CHAPTER 2

LITERATURE REVIEW, MATERIALS AND METHODS

Climatic variability is the result of the variation in the rotation of the earth, changes in the axis of its inclination, unequal distribution of land and water and unevenness of its surface. The most direct influence of climate is reflected in crop cultivation. Since each crop requires certain specific climatic requirements, any variations in this would adversely affect the growth and output. Crop failure due to variations in climate could be disastrous in a country where agriculture is the backbone of its economy. This necessitates the need for an understanding of climatic variations at the regional level, especially of short-term variations. This would help take proper remedial measures so that the impact is minimised.

Other major factors that determine the cropping pattern and agricultural output are the local terrain, soil types, technological support, etc..

A brief review of major studies carriedout in the field of land use, impact of climatic variations on crop production, application of water balance approach and agricultural regionalisation are given in the first Section of this Chapter. The second Section gives the details of materials and methods adopted in this study.

2.1 REVIEW OF LITERATURE

2.1.1.GENERAL LAND USE.

The term 'land use' means the different ways by which a piece of land is put to use over a period of time or at a point of time. Campbell (1987) defines land use as "use of land by humans, usually with emphasis on the functional role of land in economic activities'. It forms an abstraction, not always directly observable. The term 'land cover' is often used in synonym with land use, which refers to the natural vegetation, water bodies, rocks and man-made land cover resulting due to land reforms. The land use of a region is dependent on many factors such as the topography, soil, climate, socio-economic conditions and reflect the interaction between society and environment.

Land use information is of much significance to the governmental administration. Since there are wide spatial variations of economic activities, it is essential to have a comprehensive land use plan which would help prevent uncontrolled distribution of economic activities from damaging environmental and human resources, and from disrupting efficient functioning of local economies.

The ever increasing pressure of population on land and demand for food focuses the need for scientific and judicious use of every piece of land. This could be achieved only through the understanding of existing land use pattern and changes that have taken place in concerned regions.

The pioneer among the researchers who studied land use was Sir Dudley Stamp. He was instrumental in the first land use survey of Britain conducted during the thirties. With the help of volunteers, Stamp mapped the entire land areas of England, Wales and Scotland on the Ordinance Survey topographic maps. "At the time the entire country was covered by a map series at 1:10,560 (six inches to the mile). Each sheet represented six square miles, and depicted field boundaries, buildings and other cultural details".(Campbell,1987.). Stamp used the following classification scheme for the land use mapping.

1. Forest and wood lands
   a). High forest (specified as coniferous, deciduous or mixed)
   b). Coppice
   c). Scrub
   d). Forest cut and not replanted.
2. Meadowland Permanent Grass.
3. Arable or Tilled land, Fallow land.
4. Heathland, Moorland, Commons, Rough Hill Pasture
5. Gardens.
6. Land Agriculturally Unproductive, Buildings, Yards, Mines, Ponds.

Being the first land use survey, Stamp's methodology formed a precedent and model for subsequent surveys. Coleman (1961) conducted the Second Land Utilisation Survey in England. This survey was more detailed in respect to both cartographic and taxonomic details, but was analogous in many other respects to the Stamp's methods.

The Lisbon Conference of International Geographical Congress (April, 1949) made a proposal to map the entire land area of the earth using a common map base and legend. The project was primarily intended for providing land use information for economic development for the Third World Countries. Even though considerable effort was made in establishing an administrative framework for guiding and co-ordinating the work, with help of IGU and UNESCO, the World

Land Use Survey failed because of lack of proper co-ordination among various nations and financial support.

Using remote sensing data, the United States Geological Survey (USGS) prepared land use and land cover maps of the United States(1976) on scales 1:250,000 and 1:100,000. After careful examination of the existing land use patterns, the USGS adopted a hierarchical classification scheme (Table 2.1). Levels I and II are appropriate for mapping coarse levels of details while the Level III could be developed depending on the local needs.

In India nascent work was done by Chatterjee(1953), Prakasa Rao(1956), and Shafi(1960), following the methodology of Stamp. Other major works carried out on regional basis are those of Ameen(1956), Sen(1957), Bharadwaj(1961), Raina(1962) and Learmonth(1962). This was followed by number of works ranging from simple inventories of land use survey to topical descriptions using many quantitative and cartographic techniques.

In India till 1949-1950, the land area was classified into five categories. They were

1.Forests
2.Area not available for cultivation
3.Other uncultivated land excluding the current fallow
4.Fallow lands, and
5.Net sown area

LEVEL I		LEVEL II
1. Urban or Built-up Land	11.	Residential
	12.	Commercial and Services.
	13.	Industrial.
	14.	Transportation,Communication and Utilities.
	15.	Industrial and Commercial Complexes.
	16.	Mixed Urban or Built-up Land
	17.	Other Urban or Built-up Land
2. Agricultural Land	21.	Cropland and Pasture.
	22.	Orchads, Groves, Vineyards, Nurseries and Ornamental Horticultural Areas.
3. Rangeland.	31.	Herbaceous Rangeland.
	32.	Shrub and Brush Rangeland.
	33.	Mixed rangeland.
4. Forest Land	41.	Deciduous Forest Land.
	42.	Evergreen Forest Land.
	43.	Mixed Forest Land.
5. Water	51.	Streams and Canals.
	52.	Lakes.
	53.	Reservoirs.
	54.	Bays and Estuaries.
6. Wetland.	61.	Forested Wetland.
	62.	Nonforested Wetland.
7. Barren Land.	71.	Dry Salt Flats.
	72	Beaches.
	73.	Sandy areas other than Beaches.
	74.	Bare Exposed Rocks.
	75.	Strip Mines, Quarries,and Gravel pits.
	76.	Transitional Areas.
	77.	Mixed Barren Lands.
8. Tundra	81.	Shrub and Brush Tundra.
	82.	Herbaceous Tundra.
	83.	Bare Ground Tundra.
	84.	Wet Tundra.
	85.	Mixed Tundra.
9. Perennial Snow or Ice.	91.	Perennial Snowfields.
	92.	Glaciers.

TABLE 2.1. THE USGS LAND USE AND LAND COVER CLASSIFICATION

Since this scheme was found to be a very broad outline of the land use in the country and not enough to meet the planning needs, the Government of India set up the Technical Committee on Co-ordination of Agricultural Statistics in 1948, by the Ministry of Food and Agriculture. The Committee recommended a nine fold classification scheme with standard concepts and definitions for each land use class, to be followed by all the States of the country. This nine fold classification is as follows. (ICAR, 1992)

1.Forests. : Including all lands classified as forest, private or public. This also includes all the wooded lands and area of crops raised within the forest and grazing lands inside the forest.

2.Land Put to Non-Agricultural Uses. : This category includes all the built-up areas used for residential, commercial, industrial, administrative, transportation and recreational purposes. Also included in this category are the areas under water bodies like lakes, rivers and ponds.

3.Barren and Uncultivable Lands. : Includes all barren and uncultivable lands like mountains, deserts, etc., which cannot be brought under cultivation, except at high cost.

4.Permanent Pastures and other Grazing lands. : Includes all pasture lands, grazing lands and village meadows.

5.Land under Miscellaneous Tree Crops. : This category include all the cultivated areas not included in the net sown area, but are put to some agricultural uses. Lands under bamboo bushes, thatching grass, casurina trees and other groves are included in this category.

6.Cultivable Waste Lands. : Cultivable waste lands include the lands once cultivated, but not cultivated for the past five years in succession. Such lands either may be fallow or covered with shrubs or jungles which are not put to any use.

7. Fallow other than Current Fallow. : These are lands which were put to cultivation once, but are temporarily out of cultivation for period not less than one year but not more than five years.

8.Current Fallow. : This category includes all those lands which are kept fallow during the current year only. For example, if any seedling area is not cropped again in the same year, they are treated as current fallow.

9.Net Area Sown. : This includes all those cultivated areas, counting area sown more than once in the same year only once.

Following the USGS scheme of classification, the National Remote Sensing Agency, under the Department of Space, Government of India, developed the National Land Use / Land Cover Classification System (NRSA,1989) to suit the Indian conditions.(Table 2.2).

Raghavaswamy(1983) described the structural inter-relationships between land capability classes, land use pattern and population distribution in Visakhapatnam tract.

Using the remote sensing data Mohan and Gupta(1985) classified the land use types around Jaipur.

Aerial photographs of 1:50,000 scale were made use of by Natarajan et.al.(1986), in their study of land use Mewat area in Haryana. They identified four major physiographic units and the land use was studied in relation to the physiographic units.

"The changes in land use implies the changes in the areas devoted for different purposes like and recreation" (Chauhan, 1966). The changes in land use may involve a shift from one type to another or within the same class. For example, the area under paddy may change to

LEVEL I		LEVEL II
1. Built-up Land.	1.1	Built-up Land
2. Agricultural Land	2.1	Crop Land i). Kharif. ii). Rabi. iii). Kharif + Rabi.
	2.2	Fallows
	2.3	Plantations
3. Forests	3.1	Evergreen /semi evergreen forest
	3.2	Deciduous forest
	3.4	Forest blank
	3.5	Forest plantations
	3.6	Mangroves
4. Wastelands	4.1	Salt affected land
	4.2	Waterlogged land
	4.3	Marshy / swampy land
	4.4	Gullied / ravinous land
	4.5	Land with or without scrub
	4.6	Sandy areas(coastal and desertic)
	4.7	Barren rocky / stony waste, sheet rock area.
5. Water bodies	5.1	Rivers / streams
	5.2	Lake / reservoir / tank / canal
6. Others	6.1	Shifting cultivation
	6.2	Grassland / grazing land
	6.3	Snow covered / glacial area

Table.2.2. THE NATIONAL LAND USE AND LAND COVER CLASSIFICATION SYSTEM OF NRSA.(1989)

coconut area, or the change may involve transfer of agricultural land to non-agricultural uses.

Sen(1986) indicated how the land use pattern of the hills of Uttar Pradesh disrupted and destroyed the ecosystem. He also emphasised the need for change in the existing land use pattern.

Other major studies in this field include that of Mohammed(1978), and Sharma(1991).

2.1.2.AGRICULTURAL LAND USE

The term 'agricultural land use implies the different ways by which the land devoted for agriculture is used such as for the cultivation of various crops, animal husbandry, poultry and other related activities.

Agricultural land use is most dynamic and changes with the fluctuations in the climate. The impact of short-term variations of climate is immediately felt on the agricultural land use.

Within the broad agricultural system regional variations occur in cropping pattern, cropping intensity and crop combination, because of variations in climatic conditions and the socio-economic conditions of the population.

Various statistical and cartographic models are available for the assessment of crop land use, crop combination, intensity of cropping and overall agricultural performance.

Weaver(1954) proposed a statistical technique to identify crop combination involving both qualitative and quantitative aspects of crop production. Weaver's technique compares the actual percentage of cropped area occupied by various crops with the theoretical distribution in which the cropped area is equally divided among the component crops in different regions.

This procedure designates the crop combinations which are in close resemblance to the actual percentage with the theoretical distribution. Weaver used the standard deviation technique to compare the actual percentages and the theoretical distribution.

It has been proved by many studies that the Weaver's technique of crop combination analysis will be of little help in regions where the share of several crops are quite close to one another. Doi(1959) modified this technique by substituting Weaver's least standard deviation method with that of sum of squared deviations. The combination having least squared deviation is assumed as the combination for that particular region.

Thomas(1963) made a modification to the Weaver's technique. He selected all the crops in the region instead of limiting it to certain crops based on their cropland occupancy, as done by Weaver. The Thomas technique finds out the deviation of actual percentage areas of crops with the theoretical values. The squared values of deviations are added and divided by the number of crops considered. The lowest value of squared deviation divided by number of crops is assumed as the combination of that region.

Coppock(1964) suggested that the division of sum of squared deviations by number of crops is an additional calculation without bringing about any further improvement in the results. He suggested that the lowest sum of squared deviations can be taken as the combination for that particular region.

Many commendable studies have been done in India in the field of agricultural geography particularly at the regional level. "The primary purpose of agricultural geography is to undertake a geographical enquiry into the regional differences and spatial variations in agricultural formations and geographic association, and it lends itself to a greater quantification in the description of regional distributions"(Singh and Dhillon,1994).

Singh(1994) demonstrates the comparative use of these techniquesin the Kurukshetra District of Haryana. Vidyanath (1986), Ramanaiah and .Reddy(1986), Shafi(1984) and Saravanan(1994) also followed the Weaver's and Doi's techniques in their studies.

Agriculture is dependent on many factors, especially the climate. Variations of climate over different parts of the world result in variations in agricultural systems. Typically in a vast country such as India, there are many agricultural systems. This spatial variations necessitate a thorough understanding of various agricultural systems, its cropping patterns and crop productivity. In order to overcome agricultural backwardness, achieve self sufficiency and eliminate regional imbalances in agricultural output, it is necessary to regionalize the agriculture, so that through proper planning these drawbacks can be expunged. "Agricultural regionalization is the process of dividing an area into territorial units of complexes of uniformities and is the result of a set of processes.(Singh,1994).

A number of studies have been done in various parts of the country using different agricultural regionalisation methods. Location Quotient method proposed by Bhatia(1965) is widely used for analysing the regional concentration of particular crop. He derived the location quotient values indicating the regional concentration of particular crop, through dividing the area under a particular crop in the component aerial unit by the total cropped area in the same aerial unit. The resultant value is performance as a concept, means the degree to which the economic, cultural, technical, and organisational variables (ie.manmade frame) are able to exploit the abiotic resources of the area for agricultural production". (Singh,1994)

Several techniques are used for assessing the levels of agricultural productivity. The ranking coefficient method developed by Kendall in 1939 uses the hectare-yield of crops to asses the efficiency of agriculture. Shafi(1960) adopted this technique to determine the agricultural efficiency of Uttar Pradesh.

Bhatia(1967)assumed that the hectare-yield of a particular crop can be considered as the result of influence of physical and human factors connected with crop production. According to him, the agricultural efficiency would be the overall performance of all crops with regard to their yield per hectare. The contribution of each crop to the agricultural efficiency of the regions would be corresponding to the share of cropland. Bhatia's yield index, which takes into account both the hectare yield of each crop and its aerial extent, is considered to be one of the better indices of agricultural efficiency.

Enyedi (1964) proposed a new technique for determining the productivity index. He had taken into consideration the production of selected crop in the concerned aerial unit and the production of the same crop at the regional or national level and the total cropped area at the unit and national level. One major draw back of this technique is that it does not consider that in certain cases the productivity index is influenced by the magnitude of area under particular crop. Also, when the district yield is less than the State yield or National yield, its productivity index is higher than that of the state or nation.

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Hussain and Sahu(1982) identified regional concentration of rice in Assam using this technique. Other major studies include that of Das(1982), Kunyal(1987) and Singh(1994).

In places where extensive cultivation is not possible because of limitation of availability of land, intensification of cultivation, through multiple cropping, is practised. Hence, cropping intensity is considered as one of the indicators of agricultural development. Many studies have been done at the national and regional levels on the intensity of cultivation. Sohal(1993) described the changes in the intensity of cropping in Punjab.

The ever increasing population and corresponding demand for food is a major challenge facing the world today, especially in the under-developed and developing countries. The shortage in food production is mainly due to the insufficient production of food grains, even after the best efforts to enhance them. This is mainly due to unfavourable weather conditions, lack of mobilisation among farmers, primitive way of farming etc. This results in regional imbalance in the level of agricultural productivity. "The level of agricultural productivity or performance as a concept, means the degree to which the economic, cultural, technical, and organisational variables (ie.manmade frame) are able to exploit the abiotic resources of the area for agricultural production". (Singh, 1994)

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Shafi(1972) modified the Enyedi's technique where the productivity coefficient is considered to be in conformity with lower or higher yield of a particular crop at the unit areal level relative to regional or national level.

The weighted composite level of the agricultural performance propounded by Singh et.al. (1990) takes into consideration both the cropland occupancy and productivity of crops to assess the level of agricultural efficiency. This technique helps identify the weaker areas of agricultural performance which would help in proper planning for future agricultural development.

Other notable studies on the agricultural land use in different parts of the country include that of Singh (1982), Khan (1982), Srivastava (1983), Sawant and Gadgil (1983), Sharma and Coutinho (1983), Ramakrishna and Yadav (1984), Mohammad and Amani (1985), Dhillon et.al(1986), and Sharma (1987)

2.1.3. THE HYDROLOGIC CYCLE

The constant redistribution of water between the earth and the atmosphere, which is called as the hydrologic cycle, is well known to geographers, meteorologists, hydrologists, agriculturists and others concerned with water utilisation and management. The hydrologic cycle involves evaporation of water from the oceans, lakes, rivers, ponds and other water bodies, transpiration from plants, condensation of water vapour from clouds, precipitation in different forms under different conditions, movement and accumulation of water in the soil and ultimately evaporation once again back to the atmosphere. The application of 'principle of conservation of mass', often referred as the continuity equation in hydrology, would lead to the study of water balance . The continuity equation states that, for any arbitrary volume of water during any given period of time, the difference between the total input and output will be balanced by the change of water storage within the volume.

2.1.4. CONCEPT OF WATER BALANCE

Water balance or water budget is a monthly or daily comparison of water supply in the form of precipitation with the water demand or PE., where the soil moisture acts as a sort of reserve available for use to a limited extent for the purpose of evapotranspiration during the periods of water shortage. The book-keeping procedure of water balance, put forwarded by Thornthwaite(1948), based on such a comparison, provides comprehensive information on many parameters such as the amount of water stored in the soil, actual evapotranspiration, water surplus, water deficit, surface flow and underground flow in a quantitative manner.

Whenever precipitation (P) exceeds Potential Evapotranspiration (PE), the soil moisture gets recharged and when the soil moisture storage exceeds the field capacity of the soil, Water Surplus (WS) occurs. The water surplus either percolates downwards and adds to the groundwater storage, produces subsurface flow and underground flow or produces surface runoff from that area, which adds to streams, rivers and finally, to the oceans. In such cases, when precipitation equals or exceeds PE., evapotranspiration attains its potential rate, which implies that A.E. and P.E. are equal. However, when P.E. exceeds precipitation, evapotranspiration cannot be at the potential rate, the stored soil moisture gets depleted and there

will be deficiency of water. When the water deficiency becomes large with respect to the water need, the climate becomes progressively drier or more arid. On the other hand, the climate becomes more humid when large amounts of water surplus occurs. When precipitation equals P.E., the water is available for use just as needed :
there is neither water deficiency nor water surplus.

Many commendable studies have been carried out in India using Thornthwaite's book-keeping procedure of water balance by many researchers. The pioneer among them was Subrahmanyam(1956). The detailed procedures for calculating the water balance using the book-keeping procedure and its applications in various fields are given by Subrahmanyam (1982).

2.1.4a CLIMATIC CLASSIFICATION.

The major application of water balance is in the field of climatic classification. The fundamental idea of any climatic classification is to provide a concise description of various climatic types. Koeppen (1900) made a major advance in climatic classification. He used the vegetation types as an index for classifying climate. But his classification lacked the rational basis for limiting values of temperature and precipitation. Thornthwaite (1948) used the efficiency of temperature and effectiveness of precipitation for the growth and development of natural vegetation as the indices for climatic classification. He evaluated the dryness and wetness of stations by comparing the the water deficit and water surplus with the water need, through the Aridity index and Humidity index.

By definition

$$\text{Aridity Index } I_a (\%) = (WD \div PE) \times 100$$

$$\text{Humidity Index } I_h (\%) = (WS \div PE) \times 100$$

Another parameter, the Moisture Index was also developed by Thornthwaite,modified by Thornthwaite and Mather (1955), by incorporating the water surplus and water deficit in relation to the water need as

$$\text{Moisture Index } I_m = I_h - I_a$$

He used the moisture index values for classifying climates. Various limiting values have been assigned for different climatic types. Negative values of moisture index indicate dry climates and positive values moist climate. Mather and Carter (1966) modified the limiting values for dry climates.

Subrahmanyam (1958) compared the climatic types of India, classified using the Thornthwaite scheme, with the natural vegetation as reported by Champion (1936). Using the Index of Moisture adequacy, which is the ratio between AE and PE (AE ÷ PE), Subrahmanyam and Ram Mohan(1980) delineated the monsoon climates of the world in general and India in particular. Ram Mohan and Maria Juliet (1986) classified the monsoon climates of the world using the modified criteria. The climate of the State of Madhya Pradesh has been studied using the water balance approach by Subramaniam and Srimannarayana (1991).

2.1.4b DROUGHT CLIMATOLOGY.

Droughts remain as one of the most disastrous natural hazards to man even in this modern world of advanced technology. In countries where agriculture is the main source of the national income, droughts can cause havoc in their economy. The term 'drought' has different implications in different contexts. Until recently, the criteria for defining drought was the deficiency of rainfall alone. "A clear understanding and better appreciation of the problems of droughts and aridity became available after the water balance approach was put forth by Thornthwaite and Mather in 1955" (Subrahmanyam, 1982). Subrahmanyam and Subramniam (1964), Subrahmanyam (1967), Subrahmanyam and Sastri (1968) used water balance approach for the drought studies

Sastri.et.al(1982) used the Thornthwaite's technique for assessing the probabilities of occurrence of droughts in the Guhiya catchment of Rajasthan. The utility of water balance approach has been amply described by Ram Mohan and Subrahmanyam(1983). Using the water balance approach Subrahmanyam and Ram Mohan(1984) explained the droughts and agricultural land use in India, Pakistan and Bangladesh. Ram Mohan et.al.(1984) used the Index of moisture availability as the criterion for studying droughts.

Rao and Kalavathi (1985) demonstrate the relationship between the derived elements of water balance and crop concentration. The usefulness of water balance studies in agriculture has been explained by Pandey and Gupta(1991).

In Kerala, major studies have been done by Nair(1987) and James(1991). Saravanan(1994) and Haseena Raghavan(1996) also used the water balance approach in their studies.

2.1.5. IMPACT OF CLIMATIC FLUCTUATIONS ON AGRICULTURE

2.1.5a.CROP-CLIMATE AND CROP-WEATHER MODELS

The influence of climatic or weather elements on agriculture is well established through various studies in different parts of the world. Meteorologists and agriculturists have developed a number of crop-climate and crop-weather models which describe the influence of weather and climate on different crops. The influence of various weather elements on agriculture vary from region to region. In higher latitudes, for example, temperature is a limiting factor in agriculture, while in the lower latitudes rainfall is the major limiting factor. "Millions of people all over the world depend directly on rainfall as their only accessible source of water. In the absence of monsoons that bring adequate rain, lifestyles can be seriously and sometimes irreversibly disrupted. The first effect of the insufficient rain is the crop yield reduction or crop death." (Swaminathan, 1987)

Climate-agriculture relationship is basically studied using the climate impact and climate interaction models. The impact approach assumes a direct cause and effect relationship between climate and agriculture.(Virmani, 1991). Various types of models used include empirical statistical models and simulation models. Rao (1983) used the crop-climate models to assess the influence of climate and technology on wheat yield in Punjab. Jain et.al.,(1980) described the effect of climatic variables on rice yield at different stages of crop growth. Venkataraman and Rahi (1983), Subramaniam and Raju (1987) and Mavi et.al., (1993) also used crop-climate models in their studies.

A number of studies have been done which depict the influence of weather parameters on agricultural output. Venkitaraman and Krishnan (1992) gave a detailed description of the various principles of crop-weather relationship. Parry and Carter (1988) described the features of current public strategies for combating the impact of rainfall variability on agriculture in India and indicate the scope for making fuller use of the agroclimatic environment and the farmer's resource base for improving and sustaining agricultural productivity in the dry tropics, through different case studies.

Swaminathan (1987) in his study explained the impact of abnormal monsoons on the Indian economy. He is of the opinion that "with the help of science and technology, human insecurity and endeavour can convert calamities into opportunities for progress. Through concurrent advances in weather forecasting, prediction of climatic trends, and abnormal monsoon management, humankind can be insulated from hardships caused by droughts and floods to a much greater extent than has been considered possible until now".

Long-term climatic trends and their influence on agriculture can be predicted fairly accurately and proper measures can be adopted for enhanced production. But the year to year fluctuation of climate is often difficult to predict though its influence on agriculture would be large. Oram (1985) indicates a number of potentially desirable areas for action in this regard and suggests that "several of these would be beneficial both as a buffer against short term effects of variability and as a means of combating climatic changes"

.Saha and .Mooley (1988) observe that there is no significant periodicities in the long term trends in Indian monsoons. Their study of Chanda and Ratnapuri districts of Maharashtra state reveals that there is significant correlation between crop yield and monsoon rainfall variation.

Using the Weather Index approach, .Chaudhury and .Rao (1978) explain the climatic fluctuations and their impact on wheat yield in Punjab and Haryana States.

Rasmidatta (1978) on his study in Thailand reveals the influence of climatic fluctuation on corn production. He is of the opinion that conditions for corn production in Thailand are highly favourable provided proper attention is given, by way of proper use of fertilizers, cultural practices, use of insecticides, crop-weather calendars and weather modifications.

Recently food production in Sri Lanka was adversely affected by weather failures. Gooneratne (1978) analysed the pattern of rice production in Sri Lanka and the influence of weather failures on rice production. Another study of similar nature on Sri Lanka was done by Domrös (1978).

Superimposing the isohyetal map of annual rainfall and rice yield map of Bangladesh, Mowla (1978) described the relationship between rainfall and rice yield. This proves that areas having higher annual rainfall give better rice yields than areas having lower annual rainfall.

The crop-weather models usually use simple regression analysis technique to establish their inter-relations and to forecast the yield. Das et.al., (1971) used the regression model to predict the paddy yield in the Mysore State. Gupta and Singh (1988) developed a multiple linear regression model to estimate sugarcane yield. Thompson (1986) used regression analysis technique to determine the influence of variability of climate and weather on the corn yield in the States of Illinois, Indiana, Iowa, Missouri and Ohio of the United States of America.

Tanaka (1978) studied the relationship between inter-annual fluctuation of rice yield and the local and large scale climatic fluctuations over Monsoon Asia.

Commenting on the predictions of climatic fluctuations by Global Circulation Models used so far in various parts of the world, Gadgil (1995) is of the opinion that the impact of year to year variations of the Monsoon will continue to be dominant over long period changes even in the presence of global warming. She also stresses the need for a detailed study on climatic components of agricultural productivity of various crops at the district level.

2.2. MATERIALS AND METHODS

2.2.1.GENERAL LAND USE:

The district level land use data , published annually as 'Agricultural Statistics of Kerala', 'Seasons and Crop Report' and 'Statistics For Planning' by the Directorate of Economics and Statistics, Government of Kerala, have been collected for the period from 1961 to 1994. The data were collected for all the individual districts and for the State as a whole, for the above period.

For the purpose of general understanding Shafi (1984) grouped the twelve categories of land use of Uttar Pradesh into five categories viz .1). Waste land which included the barren and uncultivable land and the land put to non-agricultural uses, 2). cultivable waste land - including cultivable waste land, pastures and other grazing lands and the land under miscellaneous tree crops, 3). fallow lands, 4). net area sown and 5). total cropped area.

Since the areas under permanent pastures and grazing lands, barren and uncultivable lands and area under miscellaneous tree crops in Kerala are very few, the land use categories of the State are grouped into the following five categories in this study.

1. Forests

2. Land put to Non-Agricultural Uses (including barren and uncultivable lands)

3. Pastures(including grazing lands and miscellaneous tree crops)

4. Fallow lands (including cultivable waste lands fallow other than current fallow and current fallow).

5. Net area sown.

The inter-annual variability of each category of land use was calculated. Decadal variations of land use categories at the district level were calculated for the periods 1961 - 1971 (first decade) 1971 - 1981 (second decade) and 1981 -1991 (third decade). Since an increase in area under one category of land use will be compensated by the decrease in another category, the separate totals of all increases and decreases would be the same. This percentage is taken as the overall change for the decade, as suggested by Weaver (1954) and adopted by Sharma (1991). The following formula has been used for calculating the overall change.

$$\text{Overall change} = X \div Y$$

where X is the difference of percentages of land use categories of increases, and Y is the difference in percentages of land use categories of decreases for different periods.

2.2.2. AGRICULTURAL LAND USE.

Agricultural statistics for all the individual districts and for the State as a whole were collected for the above periods. Crops were selected for this study on the basis of their share in the total cropped area (TCA). All those crops which occupy more than 5% of the TCA are taken into consideration. In most of the districts, only major crops like paddy, coconut, tapioca and rubber have more than 5% of TCA and they together account for more than 80% of TCA. In addition to these four major crops, pepper, cardamom, tea and coffee in Idukki district, groundnut in Palakkad district ,coffee and pepper in Wayanad district, arecanut and pepper in Kannur and Kasargod districts are included since these crops occupy more than 5% of TCA.

The annual yield index was calculated for all the crops at the district level using the Bhatia's method. Yield index may be expressed as

$$I_{ya} = Y_c \div Y_r$$

where 'I_{ya}' is the yield index, 'Y_c' is the hectare yield of crop 'a' in the component aerial unit and 'Y_r' is the hectare yield of crop 'a' in the entire region.

The regional concentration of crops was calculated using Bhatia's Index of Concentration method. The location quotient was found out using the following formula

$$Ic = \frac{A_r}{TCA} \div \frac{A_{rc}}{TCA_n}$$

where

- I_c is the index of concentration
- A_r is the area of particular crop in the concerned aerial unit.
- Arc is the area of particular crop in the entire region or country
- TC is the Total Cropped area of the given areal unit
- TCn is the total cropped area of the region/country

Regional variations in the levels of agricultural performance were calculated using the methodology of Singh et.al.(1990). It takes into account both cropland occupancy and crop production. The formula for calculating the levels of agricultural performance is

$$V_w = \frac{Y_{ae}}{Y_{ar}} \times \frac{P_{ae}}{P_{ar}} + \frac{Y_{be}}{Y_{br}} \times \frac{P_{be}}{P_{br}} + \frac{Y_{ce}}{Y_{cr}} \times \frac{P_{ce}}{P_{cr}} \qquad + N = \frac{\Sigma Lqs}{N}$$

where

- V_w - is the Weighted Composite Level of regional inequality
- Y - is the crop yield in kg / hectare.
- P - is the cropland occupancy in percentage to TCA
- $_{a,b,c}$ - denotes the crops considered
- $_{e,r}$ - denotes the enumeration unit and the entire region respectively
- N - denotes number of crops considered and
- LQ - means location quotient

The summed up LQs were divided by the number of crops considered and multiplied by 100 to obtain Weighted Composite Level of Agricultural Performance.

$$WCLAP = \frac{\Sigma LQs}{N} \times 100$$

The crop combination was calculated using the Coppock's (1964) method. This is a modified version of Weaver's technique. In this technique, the crops are arranged in descending order in terms its occupancy in the total cropped area. The difference between actual and theoretical percentages are calculated starting with monoculture. It is assumed that one crop occupies 100% of the TCA in monoculture. 2, 3, 4, 5 combinations are progressively foundout, assuming its crop land occupancy to be 50, 33.33, 25 and 20 percentage respectively. The best fit combination is determined by the least-square method. Here, the difference between the actual and theoretical percentages are squared and summed up. The lowest sum of least-square is taken as the best fit.

In order to assess the regional differences in crop productivity Singh's (1976) methodology has been adopted in this study. In this technique, the yield index and concentration index are ranked separately for all the districts. The yield index and concentration index are found out taking the mean data for two time periods- 1961 to 1971 and 1981 to 1991. The yield and concentration indices ranks of individual crops are added and there after divided by 2. This gives the Crop Yield and concentration Indices ranking coefficient. The lower the coefficient values, the higher will be the productivity levels.

2.2.3. WATER BALANCE

Thornthwaite (1948) and Thornthwaite and Mather(1955) methods were followed to calculate the annual water balance of 19 selected stations of Kerala. The monthly temperature and rainfall data for these stations were obtained from IMD for the period 1950 to 1986. The annual water surplus and water deficit for all the stations have been workedout. From this the relative dryness and wetness of the stations have been evaluated using the aridity (I_a) and humidity (I_h) indices, calculated using the following formulae.

$$I_a = WD \div PE \times 100$$

$$I_h = WS \div PE \times 100$$

In order to findout the climatic type of individual stations the moisture index was calculated using the formula

$$I_m = I_h - I_a$$

The different climatic types and their limits of I_m values are given in Table 2.3.

CLIMATIC TYPES			MOISTURE INDEX (%)
Humid climates			
	Perhumid	A	100 and above
	Humid	B_4	80 - 100
		B_3	60 - 80
		B_2	40 - 60
		B_1	20 - 40
	Moist sub-humid	C_2	0 - 20
Dry climates			
	Dry sub-humid	C_1	-33.3 to- 0
	Semi-arid	D	-66.6 to -33.3
	Arid	E	below - 66.6

Table.2.3 MOISTURE INDEX LIMITS AND CLIMATIC TYPES

{ After Carter and Mather, 1966 }

Inter-annual variability of various water balance parameters were determined. Identification of climatic shifts, droughts and categorisation of droughts were done.

In order to asses the trend in the annual rainfall, water surplus, water deficiency, potential evapotranspiration and actual evapotranspiration linear regression trend lines have been fitted on the individual graphs showing the annual values. This was done using the MICROSOFT EXCEL software. All the diagrams have also been prepared using this software.

Categorisation of droughts have been done following the methodology of Subrahmanyam and Subramaniam(1965) The departure of Ia from median values of all the individual stations were calculated and the percentage departures were plotted on a graph. Table 2.4 gives the different categories of droughts

Departure of I_a from median	Drought Intensity
$< 1/2\ \sigma$	Moderate
$1/2\ \sigma$ to σ	Large
σ to $2\ \sigma$	Severe
$> 2\ \sigma$	Disastrous.

Table.2.4. CATEGORISATION OF DROUGHTS

The choropleth technique is used to represent various themes on maps. These maps are prepared using the Geographical Information Systems (GIS) software MAP MAKER. The outline map of Kerala was first scanned in the 'tiff' format and later converted to 'dra' format in the software, by polygonizing all the individual districts. After assigning different symbols to each polygon, it was then converted to 'map' format to produce the final map.

To asses the influence of climatic fluctuations on agriculture, coefficient correlation and regression models were used. The coefficient of variabilities of area, production and yield of major crops for selected districts have been calculated using the following formula.

Coefficient of Variability = Standard deviation ÷ Mean x 100

The Coefficient of Determination (R^2) was calculated through the regression analysis. The R^2 values have been calculated for the annual rainfall and crop area, rainfall and crop production, and rainfall and crop yield of paddy, tapioca, coconut and rubber, for selected stations. These stations Have been selected assuming that they represent the concerned districts in which they are located. The R^2 values would give the degree of dependence of area, production and yield of major crops on rainfall.