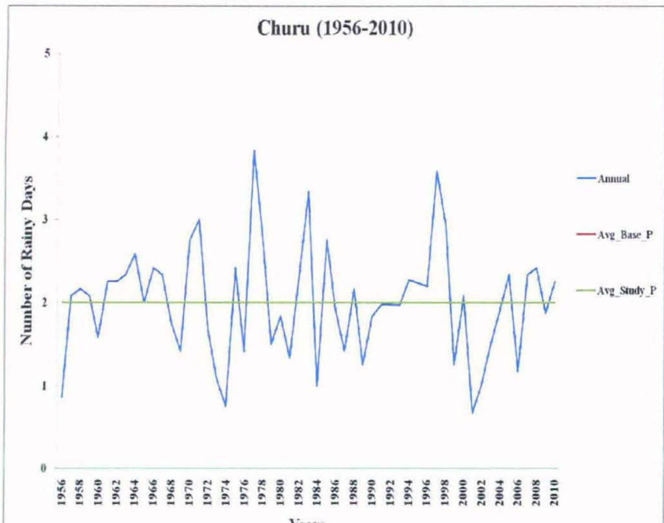
Source: National Data Centre, IMD, Pune

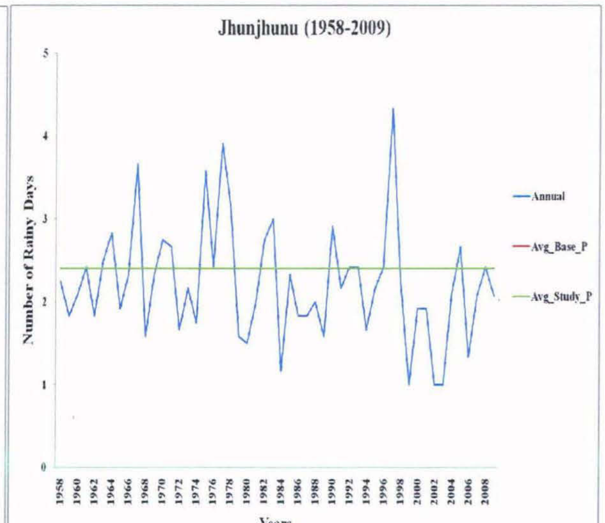

Churu (1956-2010)
Number of Rainy Days
Years
Winter
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Number of Rainy Days
Years
Winter
Avg_Base_P
Avg_Study_P


Churu (1956-2010)
Number of Rainy Days
Years
Monsoon
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Number of Rainy Days
Years
Monsoon
Avg_Base_P
Avg_Study_P


Churu (1956-2010)
Number of Rainy Days
Years
Annual
Avg_Base_P
Avg_Study_P


Jhunjhunu (1958-2009)
Number of Rainy Days
Years
Annual
Avg_Base_P
Avg_Study_P

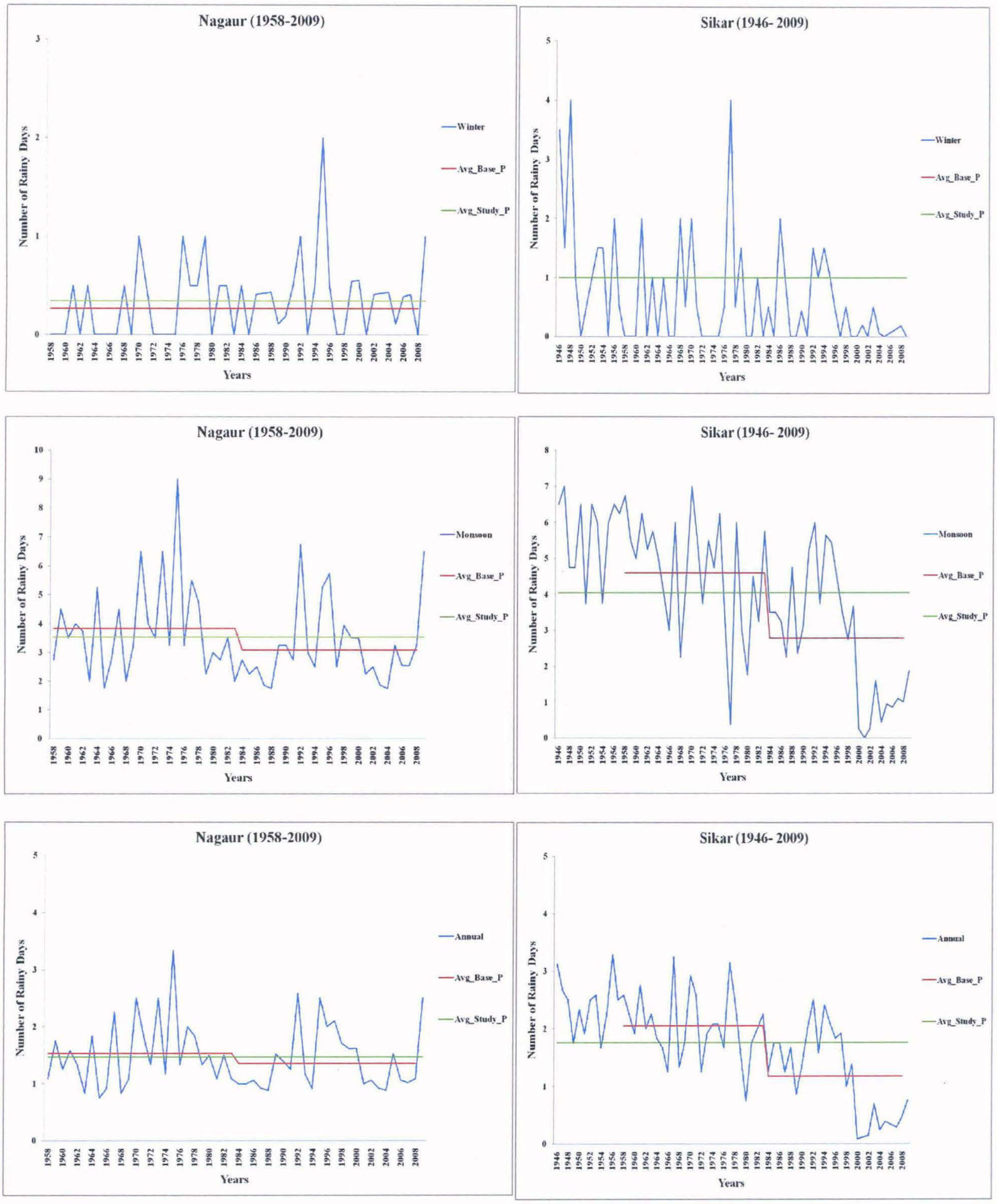


Figure 4.16: Analysis of seasonal variation in Mean Monthly Number of Rainy Days

Source: National Data Centre, IMD, Pune

4.5 SPATIAL CLIMATIC VARIATION ANALYSIS USING COEFFICIENT OF VARIATION METHOD

The climatic indicators i.e. temperature, rainfall etc. vary over the time as well as over space. The great topographic undulations and natural dividers, barriers cause these elements to vary from one place to another. The areal extent is one of the most important factors behind the spatial variation recorded in the climatic parameters. Coefficient of variation is one of the best statistical methods to calculate the spatial variability and it also provides data to analyze variability of two or more stations.

In this analysis all the stations were included but a common time period (1958-2008) was used as all the stations didn't have data for the same contemporary period and the time span was short for all stations. Extrapolation for rainfall and temperature data series was done for Churu, Jhunjhunu, Sikar and Nagaur districts for missing data sets. Three major climatic elements were included in this analysis viz. Mean Monthly temperature, total monthly rainfall and monthly rainy days. Other elements inclusion was unnecessary and could make the analysis more complex and difficult to interpret. All the four seasons of a year namely winter, pre-monsoon, monsoon and post-monsoon were included along with the annual records. Table 4.5 systematically represents the information about the stations.

Table 4.5 Information about the meteorological stations used in the spatial variability analysis using Coefficient of Variation Metho

Period	Station	Variable	Season
1956-2010	Churu	Mean Monthly Temperatur	Winter
1958-1998	Nagaur	Mean Monthly Rainfall	Pre-Monsoon
1958-2009	Pilani (Jhunjhun	Number of Rainy Days	Post-Monsoon
1946-2003	Sikar		Annual
Note:- Variables and Seasons are common to all stations.			

Table 4.6 Analysis of seasonal climatic variability using Coefficient of Variation (CV) method

Seasonal Spatial Variation in Mean Monthly Temperature

1958-2008 CV in Per Cent

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	5.1	3.2	1.8	3.4	1.8
Nagaur	5.1	3.0	1.9	3.7	1.9
Jhunjhunu	5.0	3.1	2.1	3.1	1.7
Sikar	5.2	3.3	1.9	3.6	1.9

Source : National Data Centre, IMD, Pune

Seasonal Spatial Variation in Mean Monthly Rainfall

1958-2008 CV in Per Cent

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	393.4	74.8	46.7	254.7	60.0
Nagaur	122.3	103.0	53.4	113.6	48.3
Jhunjhunu	109.2	78.1	52.0	175.6	42.9
Sikar	249.3	338.7	122.1	266.4	57.6

Source : National Data Centre, IMD, Pune

Seasonal Spatial Variation in Mean Monthly number of Rainy Days

1958-2008 CV in Per Cent

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	82.5	65.5	36.4	134.2	33.7
Nagaur	114.9	89.8	44.0	146.7	39.3
Jhunjhunu	91.1	63.1	36.1	140.5	31.5
Sikar	172.1	228.9	85.2	246.3	46.9

Source : National Data Centre, IMD, Pune

4.5.1 MEAN MONTHLY TEMPERATURE

Table 4.6 represents the spatial variability in climatic variables. Mean monthly temperature recorded highest spatial variability during the post monsoon season. All the four districts experienced variability in the mean monthly temperature. Moving from post monsoon towards winter and pre monsoon season, the variability decreases and lowest variability recorded in the winter season. After monsoon season once again it increases towards post-monsoon season. The annual spatial variability is quite low. Figure 4.17 depicts the spatial variability in mean monthly temperature in Churu, Jhunjhunu, and Nagaur and Sikar districts.

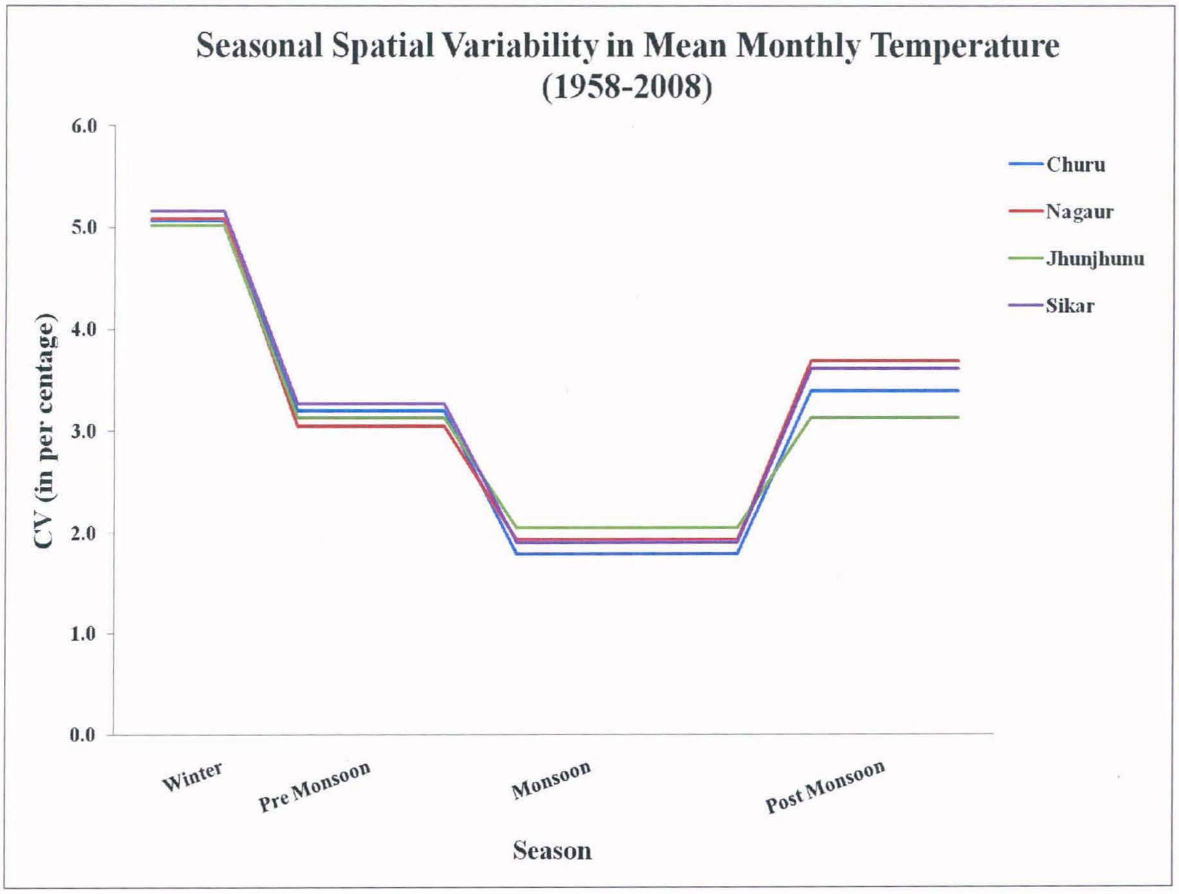


Figure 4.17: Seasonal Spatial Variability in Mean Monthly Temperature

Source: National Data Centre, IMD, Pune

4.5.2 MEAN MONTHLY RAINFALL

Figure 4.18 represents the spatial variability in total monthly rainfall of Churu, Jhunjhunu, and Nagaur and Sikar districts. The Maximum variability was recorded in the pre monsoon season. Sikar experienced a relatively highest variability in the pre monsoon season. There was relatively very high variability in rainfall during winter season. Churu and Sikar recorded exceptionally high variability in this season. Monsoon season recorded relatively lowest variability in rainfall. As the South-West monsoon commences with almost equal intensity over these districts. Therefore, variability in rainfall is very low in the monsoon season. The South-West Monsoon leads to temperature harmonizing effect which causes relatively less variability in temperature recorded during monsoon season.

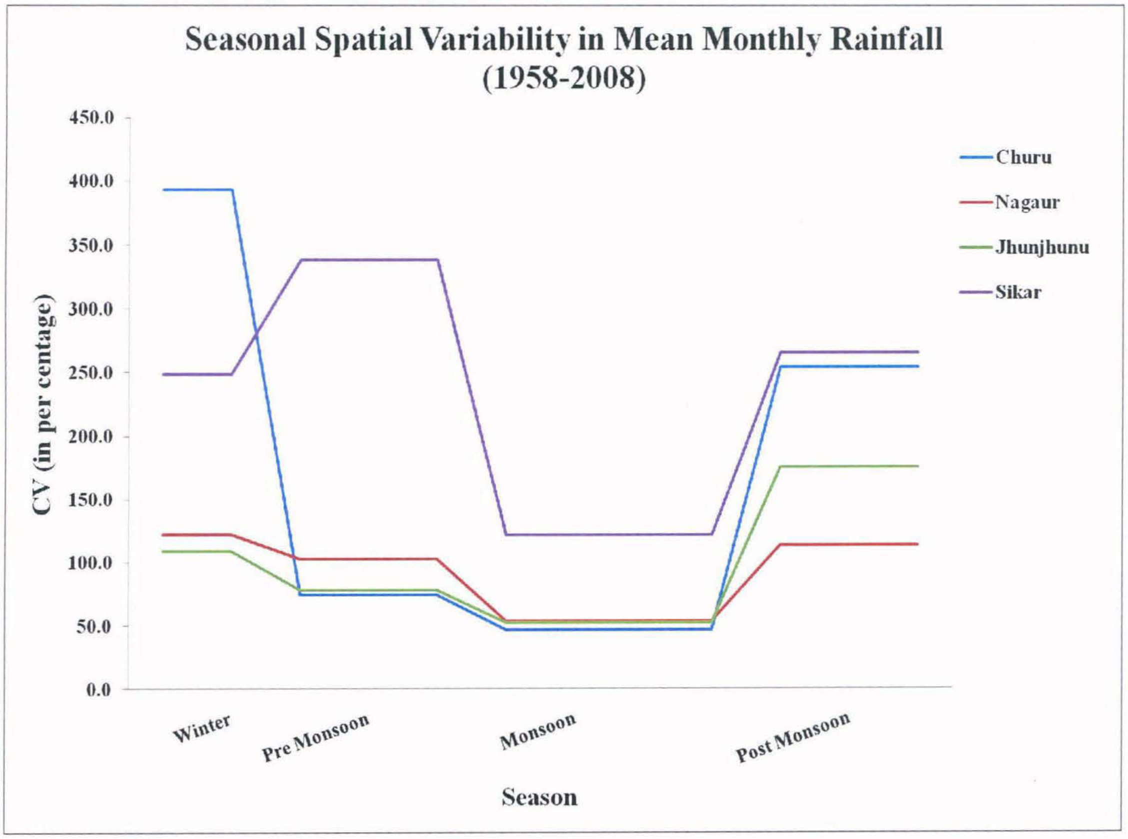


Figure 4.18: Seasonal spatial variability in Mean Monthly Rainfall

Source: National Data Centre, IMD, Pune

4.5.3 MEAN MONTHLY NUMBER OF RAINY DAYS

Variability in rainy days experienced similarity with the variability in monthly rainfall. The pre monsoon season marked relatively high variability in the mean monthly number of rainy days. Sikar experienced highest variability in the pre monsoon season. Churu recorded relatively low variability in winter and post-monsoon seasons. Monsoon season experienced lowest variability in mean monthly number of rainy days. Sikar recorded high variation as compared to other stations in all seasons. Rainfall and number of rainy days are closely related to each other. That is why the spatial variation in rainfall and number of rainy are correlated to each other.

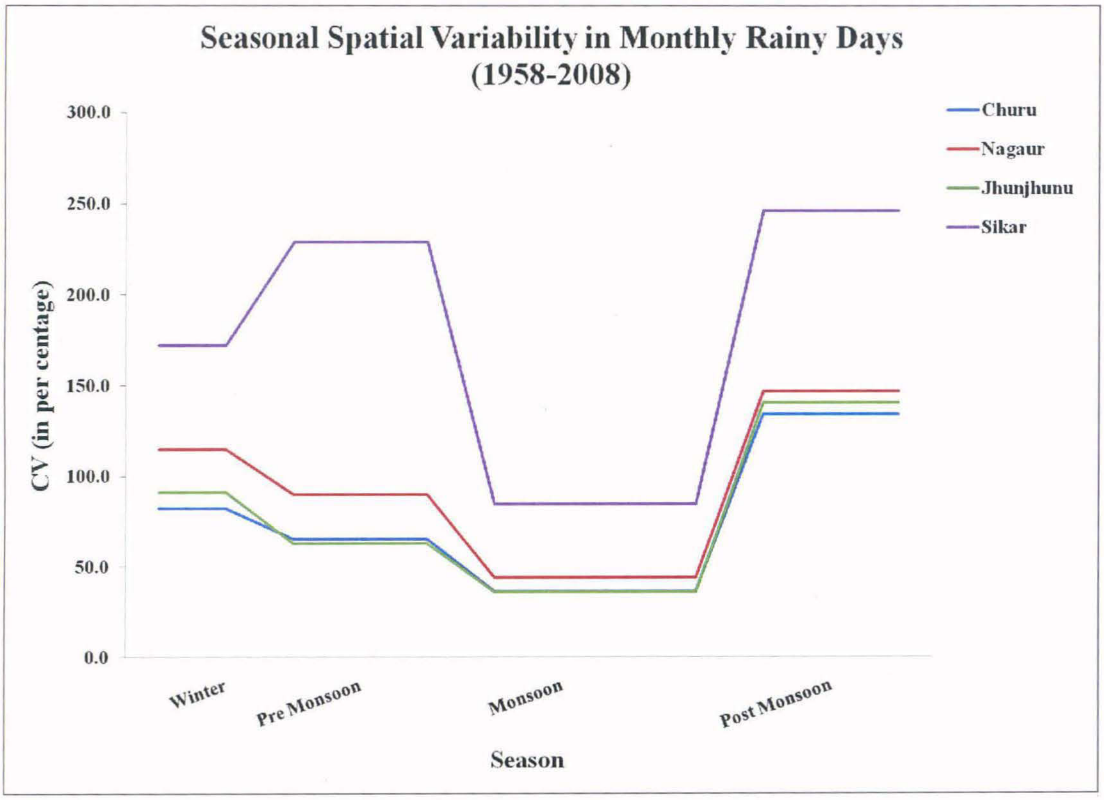


Figure 4.19: Seasonal spatial variability in Monthly Rainy Days

Source: National Data Centre, IMD, Pune

4.5.4 RESULTS AND DISCUSSION

The spatial variation analysis incorporates the topographical undulations of the earth surface. Coefficient of variation, represented in the per cent form, is the best method to measure the spatial variation in the time series data. Some of the major results of the analysis are as follows:-

i. Monsoon season recorded minimum variability in the mean temperature. As the South-West Monsoon proceeds towards the region, the temperature harmonizing effect leads to almost equalizing the monsoonal temperature of all the stations every year.
ii. Rainfall is mainly influenced by the regional relief and Physiographic features. Pre-monsoon rainfall experienced maximum variation in rainfall across the study area followed by the winter rainfall. The western disturbance influenced rainfall led to such type of variability.
iii. The variability in monthly rainy days is similar to the variability in rainfall. Relatively high variability in monthly rainfall recorded during pre-monsoon season while low variability is marked in monsoon season.
iv. Overall, relatively low variability in climatic parameters, such as rainfall and temperature is marked during monsoon season while the highest variability in mean monthly temperature is observed during pre monsoon season.

4.6 CHAPTER SUMMARY AND CONCLUSION

The cyclic fluctuations in climatic parameters suggest about the changing pattern of climate and on that basis the future climate become predictable with much accuracy. The study area, a part of the Great Indian Desert is the hot spot of the desertification and climate studies as the encroachment of Thar Desert towards its eastern marfins has been a serious concern for the people of this region. That's why the current study has immense importance.

The temporal-seasonal variation analysis is based on two methods i.e. the moving average and simple average method. Normalized Accumulated Departure from Mean (NADM) also used for the stations having short span data series. In this study moving average is used to see the variations in temperature and rainfall experienced by the meteorological stations over the period of time. Cyclic fluctuations were recorded in the mean monthly maximum temperature. Variation in mean monthly minimum temperature was recorded in the fourth quarter of the last century. There were maximum fluctuations in temperature experienced by the region during 1975-90. The last 20 years (1981-1999) experienced relatively high variations in the mean monthly temperature with 1989-99 as the most prominent part of it.

Moving average filters the minor fluctuations in the time series data. The normalized accumulated departure from mean (NADM) method permits the distinction between periods of high and low values by clearly defining the limits. Beside this, the NADM curves permits visual as well as statistical comparison of unlike data series. Simple average method facilitate the comparison of two climatic or base line periods and identify the variation occurred in the second period over the first one. That's why for the variation analysis with quantified results, simple average method is much more appropriate and useful than other methods. After dividing the whole data series in two Base-line Periods (BPs); the simple average of each period compared with the next one will give absolute value of the variation in the data series. Less number of variables and less number of seasons were included to do more specific, rational and more productive analysis.

Temporal analysis suggests about the station specific variations or trends in the data series. It doesn't compare one station to another in terms of variation faced by each one. Spatial variation analysis fulfills this quarry. The Coefficient of Variation is the method to calculate variability. It's a very rational and accurate statistical technique used for quantification of variability in time series data. Monsoon season recorded minimum variability in mean temperature. As the South-West Monsoon proceeds towards the region, the temperature harmonizing effect leads to almost equalizing the monsoonal temperature of all the stations every year. Therefore, variability in temperature reduced from high post monsoon to low monsoon. Relatively low variability in climatic parameters, such as rainfall and temperature is marked during monsoon season while the highest variability in mean monthly temperature is observed during post monsoon season.

Chapter Five

Trends in the climate of the Churu, Jhunjhunu, Nagaur and Sikar Districts

5.1 INTRODUCTION

The analysis of temporal and spatial variations in climatic elements suggest about the things which already had taken place. This analysis covered the past or the recent past. But, it didn't look in the future behavior of the climatic variables. The vital information is provided by the trend analysis carried out with the help of many non-parametric and statistical methods. The least square regression line method is the best technique for trend analysis. Mann-Kendal's nonparametric test is also used by the climatologists to assess the trends of climatic variables. The simple linear regression method has been used for the trend analysis and for visual representation of climatic elements; the best-fit trend line (linear trend line) has been used. Both the techniques were conducted with the help of Microsoft Excel workbook to determine the nature of trends i.e. whether positive or negative. The b-values were calculated while putting the time series data (years) as the independent variable and climatic data (temperature, rainfall etc.) as the dependent variable. The b-value in a simple linear regression model represents the slope of the regression line which explicitly indicates trend in the dependent data series. The equation for the slope of the regression line is:

$$b = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sum (x-\bar{x})^2}$$

Where, x and y are independent and dependent (in Y on X regression line i.e., y = a + bx) variables respectively. The results of trend analysis were scrutinized with the help of F-test. The confidence levels derived with the help of F-test, determined whether a trend is a significant or insignificant.

5.2 TREND ANALYSIS USING SIMPLE LINEAR REGRESSION METHOD

Trend analysis provides information about the momentum of data series. Simple linear regression method is one of the best methods for the trend analysis of a time series data. Trends in temperature and rainfall data of the selected districts can give very sound bases for the prediction of the near future climate of these districts. On the basis of climatic parameters, the analysis is divided in two parts:-

1. Trends in temperature and rainfall and number of rainy days data series.
2. Trends in extreme events such as highest maximum, lowest minimum and highest monthly rainfall.

The basic information about the meteorological stations used in this analysis is given in Table 5.1.

Table 5.1: Information about the meteorological stations used in the Simple Linear Regression analysis

Station	Data Span	Variable	Seasons	Months
Churu	1956-2010	Mean Monthly Maximum Temperature	Winter	January- February
Nagaur	1958-2009	Mean Monthly Minimum Temperature	Pre-Monsoon	March - May
Pilani (Jhunjh	1958-2009	Mean Monthly Temperature	Post-Monsoon	June - September
Sikar	1946-2009	Mean Monthly Highest MaximumTemperature	Annual	October - December
		Mean Monthly Lowest Minimum Temperature		
		Mean Monthly Rainfall		
		Number of Rainy Days		
Note:- Variables and Seasons are common to all stations.				

Table 5.2: Trend analysis of Mean Monthly Maximum, Mean Monthly Minimum and Mean Monthly Temperature using Simple Linear Regression Method

Trend analysis of Mean Monthly Maximum Temperature

(b-values)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	-0.005	0.044	0.043	0.041	0.035
Nagaur	0.023	0.021	-0.016	0.032	0.012
Pilani (Jhunjhunu)	-0.021	0.011	0.002	0.007	0.001
Sikar	-0.036	-0.033	-0.006	-0.068	-0.033

Trend analysis of Mean Monthly Maximum Temperature

(trends)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	(-)	(+)*	(+)*	(+)*	(+)*
Nagaur	(+)	(+)	(-)	(+)*	(+)
Pilani (Jhunjhunu)	(-)	(+)	(+)	(+)	(+)
Sikar	(-)*	(-)*	(-)	(-)*	(-)*

Trend analysis of Mean Monthly Minimum Temperature

(b-values)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	-0.026	0.019	0.026	0.032	0.017
Nagaur	-0.043	-0.093	-0.108	-0.073	-0.085
Pilani (Jhunjhunu)	0.037	0.022	-0.005	0.018	0.014
Sikar	0.0144	0.0373	0.0179	0.0363	0.0267

Trend analysis of Mean Monthly Minimum Temperature

(trends)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	(-)	(+)	(+)	(+)*	(+)
Nagaur	(-)*	(-)*	(-)*	(-)*	(-)*
Pilani (Jhunjhunu)	(+)*	(+)	(-)	(+)	(+)
Sikar	(+)	(+)	(+)	(+)	(+)

Trend analysis of Mean Monthly Temperature

(b-values)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	0.007	0.020	0.003	0.017	0.012
Nagaur	0.004	0.018	0.010	0.024	0.014
Pilani (Jhunjhunu)	0.002	0.011	0.002	0.008	0.006
Sikar	0.001	0.005	-0.002	0.014	0.004

Trend analysis of Mean Monthly Temperature

(trends)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	(+)	(+)*	(+)	(+)	(+)
Nagaur	(+)	(+)*	(+)	(+)*	(+)
Pilani (Jhunjhunu)	(+)	(+)	(+)	(+)	(+)
Sikar	(+)	(+)	(-)	(+)	(+)

Source: National Data Centre, IMD, Pune

(+) Increasing Trend
(-) Decreasing Trend
* Significant at 95 % Confidence Level

5.2.1 MEAN MONTHLY MAXIMUM TEMPERATURE

Table 5.2 and Figure 5.1 and 5.2 shows trends in mean monthly maximum temperature of Churu, Jhunjhunu, Nagaur and Sikar districts.

With the station wise perspective, Churu recorded increasing trends in the maximum temperature for all seasons (significant at 95 % confidence level) except for winter. Unlike this, Sikar recorded decreasing trends throughout all the seasons of the year (significant at 95 % confidence level). The post-monsoon season recorded increasing trend at all the stations except Sikar. Nagaur recorded increasing trends in the maximum temperature for all seasons except for Monsoon. Jhunjhunu recorded increasing trends in the maximum temperature for all seasons except for winter.

5.2.2 MEAN MONTHLY MINIMUM TEMPERATURE

Churu experienced increasing trend in all seasons in mean monthly minimum temperature except for winter where it recorded a decreasing trend. Nagaur had marked decreasing trend in all the seasons of a year (significant at 95 % confidence level). Jhunjhunu had marked increasing trend in all the seasons of a year except in winter. Sikar had marked increasing trend in all the seasons of a year.

5.2.3 MEAN MONTHLY TEMPERATURE

Here all the four districts viz. Churu, Jhunjhunu, Nagaur and Sikar experienced increasing trend of temperature through all the four seasons of a year except for Sikar which recorded decreasing trend for Monsoon season.

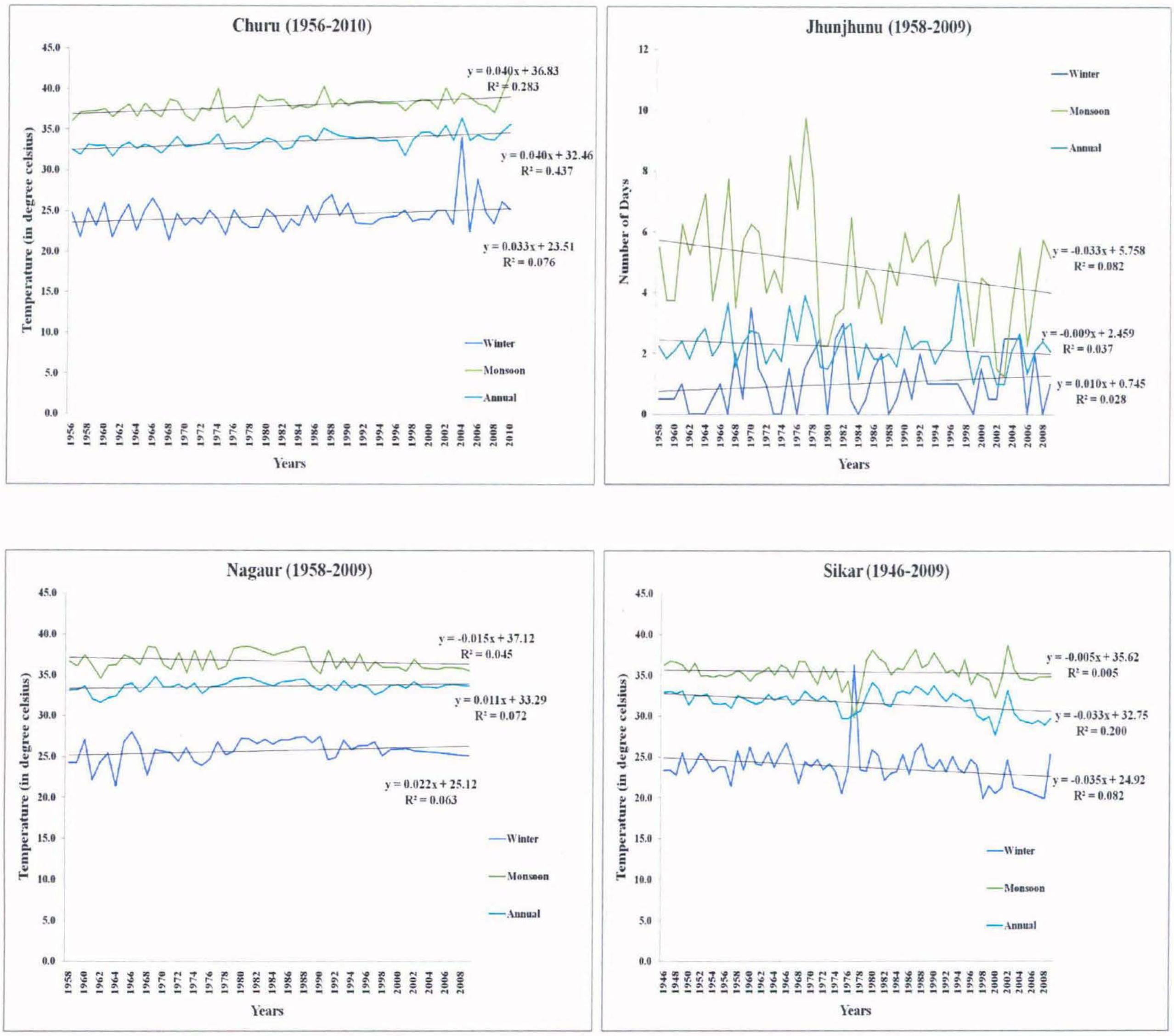


Figure 5.1: Trend in Mean Monthly Maximum Temperature

Source: National Data Centre, IMD, Pune

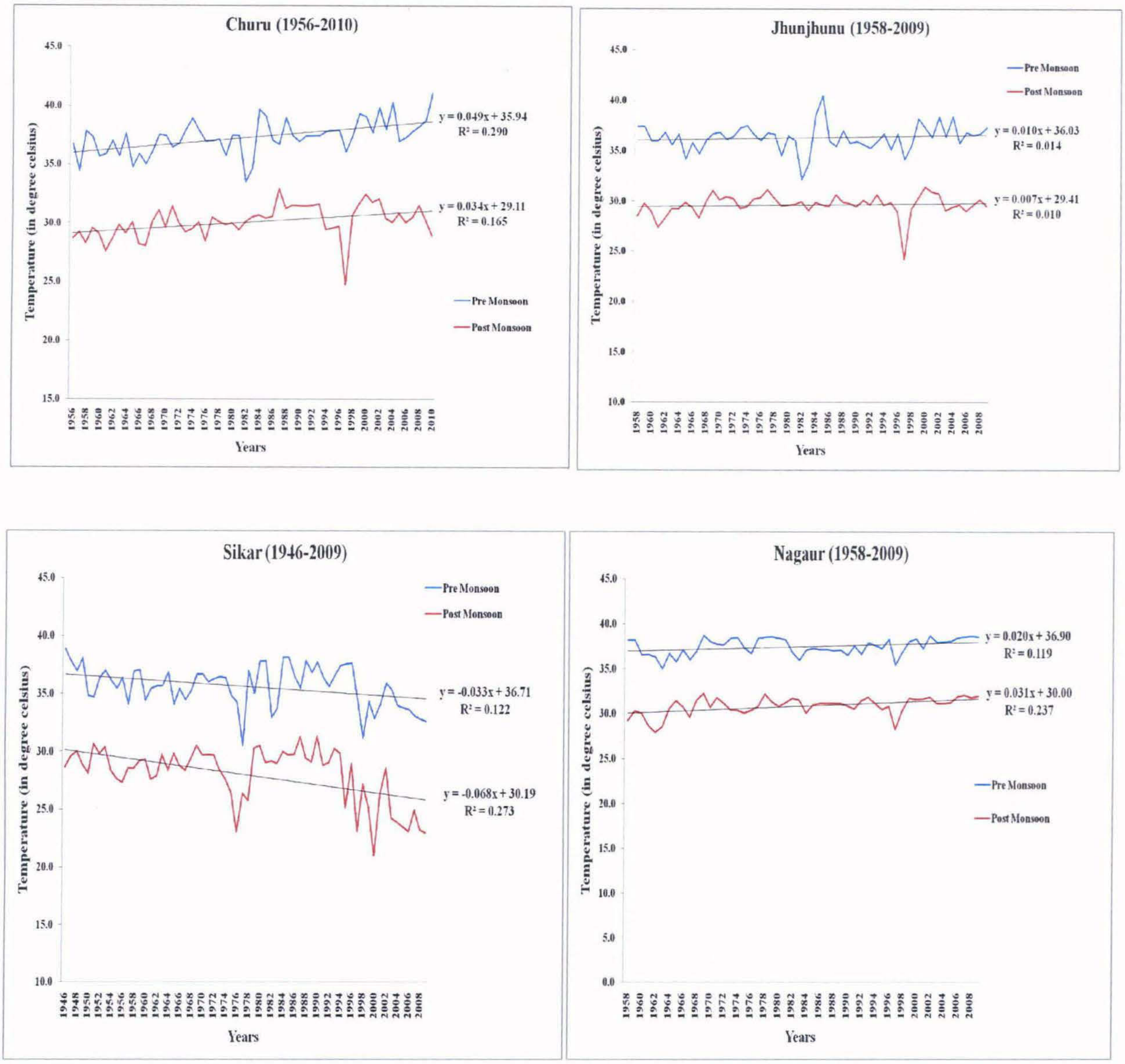


Figure 5.2: Trend in Mean Monthly Maximum Temperature

Source: National Data Centre, IMD, Pune

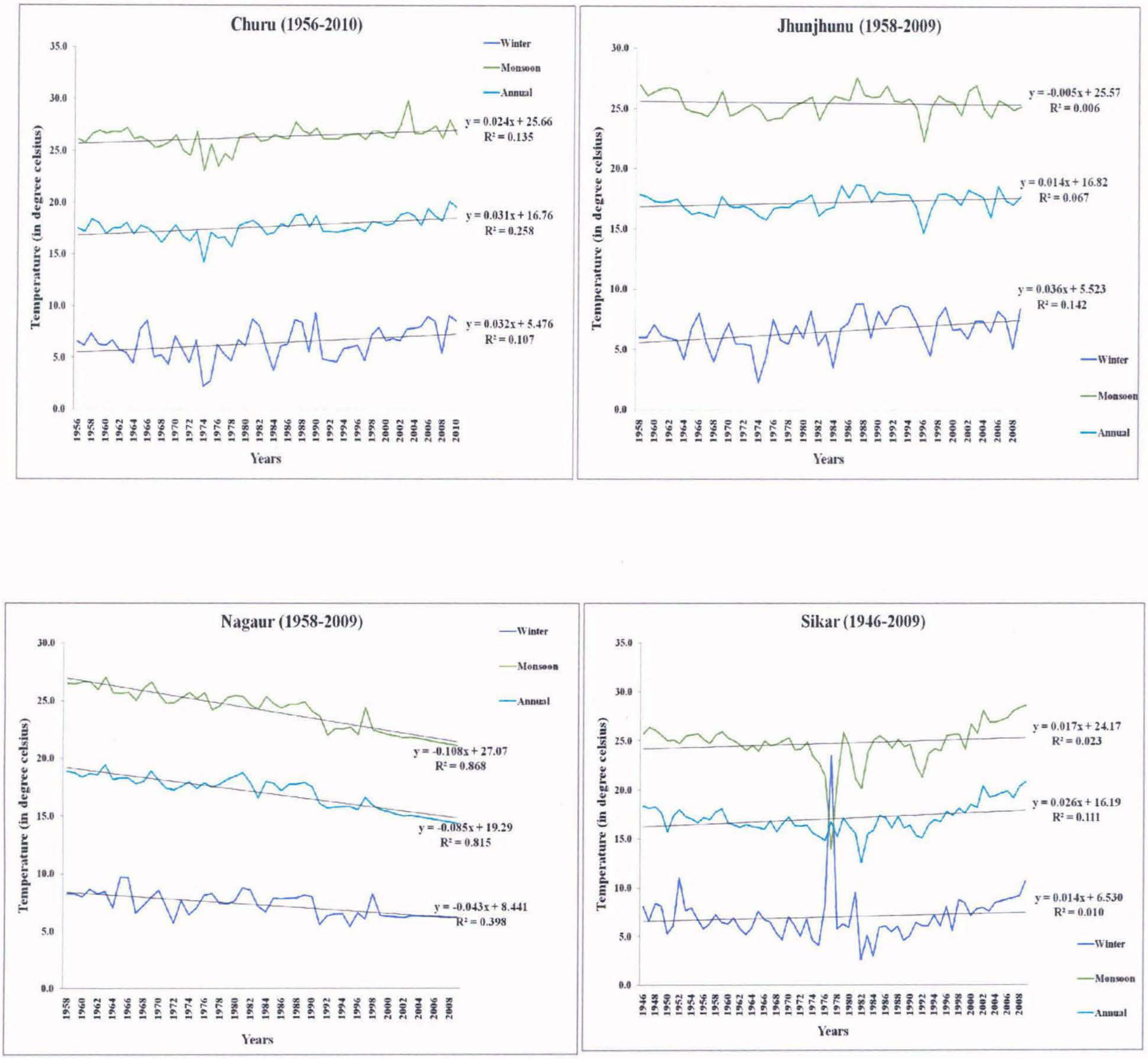


Figure 5.3: Trend in Mean Monthly Minimum Temperature

Source: National Data Centre, IMD, Pune

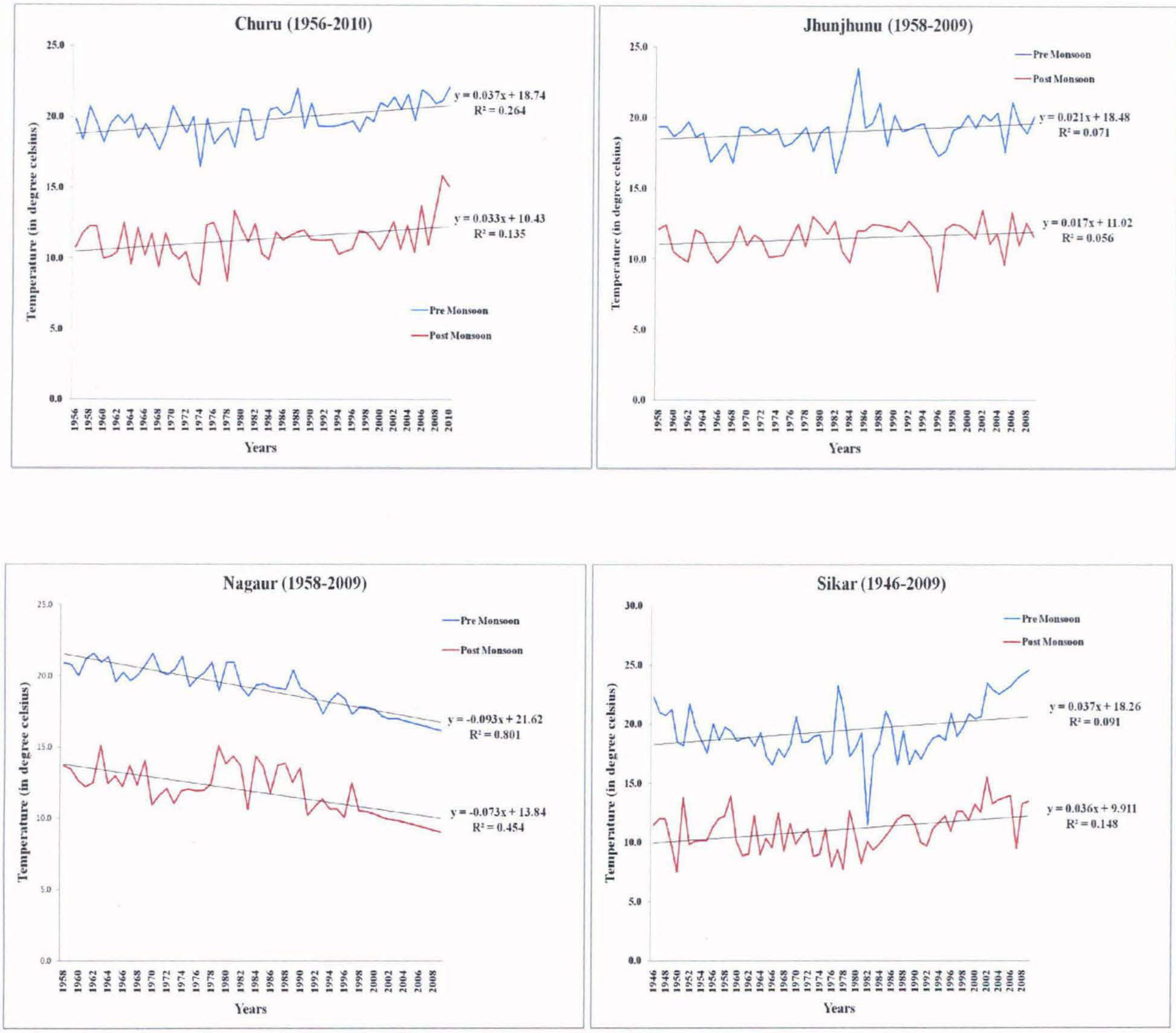


Figure 5.4: Trend in Mean Monthly Minimum Temperature

Source: National Data Centre, IMD, Pune

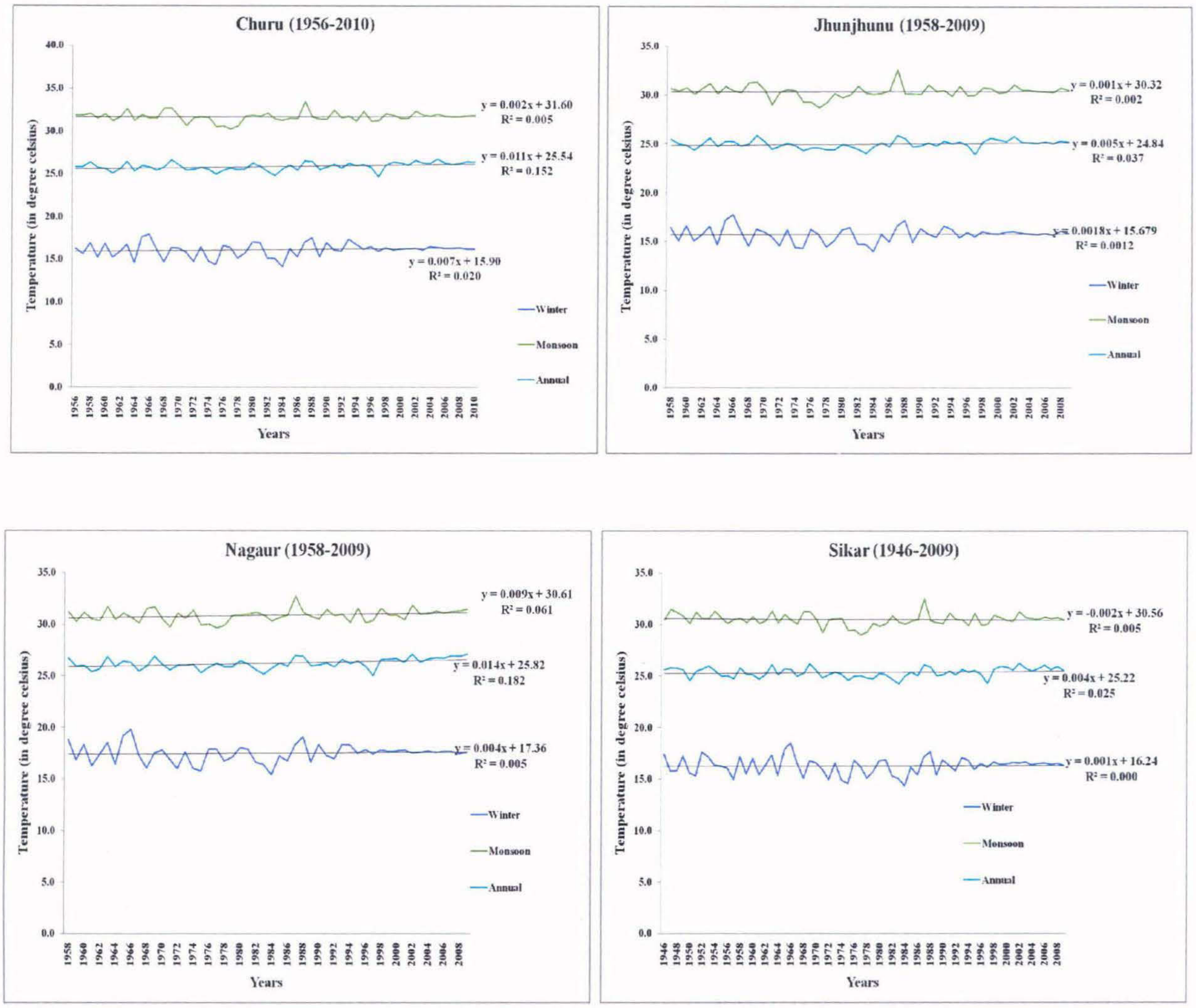


Figure 5.5: Trend in Mean Monthly Temperature

Source: National Data Centre, IMD, Pune

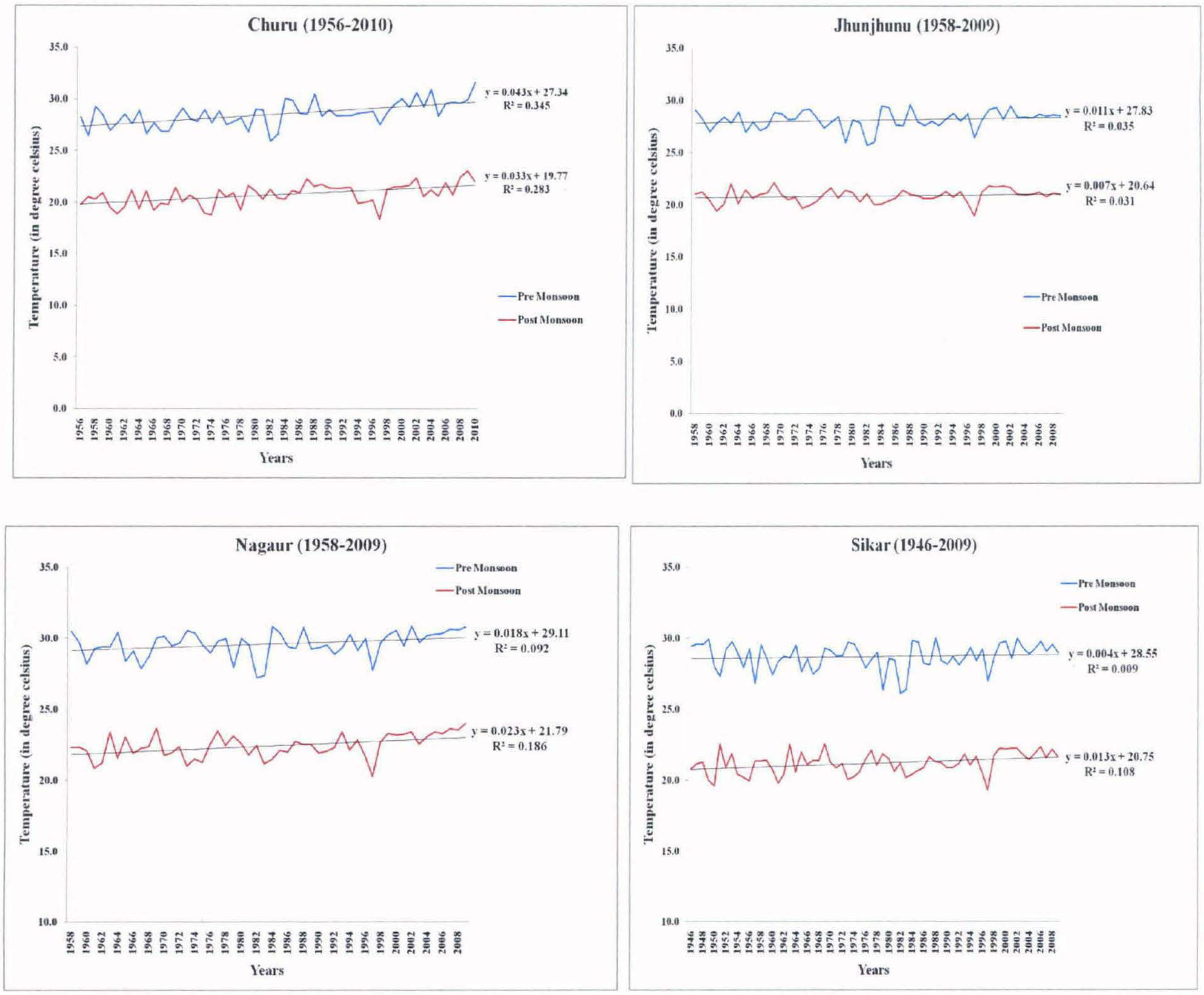


Figure 5.6: Trend in Mean Monthly Temperature

Source: National Data Centre, IMD, Pune

5.2.4 TOTAL MONTHLY RAINFALL

Churu recorded decreasing trend in Mean Monthly Rainfall (significant at 95 % confidence level) in winter and monsoon seasons whereas increasing trend was recorded for pre monsoon and post monsoon seasons. Nagaur and Jhunjhunu recorded increasing trend in Mean Monthly Rainfall (significant at 95 % confidence level) through all seasons except for Jhunjhunu which showed a decreasing trend in monsoon season. Interestingly Sikar recorded a decreasing trend in Mean Monthly Rainfall (significant at 95 % confidence level) in all seasons. Since monsoon rainfall constitutes a major chunk of the total annual rainfall, that's why the annual rainfall also recorded decreasing trend in these districts. Only pre-monsoon rainfall displayed an increasing trend for all the stations except for Sikar. But the sharp decreasing trend in monsoon rainfall and winter rainfall, which is received from the western disturbances, caused the annual rainfall to follow a decline. The annual rainfall marked decreasing trend for all districts except for Nagaur. Decreasing trends in the monsoon rainfall is prime point of concern as not only the economy of these districts but also the normal life is fully dependent on the monsoon rainfall and subsequent storage of that.

Table 5.3: Trend analysis of Mean Monthly Rainfall and Mean Monthly Rainy Days using Simple Linear Regression Method

Trend analysis of Mean Monthly Rainfall

(b-values)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	-0.147	0.111	-0.463	0.035	-0.143
Nagaur	0.163	0.005	0.429	0.245	0.433
Pilani (Jhunjhunu)	0.108	0.129	-0.422	0.014	-0.087
Sikar	-0.092	-0.004	-0.379	-0.089	-0.498

Trend analysis of Mean Monthly Rainfall

(trends)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	(-)*	(+)*	(-)*	(+)	(-)*
Nagaur	(+)*	(+)	(+)*	(+)*	(+)*
Pilani (Jhunjhunu)	(+)*	(+)*	(-)*	(+)	(-)*
Sikar	(-)*	(-)	(-)*	(-)*	(-)*

Trend analysis of Mean Monthly Rainy Days

(b-values)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	0.004	0.001	-0.008	0.000	-0.002
Nagaur	0.006	0.009	-0.014	0.000	-0.001
Pilani (Jhunjhunu)	0.010	0.008	-0.033	-0.006	-0.009
Sikar	-0.019	-0.006	-0.073	-0.008	-0.031

Trend analysis of Mean Monthly Rainy Days

(trends)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	(+)	(+)	(-)	(+)	(-)
Nagaur	(+)	(+)	(-)	(+)	(-)
Pilani (Jhunjhunu)	(+)	(+)	(-)*	(-)	(-)
Sikar	(-)	(-)	(-)*	(-)	(-)*

Source: National Data Centre, IMD, Pune

(DNA; Data Not Available)

(+) Increasing Trend
(-) Decreasing Trend
* Significant at 95 % Confidence Level

5.2.5 MEAN MONTHLY RAINY DAYS

The mean monthly rainy days in Churu, Jhunjhunu, Nagaur and Sikar districts recorded decreasing trends annually. Churu and Nagaur recorded increasing trend for mean monthly rainy days in all three seasons except for monsoon where these districts recorded a decreasing trend. Jhunjhunu recorded increasing trend for mean monthly rainy days in winter and pre monsoon seasons and a decreasing trend in monsoon and post monsoon seasons. Sikar recorded decreasing trend for mean monthly rainy days in all seasons of the year. The pre-monsoon data series depicted increasing trend in monthly rainy days except for Sikar.

The rainfall scenario is much evident in Churu, Jhunjhunu, Nagaur and Sikar districts. A decreasing trend in monsoon rainfall is common for all these districts which consequently marked a decreasing trend in annual rainfall. The pre-monsoon rainfall, interestingly, showed increasing trend at all the meteorological stations. Number of rainy days is directly correlated with the monsoon rainfall. The trend analysis results of monthly rainfall and rainy days are highly similar to each-other. The annual data sets show that the monthly rainy days experienced decreasing trend which is also true for mean monthly rainfall except for Nagaur where annual data sets for mean monthly rainfall showed an increasing trend.

Table 5.4: Trend analysis of extreme events using simple linear regression method

Trend analysis of Highest Maximum Temperature

(b-values)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	0.013	0.055	0.048	0.063	0.048
Nagaur	0.024	-0.011	-0.034	-0.033	-0.018
Pilani (Jhunjhunu)	-0.014	0.013	-0.004	0.021	0.005
Sikar	-0.043	-0.012	-0.001	-0.027	-0.017

Trend analysis of Highest Maximum Temperature

(trends)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	(+)	(+)*	(+)*	(+)*	(+)*
Nagaur	(+)	(-)	(-)*	(-)*	(-)
Pilani (Jhunjhunu)	(-)	(+)	(-)	(+)*	(+)
Sikar	(-)*	(-)	(-)	(-)*	(-)

Trend analysis of Lowest Minimum Temperature

(b-values)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	-0.048	0.011	0.015	0.022	0.005
Nagaur	0.008	-0.068	-0.144	-0.049	-0.076
Pilani (Jhunjhunu)	0.030	0.027	-0.002	0.023	0.017
Sikar	0.074	0.080	0.033	0.071	0.061

Trend analysis of Lowest Minimum Temperature

(trends)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	(-)*	(+)	(+)	(+)*	(+)
Nagaur	(+)	(-)*	(-)*	(-)*	(-)*
Pilani (Jhunjhunu)	(+)*	(+)*	(-)	(+)*	(+)
Sikar	(+)*	(+)*	(+)*	(+)*	(+)*

Trend analysis of Heaviest Monthly Rainfall

(b-values)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	-0.113	0.067	-0.141	-0.066	-0.065
Nagaur	0.005	-0.044	0.740	0.085	0.258
Pilani (Jhunjhunu)	0.061	0.086	-0.067	0.003	0.010
Sikar	-0.030	-0.024	-0.322	-0.075	-0.137

Trend analysis of Heaviest Monthly Rainfall

(trends)

Station	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Churu	(-)*	(+)*	(-)*	(-)*	(-)*
Nagaur	(+)	(-)*	(+)*	(+)*	(+)*
Pilani (Jhunjhunu)	(+)*	(+)*	(-)*	(+)	(+)
Sikar	(-)	(-)	(-)	(-)*	(-)*

Source; National Data Centre, IMD, Pune

(+) Increasing Trend
(-) Decreasing Trend
* Significant at 95 % Confidence Level

5.2.6 TREND ANALYSIS OF EXTREME EVENTS

5.2.6.1 Monthly Highest Maximum Temperature

Churu reflected significant increasing trend in highest maximum temperature (significant at 95 % confidence level) for all seasons of the year. Nagaur recorded decreasing trend for all seasons except for winter where increasing trend was recorded. Jhunjhunu recorded increasing trend for pre monsoon and post monsoon seasons whereas winter and monsoon data sets recorded decreasing trend for Jhunjhunu. Sikar reflected significant decreasing trend in highest maximum temperature (significant at 95 % confidence level in winter and post monsoon seasons) for all seasons of the year.

5.2.6.2 Monthly Lowest Minimum Temperature

Churu reflected significant increasing trend in lowest minimum temperature for all seasons except for winter where decreasing trend was recorded. Nagaur recorded decreasing trend in lowest minimum temperature for all seasons except for winter where increasing trend was recorded. Jhunjhunu recorded increasing trend for all seasons except for monsoon where decreasing trend was recorded. Sikar reflected significant increasing trend in lowest minimum temperature (significant at 95 % confidence level) for all seasons of the year.

5.2.6.3 Monthly Heaviest Rainfall

Churu reflected decreasing trend in monthly heaviest rainfall for all seasons except for pre monsoon season where increasing trend was recorded. Nagaur recorded increasing trend in monthly heaviest rainfall for all seasons except for pre monsoon season where decreasing trend was recorded. Jhunjhunu recorded increasing trend for all seasons except for monsoon where decreasing trend was recorded. Sikar reflected significant decreasing trend in monthly heaviest rainfall (significant at 95 % confidence level in post monsoon season) for all seasons of the year.

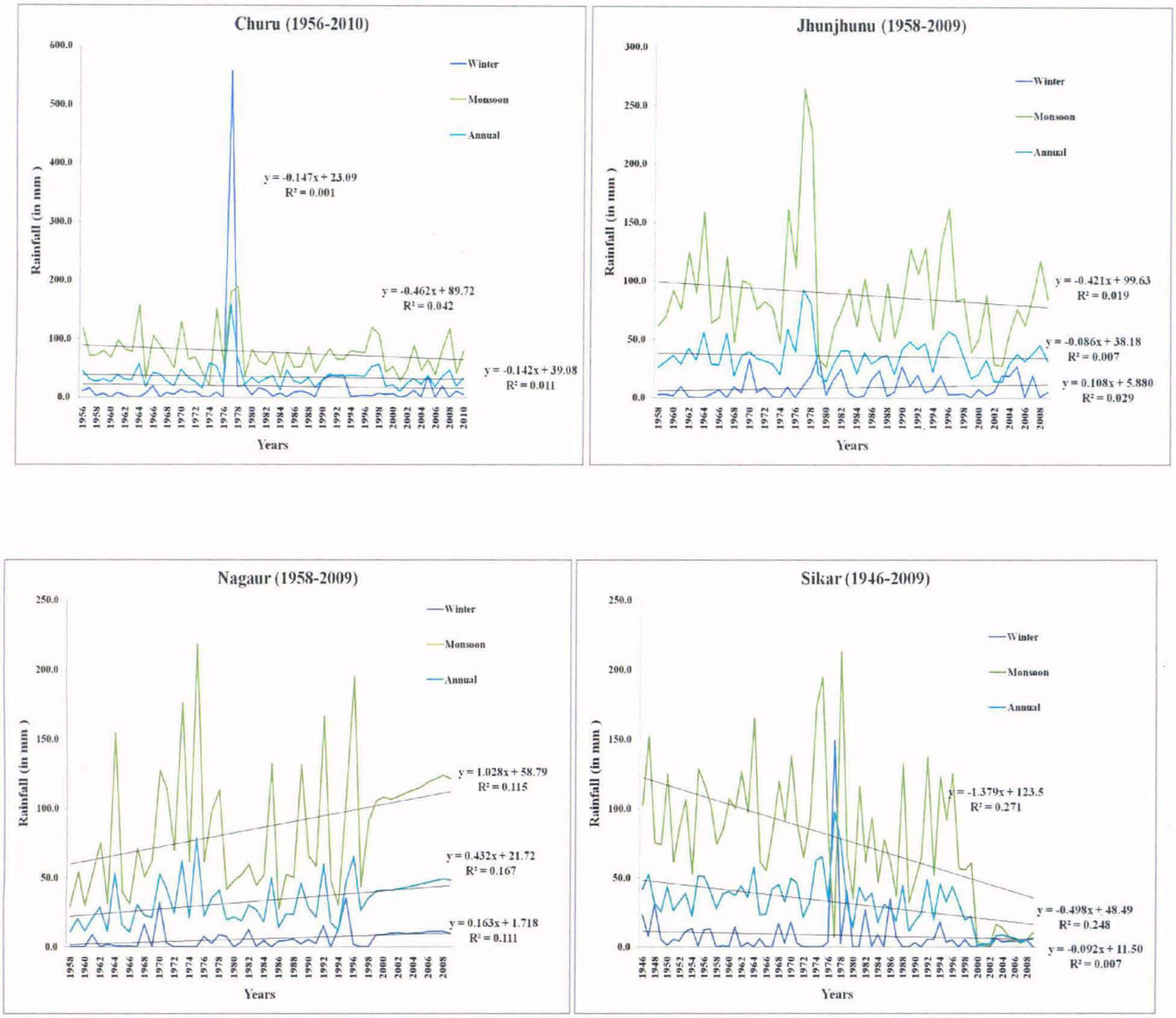


Figure 5.7: Trend in Mean Monthly Rainfall

Source: National Data Centre, IMD, Pune

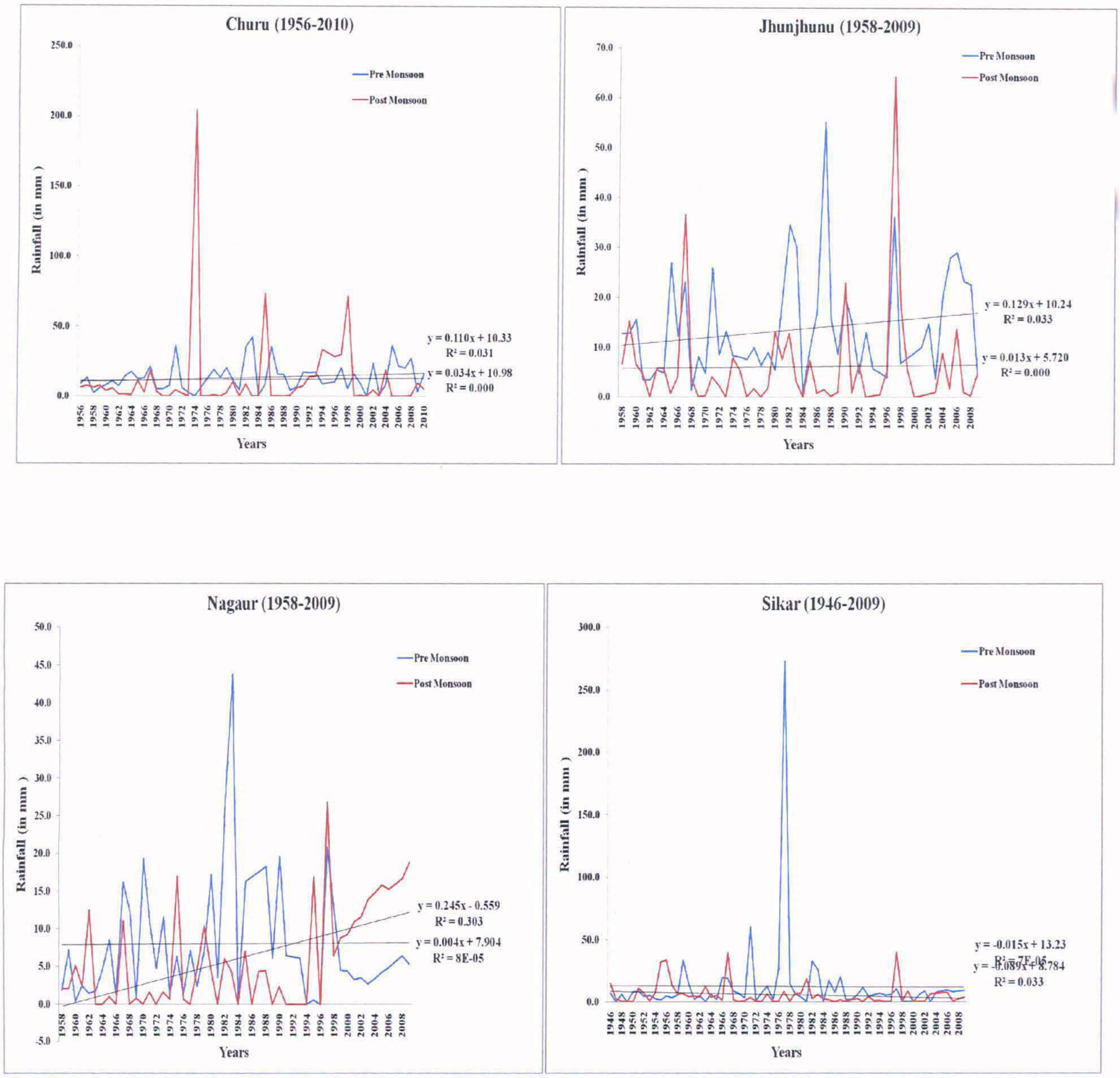


Figure 5.8: Trend in Mean Monthly Rainfall

Source: National Data Centre, IMD, Pune

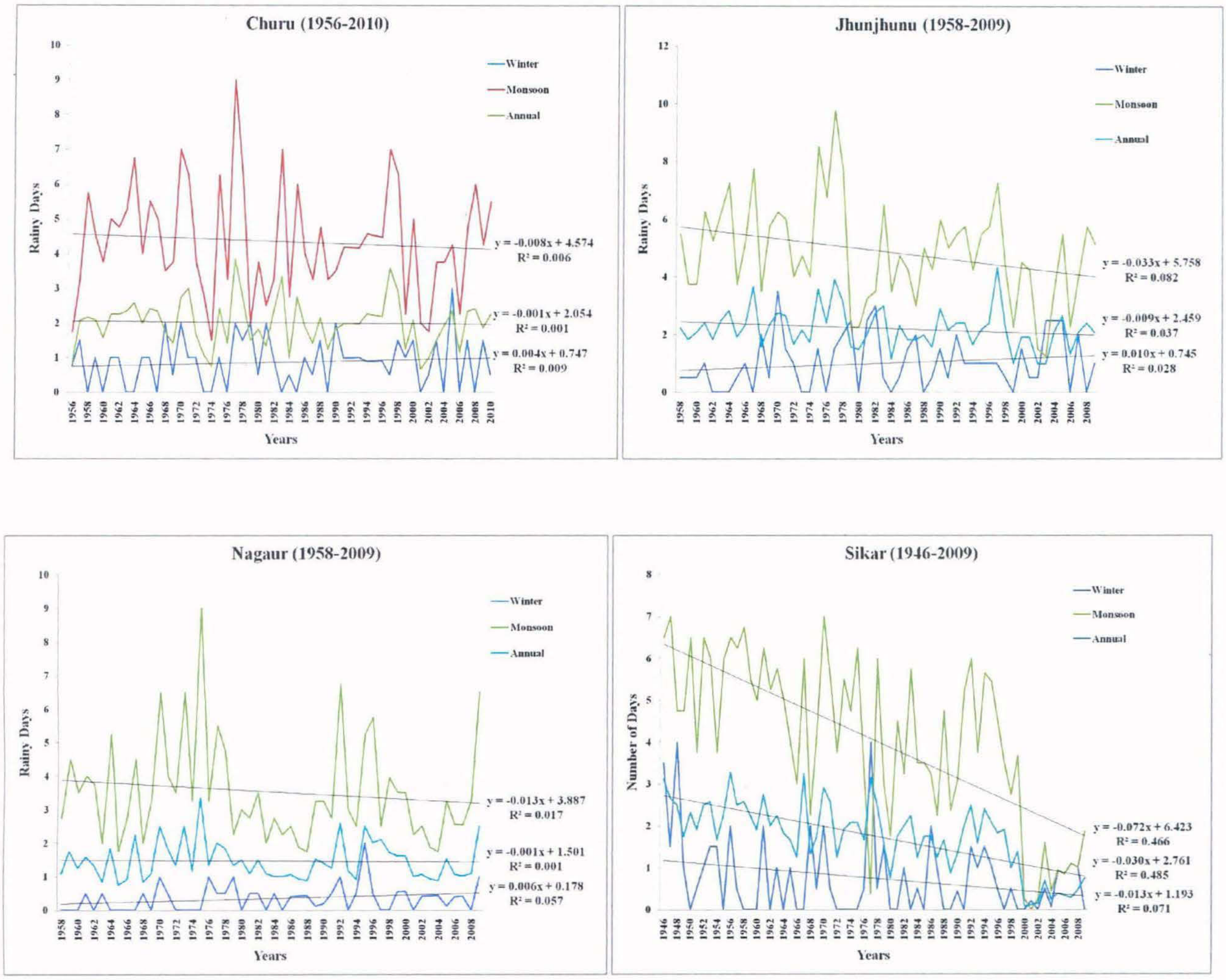


Figure 5.9: Trend in Mean Monthly Rainy Days

Source: National Data Centre, IMD, Pune

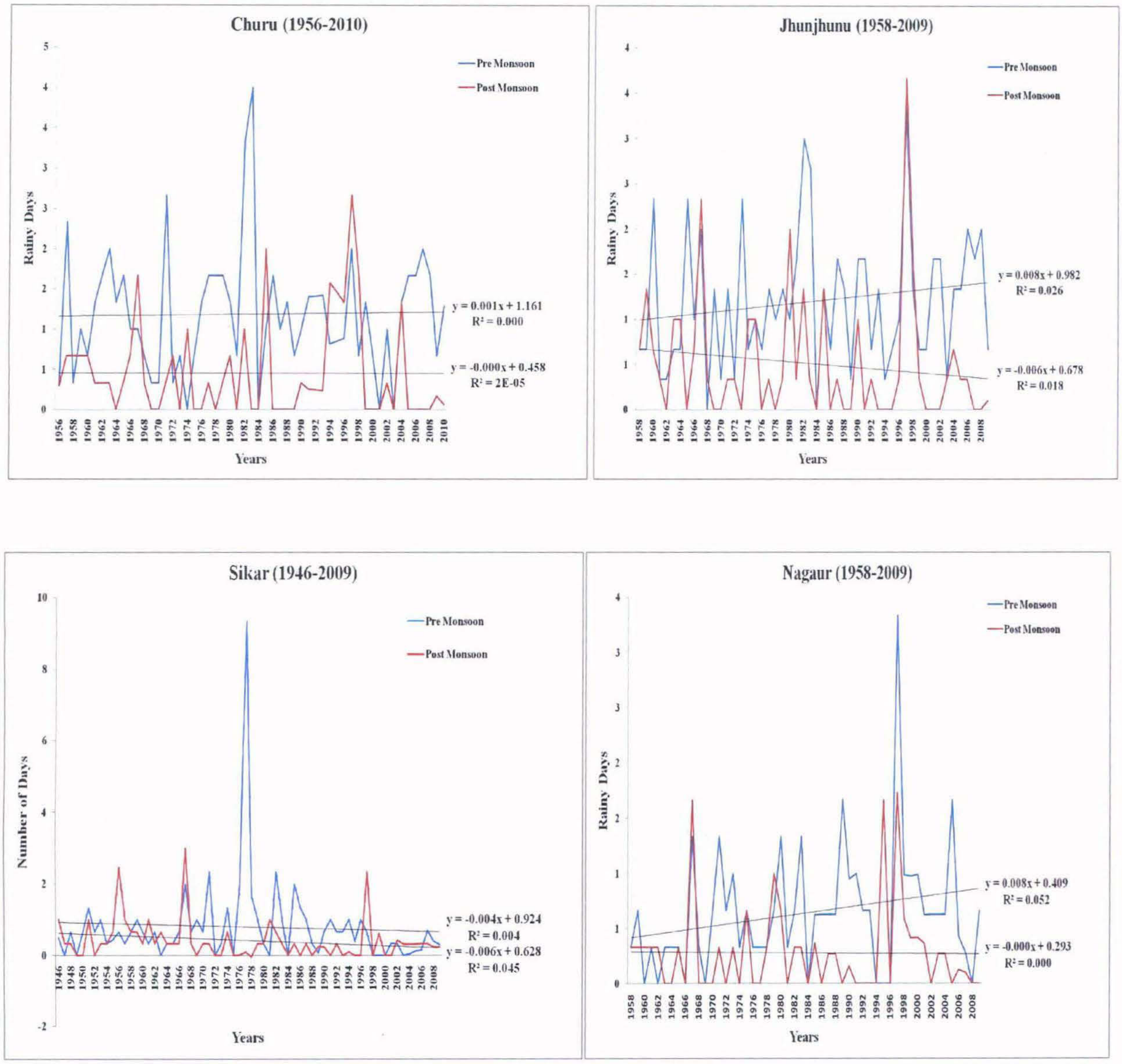


Figure 5.10: Trend in Mean Monthly Rainy Days

Source: National Data Centre, IMD, Pune

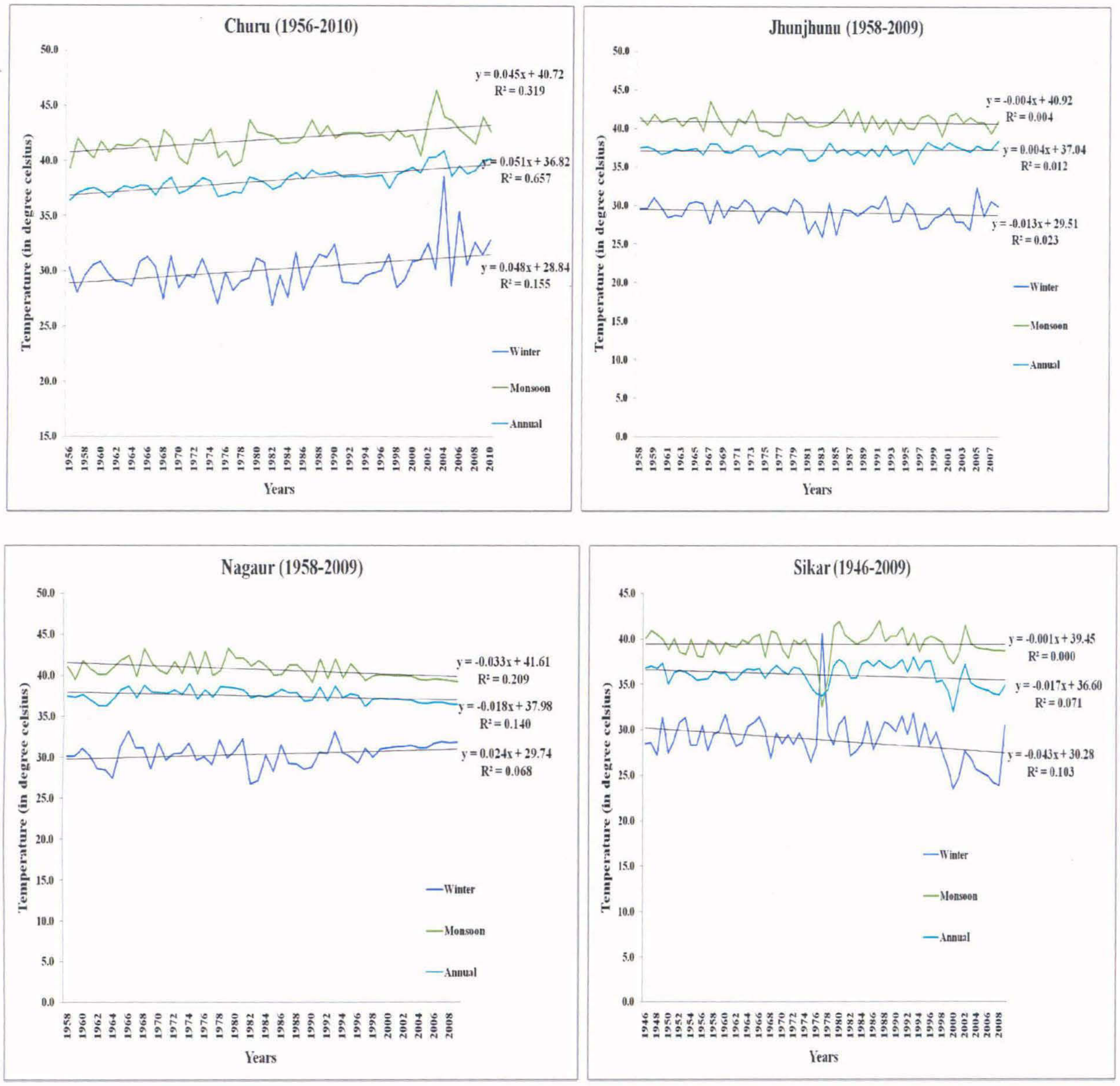


Figure 5.11: Trend in Mean Monthly Highest Maximum Temperature

Source: National Data Centre, IMD, Pune

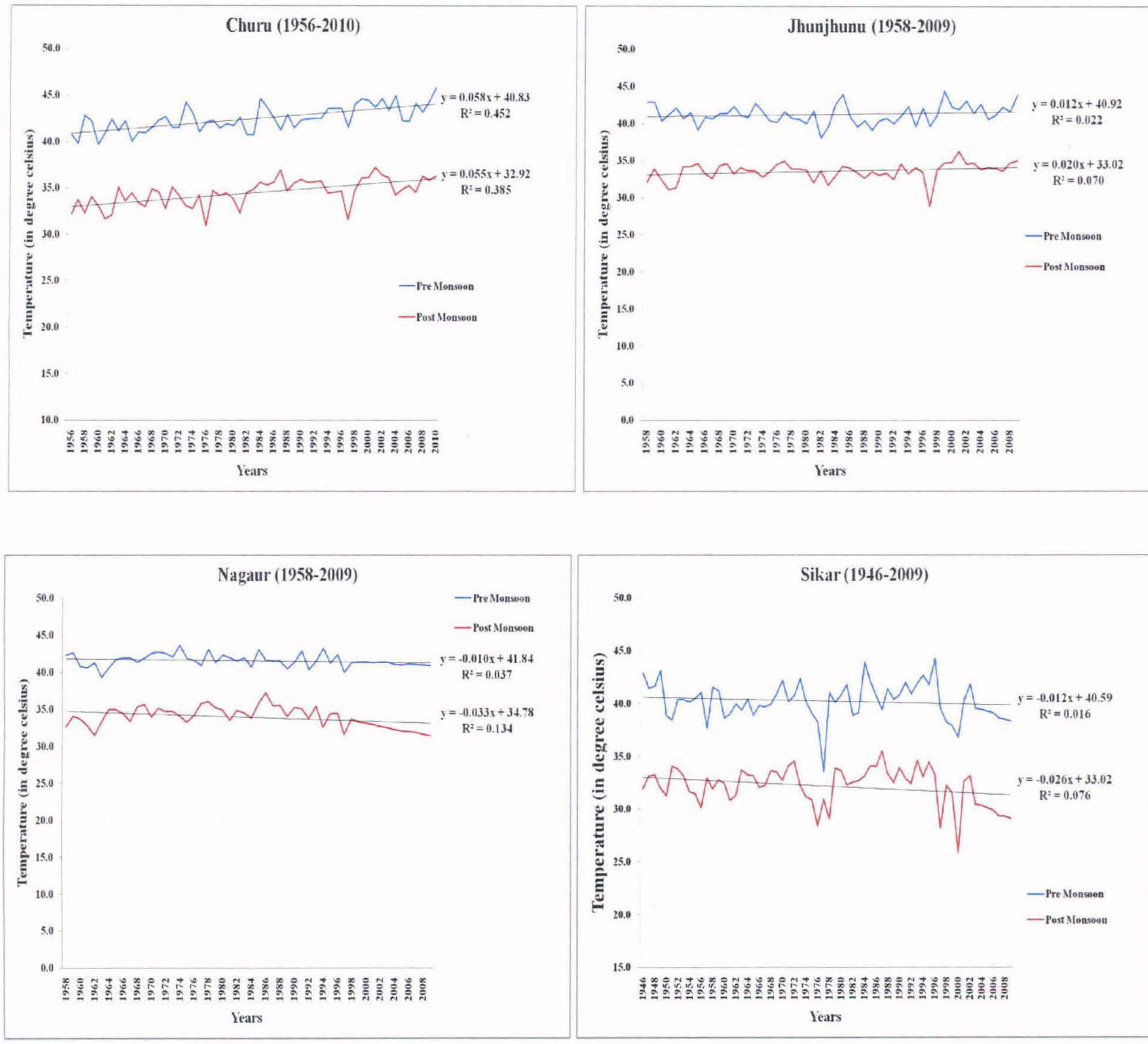


Figure 5.12: Trend in Mean Monthly Highest Maximum Temperature

Source: National Data Centre, IMD, Pune

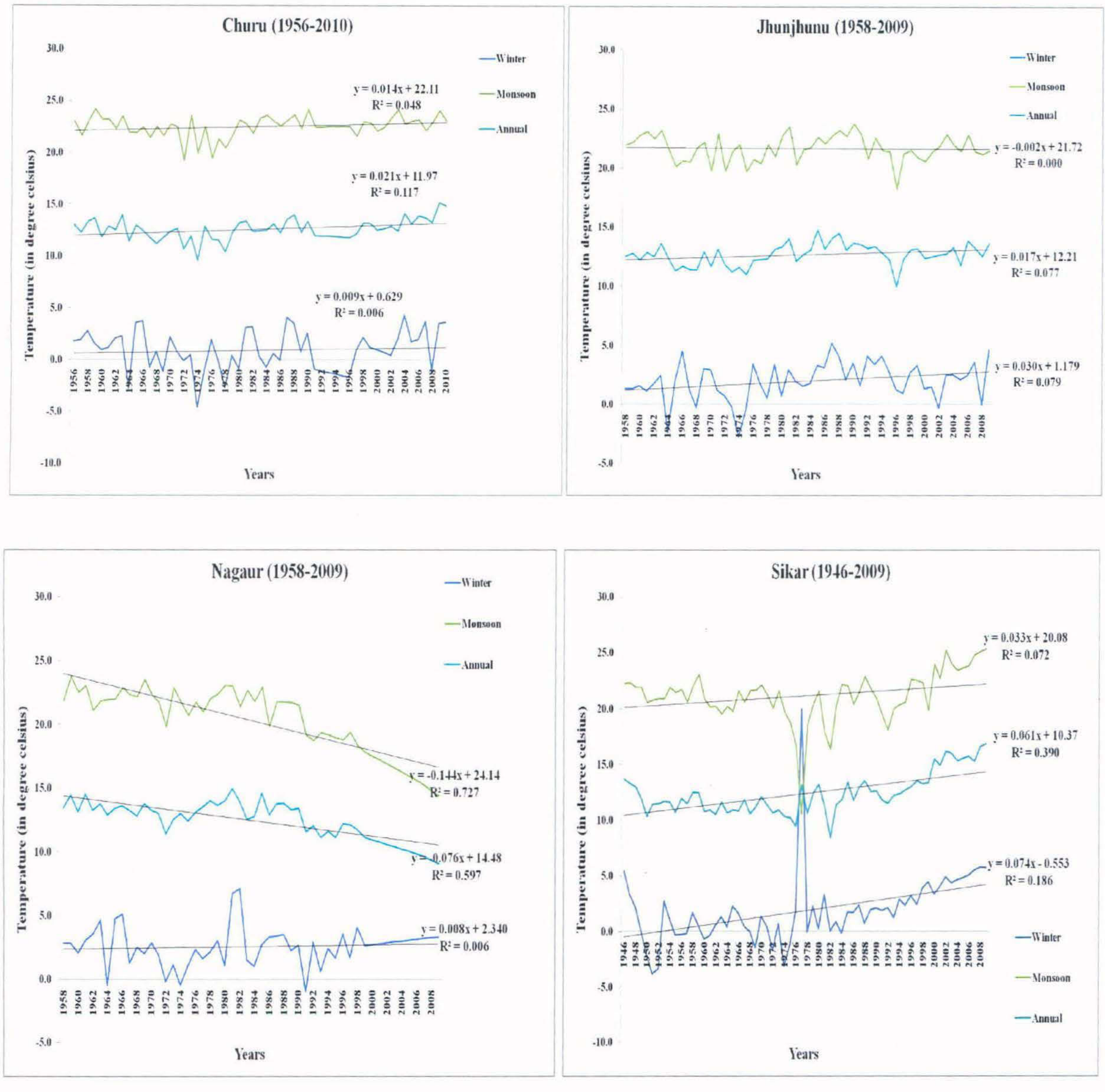


Figure 5.13: Trend in Mean Monthly Lowest Minimum Temperature

Source: National Data Centre, IMD, Pune

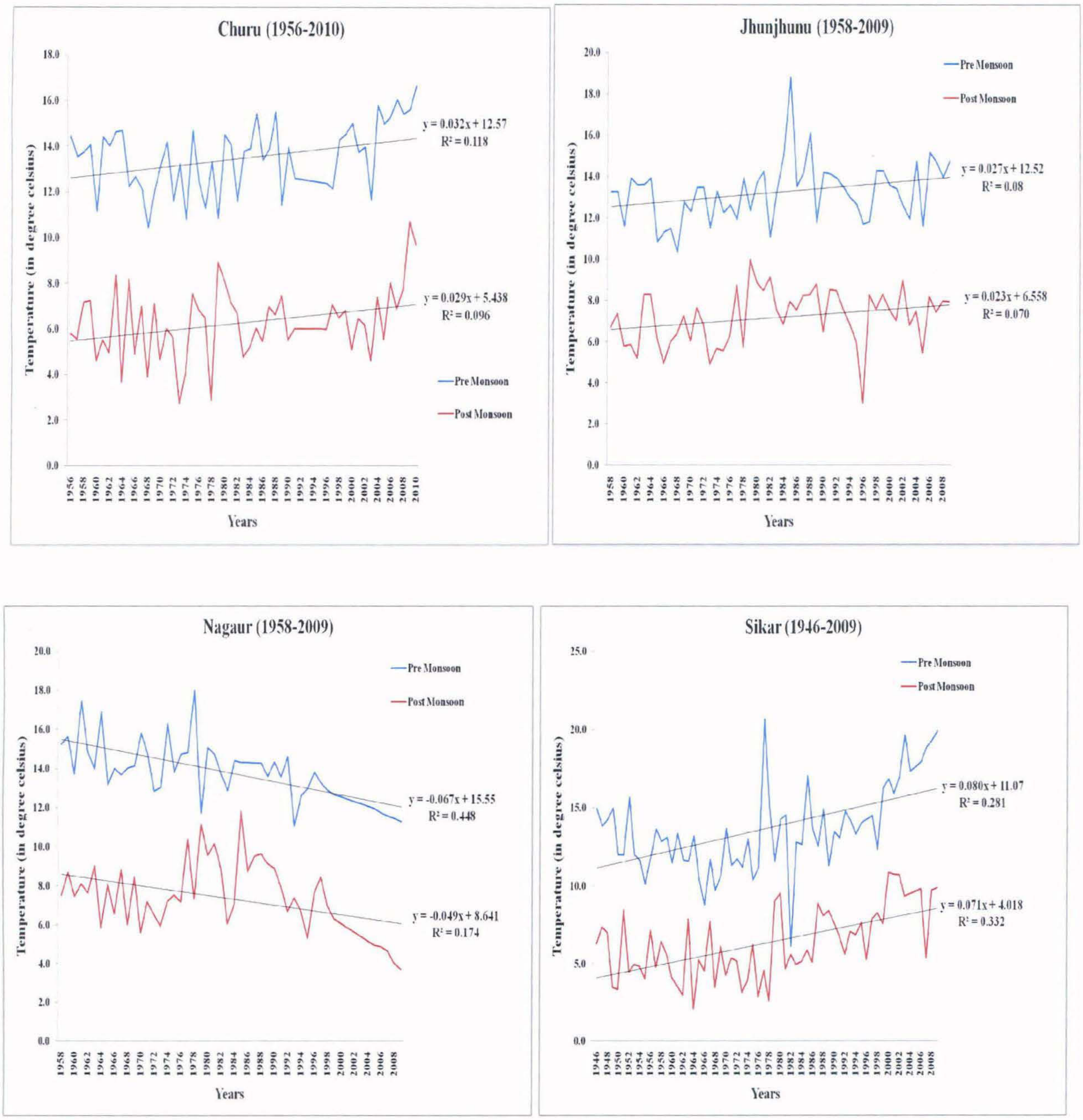


Figure 5.14: Trend in Mean Monthly Lowest Minimum Temperature

Source: National Data Centre, IMD, Pune

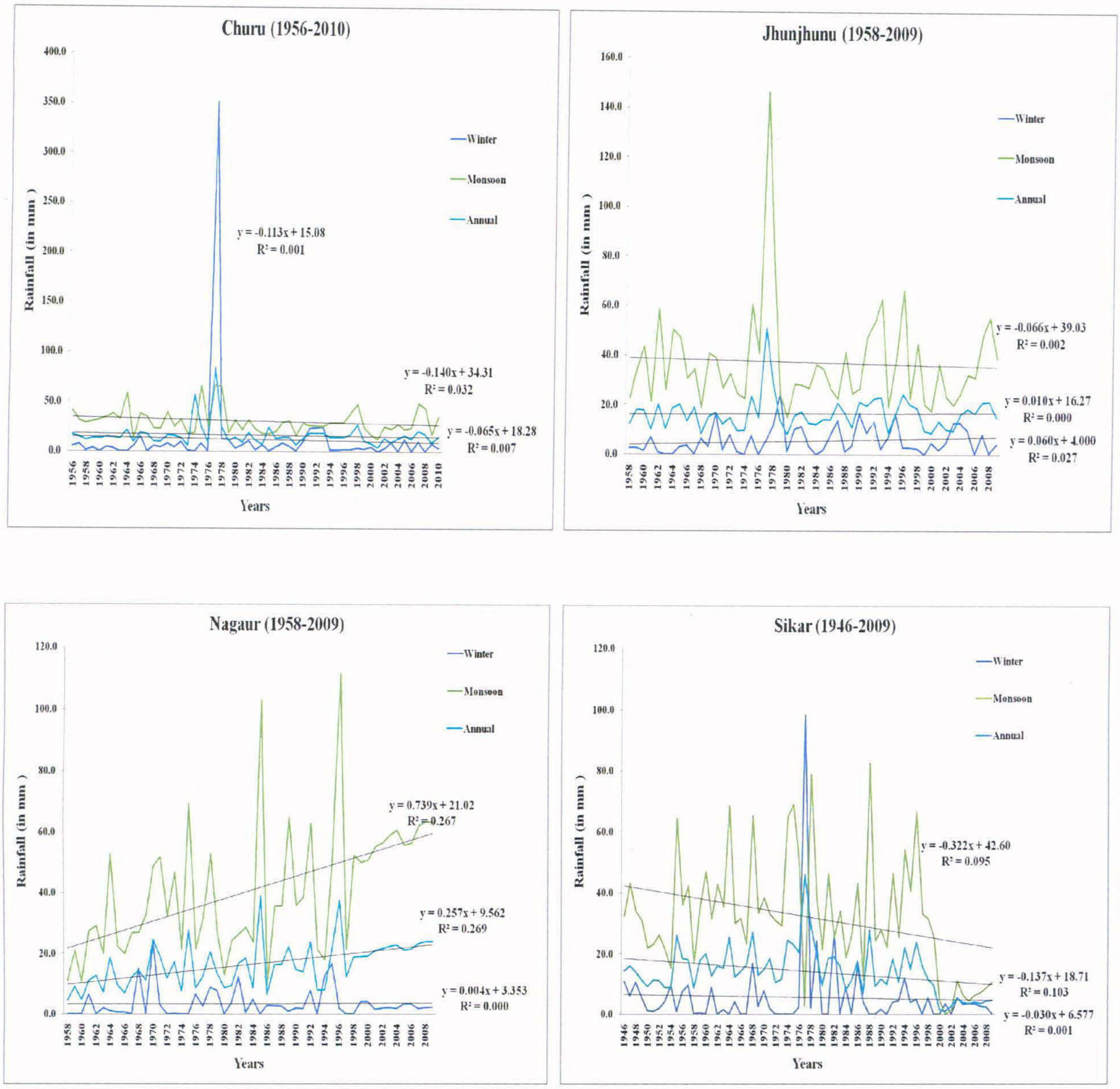


Figure 5.15: Trend in Mean Monthly Heaviest Rainfall

Source: National Data Centre, IMD, Pune

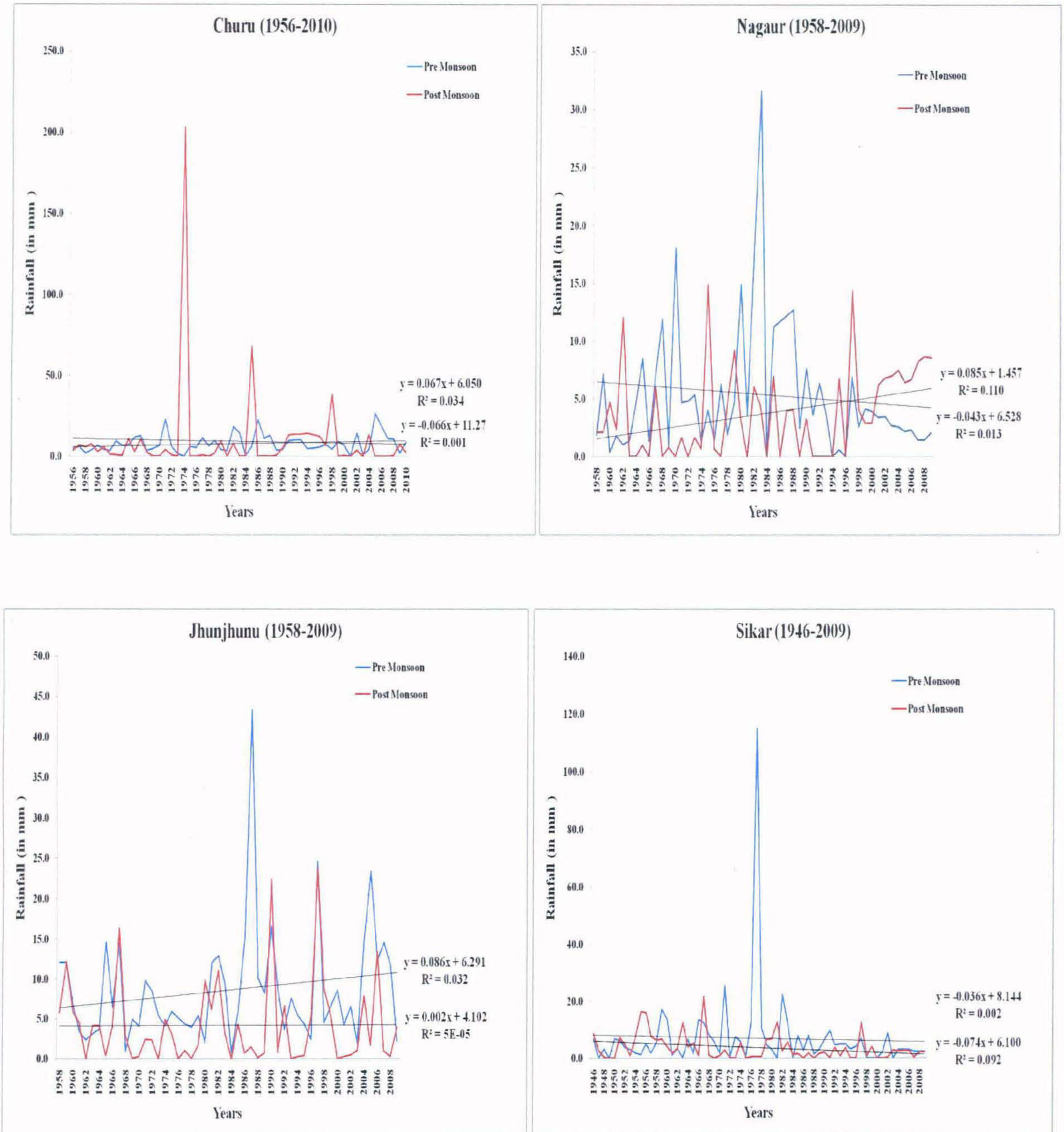


Figure 5.16: Trend in Mean Monthly Heaviest Rainfall

Source: National Data Centre, IMD, Pune

5.3 RESULTS AND DISCUSSION

The simple linear regression analysis provided very interesting information about trends in the climatic variables. The major results of the analysis are listed below;-

i. It is expected that all the four districts reflected statistically significant positive or negative trend in the selected climatic parameters recorded for a relatively longer time span.

ii. The temperature regime displayed a significant increasing trend in Churu, Jhunjhunu and Nagaur districts except Sikar which recorded a decreasing trend in mean monthly maximum temperature.

iii. Mean monthly temperature reflected significant increasing trends in Churu, Jhunjhunu, Nagaur and Sikar districts.

iv. Churu showed significant increasing trend in maximum and mean monthly temperature.

v. Minimum temperature showed decreasing trend in Nagaur.

vi. The rainfall scenario is more evident in the study area. A decreasing trend in monsoon rainfall is common for all the stations in the region except for Nagaur which recorded an increasing trend which is consequently followed by the decreasing trend in annual rainfall in the study area except for Nagaur.

vii. Sikar reflected decreasing trend in rainfall received during pre monsoon, monsoon, post-monsoon and winter season while Nagaur marked a significant increasing trend in monthly rainfall in all seasons.

viii. Rainy days denote wet period. The trend analysis results of monthly rainfall and rainy days are quite similar to each-other. Rainy days in monsoon season experienced significant decreasing trend in all the four districts while Sikar experienced decreasing trend in rainy days during all seasons.

ix. The trend analysis of climatic extremes suggests that Sikar recorded significant increasing trend in lowest minimum temperature and decreasing trend in highest maximum temperature. On the other hand, Churu experienced increasing trend in temperature extremes.

x. Churu and Nagaur recorded decreasing trend in heaviest rainfall while Nagaur recorded an increasing trend for the same.

Chapter Six

Summary and Conclusion

Desertification is the degradation of the land in arid, semi-arid and sub-humid dry areas caused by climatic changes and human activities. It is accompanied by a reduction in the natural potential of the land and depletion in surface and ground-water resources. But above all it has negative repercussions on the living conditions and the economic development of people. Desertification not only occurs in natural deserts, but can also take place on land which is prone to desertification processes.

As per the Desertification and Land Degradation Atlas of India published by the Space Application Centre in 2007, about 32.07 % of the land is undergoing various forms of degradation and 25% of the geographical area is affected by desertification. About 69% of the country's lands are dry lands and degradation of these lands has severe implications for the livelihood and food security of millions.

Desertification has become a major worldwide environmental problem. In India arid zone covers about 12% area of the country. The Thar Desert of Rajasthan is located partly in India and partly in Pakistan. About 85% of the desert lies in India and the rest lies in Pakistan. About 91% of the desert i.e. 2.08 million square kilometers falls in Rajasthan which covers about 61% of the geographical area of the state (Sinha *et al.*, 2000). Bordering the desert on four sides are Indus Plains to the west, Aravali range to the south east, Rann of Kutch to the south and Punjab plains to the east and north east. Also known as "The Great Indian Desert", Thar covers an area of 200,000 square kilometers. Desertification is one of the major slow hazards found in north western part of the country especially in Rajasthan State. The state of Rajasthan is situated in the north-western part of Indian union covering the complete arid Great Indian Desert and parts of semiarid climatic zone. Its location in the western fringe of Indian landmass has placed the state enroute to hot western winds during summers and Mediterranean cyclones during the winters. Aravali ranges divide the state of Rajasthan into two parts, from northwest towards south-east.

The origin of the arid region of Rajasthan, the Thar Desert has always been disputed. Some believe that the Thar Desert is a true natural desert caused by climatic factors (Sen & Mann, 1977). Evidences indicates that this area underwent xerification more than once during the Quaternary period and human activities only intensified the desertification process (Ghose *et al.*, 1977). However, others believe that this area had a luxurious vegetation cover that has been destroyed by human exploitation, and thus the origin of Thar Desert is a recent event, and the desert is man-made (Lukose, 1977). It was a Prosopis savannah before its long history of overgrazing and wood collecting determined its current appearance (Breckle, 2002).

Owing to publicity given to Planning Commission's view that the Rajasthan desert is encroaching on 50 square miles of fertile land every year, raised eyebrow of geographers in particular and that of inhabitants in general. The topographical maps on which reliance was placed for the extension of desert were exhibited at 'Symposium on the Rajputana Desert' by Colonel Gambhir Singh of the Survey of India (Sunderlal Hora, 1952). During discussion, it became abundantly clear that there is not reliable evidence from topographical surveys, conducted since 1885 for different purposes, in favor of the spread of desert like conditions. Shri K.V. Krishnamurthy, Extra asst Director- Central Water and Power Commission also supported the view that no scientific data revealed expansion of desert. Dr. S.K. Pramnik also supported the view on the basis of his statistical analysis of rainfall, temperature, humidity and wind at a number of places in Rajasthan and surrounding regions in which he found tha there had been no appreciable deterioration (rise in temperature, fall in rainfall, decrease in humidity and increase in wind) in any of these elements within the last 70 or 80 years. Dr. S.K. Banerji supported the opposite view by criticizing the phrase 'no appreciable change.' Because according to him the word "appreciable" has no definite meaning. According to him the comparison of 1886, 1920 and 1940 normals for individual stations show a definitely downward trend in the arid regions of Rajputana and an upward trend on the Aravalis.

The encroachment of Thar Desert towards its eastern border has become a serious problem to the districts like Churu, Jhunjhunu, Nagaur and Sikar. A large number of population and animals of this region are at risk due to shifting of sand dunes, dust storms, land degradation and as a consequence decreasing agricultural productivity.

That's why the current study has significant locational and situational importance. The LANDSAT imagery of the study area (1989-2010) and secondary data of agricultural area, production and yield (1956-2008) together with instrumental records of rainfall and temperature provided by the National Data Centre, Indian Meteorological Department, Pune were included in the study. Study covered spatio temporal variations analyzed with the help of unsupervised classification and line diagrams, the moving average, normalised accumulated departure from mean and simple average method, spatial variation analysis by coefficient of variation and trend analysis by simple linear regression method.

The land use land cover analysis indicates towards spread of land degradation i.e. desertification in Nagaur district as the area under barren land has increased from 41.51% to 41.60 %. But this is a very slight increase during a period of twenty years and thus gives only a vague picture of the problem of desertification. There has not been any significant change in land use land cover in other districts also. Almost all the classes except Urban and built up area showed decline during 1989-2000 and thereafter an increase was registered.

The analysis of agricultural area, yield and production establishes Sikar and Jhunjhunu as more prosperous than Churu and Nagaur. But decline in agricultural area, yield and production cannot be entirely attributed to desertification because these parameters also depends on other factors like time of rainfall, agricultural infrastructure and technology etc.

The temporal-seasonal variation analysis using moving average method suggests cyclic fluctuation in rainfall and temperature regime in the study area while the normalized accumulated departure from mean (NADM) and simple average method quantifies the variability in rainfall and temperature and also permits visual as well as statistical comparison of unlike data series. Cyclic fluctuation recorded in mean monthly maximum temperature in the study area.

The temperature regime displayed a significant increasing trend in Churu, Jhunjhunu and Nagaur districts except Sikar which recorded a decreasing trend in mean monthly maximum temperature.

The meteorological stations in the study area recorded decrease in rainfall in monsoon season for Nagaur which recorded an increasing trend in all seasons. The seasonal variation analysis using simple average method provides that increasing trend in maximum temperature was more prominent in Churu while the increasing trend in minimum temperature became more prominent in Sikar. A decreasing trend in rainfall recorded was recorded in Sikar in all seasons. Spatial variation analysis using coefficient of variation method provides some interesting findings. Relatively low variability in climatic parameters, such as rainfall and temperature is marked during monsoon season while relatively high variability in mean temperature is observed during post monsoon and winter seasons.

The trend analysis of rainfall and temperature regimes using simple linear regression method marked striking results. The temperature regime displayed statistically significant (at 95 % confidence level) increasing trends in all the four districts while a decreasing trend in monsoon season was recorded for Sikar. Churu, Jhunjhunu and Nagaur recorded an increasing trend in maximum temperature. On the other hand, Sikar reflected decreasing trend in maximum temperature. Nagaur recorded decreasing trend in minimum temperature while Sikar registered an increasing trend in the same. The monsoon and winter season temperature depicted a significant increasing trend in the all districts. The monthly rainy days marked a decreasing trend during monsoon season in all districts.

In the concluding remarks; this study provided vital records of the land use land and cover climatic conditions of the study area and also experienced the data scarcity and un-availability of authentic and continuous data series for climatic elements. The maximum temperature recorded fluctuations and also reflected increasing trend in Churu district. Minimum temperature recorded decreasing trend in Nagaur and increasing trend in Churu and Sikar. A decrease in rainfall recorded in winter and monsoon season. Spatial variation analysis represented that monsoon season recorded lowest spatial variability in both, rainfall and temperature regime. The pre monsoon season reflected relatively high variability in temperature regime. A decreasing trend in monsoon rainfall was a major concern point in the study area.

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