CHAPTER 7

SUMMARY AND CONCLUSION

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. A brief review of major studies carried out 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 the Second Chapter. The second Section of this Chapter gives the details of materials and methods adopted in this study.

The third chapter consists of a discussion of the important physical features of Kerala State. The location, extent, administrative divisions, physiography, drainage, geology, soils and vegetation types are discussed.

The wide variations in the topography from the coastal regions to the Western ghats, have resulted in the evolution of a broad climatic spectrum over the State. The salient features of agroclimatology of the region have been described in the Fourth Chapter. The spatial and temporal distribution of temperature, rainfall, rainfall variability, relative humidity and winds have been presented in the second section of this Chapter.

Due to the influence of the South-West monsoon the maximum temperature is recorded in the pre-monsoon months. At the coastal stations the maximum temperature is often around 33^0C during April while the minimum temperature is around 22^0C during January. The interior stations have a higher maximum temperature (about 37^0C), and minimum temperature is usually less than that at the coastal stations.

The lowest mean monthly temperature at all stations in the State occur in July or August and the highest during the pre-monsoon months.

The State receives abundant rainfall mainly from the South-West monsoon. The mean annual rainfall of the state is about 300 cm. Most part of the State has two peaks of rainfall - one during the South-West monsoon period and the other during the North-East monsoon period. 66 % of the total annual rainfall the State is contributed by the South-West monsoon. The monsoon rainfall is more than 80% of the annual rainfall in the extreme northern part of the State and gradually decreases to about 45% in the extreme south. The North-East monsoon season lasts from October to November and contribute about 18% of the annual rainfall of the State. The southern districts of the State get about 30% of the annual rainfall during this period, while it accounts for only 9 % of the annual rainfall in the northern districts. The rainfall variability of the State as a whole is low - it ranges from 15% in the northern districts to 30 % in the southern districts.

Being located on the coast, the relative humidity of the State is usually high. The average relative humidity of the coastal regions of the State is about 77%. A maximum of around 88% occurs during monsoon months, while the minimum is about 66 %, experienced during January.

The agroclimatic zonation of the State has been presented in the Second Section of the Fourth Chapter. Under the National Agricultural Research Project, the State was divided into the following five agroclimatic zones.

a. Northern Zone: Comprises of Kasargod, Kannur, Kozhikode and Malappuram districts .This zone has a 293 km of coastline. The highland comprises of about 300 sq.kms. and midland about 400 sq.kms.

b. Central Zone: This zone includes all the areas of the State excluding the high ranges, Coastal zone and Kole lands of Ernakulam, Thrissur and Palakkad districts.

c. South Zone: Consists of Kottayam, Alappuzha, Pathanamthitta, Kollam and Thiruvananthapuram districts.

d. High Altitude Zone : This encompasses the high ranges with an elevation above 750m of Wayanad, Palakkad, Idukki, Kollam and Thiruvananthapuram districts. It has a total geographical area of 11140 sq.km.

e. Problem Area Zone : This include the lowland areas, Onattukara, Kuttanad and Kole lands, Pokkali and low rainfall areas of Malappuram, Thrissur, rnakulam, Kottayam and Alappuzha.

In the third section of this Chapter detailed analysis of rainfall, potential evapotranspiration (PE), actual evapotranspiration (AE), water surpluses (WS), water deficits (WD), climatic shifts and incidence of droughts have been projected for nineteen selected stations over the State. Of this seven stations are in the Highland Zone, four each in the Northern and Southern Zone , three in the Central Zone and one in the Problem Zone.

In the Northern Zone only Irikkur displayed a noticeable decreasing trend in the annual rainfall, while the other three stations -Perinthalmanna, Kannur and Kasargod - did not show any trend. PE and WD showed increasing trend in all the stations of this Zone, while WS exhibited declining trend in all stations. AE also revealed decreasing trend in all stations except Kannur, where it showed increasing trend. In this zone majority of the climatic shifts were towards drier side. Significantly, Irikkur had the largest number of disastrous droughts (5) among all the stations studied in Kerala. Perinthalmanna had two, disastrous droughts, Kannur had one, while Kasargod did not experience any disastrous droughts.

All the stations in the Central Zone showed declining trend in rainfall, actual evapotranspiration and water surplus. PE displayed increasing trend only in Kodungalloor, while in Malayattoor and Mannarakkad there were no conspicuous trend in PE. In this zone also the majority of the climatic shifts experienced by these stations were towards the drier side. Mannarakkad had two disastrous droughts, Kodungalloor had one, while Malayattoor did not experience any disastrous droughts during the period of study.

Three stations - Attingal, Kottayam and Neriamangalam - among the 4 southern zone stations exhibited marked declining trend, while the other station Thiruvananthapuram did not show any trend. The station Neriamangalam receives highest mean annual rainfall in Kerala - 4637mm.

Thiruvananthapuram, Attingal and Kottayam showed increasing trend in PE, while Neriamangalam displayed a decreasing trend. Excepting Thiruvananthapuram, all the stations presented a declining trend in AE. The water surplus (WS) of Thiruvananthapuram, Attingal and Neriamangalam displayed decreasing trend, while the water deficit (WD) of these stations showed increasing trend.

In general, the Southern Zone stations experienced climatic shifts equally towards moist and drier sides. Of the four stations, Attingal had highest disastrous droughts (3), while the other three stations had one each during the period of study. While Neriamangalam had three severe droughts, the stations had one severe drought.

Of the seven stations in the Highland Zone five are in Idukki district and two in Wayanad district. Among these Marayoor showed an increasing trend in rainfall, while the other stations showed marked declining trend. All the stations exhibited increase in PE. Increase in WS was seen at three stations - Devikulam, Marayoor and Vandanmedu. Of these, Devikulam and Vandanmedu showed increasing in WD also. Peermedu and Marayoor showed prominent climatic shifts towards drier side. Vythiri, Mananthavady and Karikode had two disastrous droughts, while the other stations had one each, excepting Vandanmedu, which did not have any disastrous droughts. On the other hand, Vandanmedu had six severe droughts during this period.

To summarise, almost all the stations in all agroclimatic zones showed a declining trend in rainfall, AE and WS. Most of the stations exhibit an increasing trend in AE and WD.

These results are in conformity with the findings of James (1991).He had further shown that many of the stations which do not show any significant decreasing trend in annual rainfall or even some stations which have shown increasing tendencies , have exhibited very significant decreasing trend in annual AE. Stations in the northern half of the State which do not exhibit any significant decrease in annual rainfall or increase in PE, show a prominent decreasing trend in AE. This implies that the seasonal distribution of both rainfall and PE play a major role in these cases.

In all stations excepting the one in High Altitude Zone, which exhibit decreasing trend in rainfall have shown decreasing trend in WS too. Of the seven stations in this zone four stations show decreasing trend in WS while three display an increasing trend.

According to James (1991), the water surplus and hydrologically available water is getting reduced much faster than the actual rainfall itself. At many stations water surplus and deficit co-exist in different seasons of the year. Even though the State as a whole does experience heavy rainfall, mainly due to South-West monsoon, and large water surpluses are observed, they are showing decreasing trend. On the other hand water deficits are also present at most stations and have been showing increasing trend. In fact the average annual water surplus is about six times the water deficit, though there are many regions without any surplus. Water surplus occurs for only in a few months: about 89% of the surpluses occur in the monsoon season and during the cool weather season there is no surplus any where in the State. About the half of the annual water deficits are experienced during the winter and pre monsoon months.

The coexistence of water surplus and water deficit at different times of the year in different parts of the State is an important aspect of its hydrometeorology.

As is well known, the moisture regime of any region is influenced more by the temporal distribution of rainfall than by its cumulative total. An year or crop growing season may experience above normal rainfall but still be affected by droughts of severe or disastrous magnitude.

Studies of climatic shifts over the state show that the moisture regime of the different agroclimatic zones in the State undergo wide fluctuations both in the drier and wetter directions. Very often the shifts cause the climatic regime to move into more humid or less humid classes. As most stations in the State belong to the humid and perhumid categories, shift in the wetter directions are not ecologically significant. In such humid climates shifts into the drier categories because of deficient rainfall that is more critical in influencing the agricultural land use.

A general comparison of the number and categories of droughts years at different stations reveals no evidence of any spatial coherence. In other words, droughts do not always occur at the same time or with the same intensity in different parts of the State. Expectedly the disastrous droughts were least common, while moderate droughts were most frequent.

A detailed comparison of the years in which droughts occurred at various stations and the years in which there were climatic shifts of significant magnitude reveals interesting facts. During many of the years when the climate shifted to the drier side stations experienced droughts of one or other categories. However, during some years many stations did not experience droughts eventhough shifts in climate to the drier side were observed. There have also been occasions when even severe or disastrous droughts have been observed when there have been increase in moisture index (I_m) values. At some stations droughts have occurred even when there were no perceptible climatic shifts.

These results highlight the greater ecological importance of appropriate rainfall distribution than of rainfall totals. It is possible for the crops to experience droughts during certain periods of their growth even if there is excessive rainfall during other periods. Moisture stress during critical phases of crop growth cannot be mitigated by excessive water availability during other phases.

The first Section of the Fifth Chapter presents the existing land use pattern of the State. It is observed from this study that with the available limited land resources Kerala has attained stability in its land use pattern over the years. The State as a whole has 27.85% of the total geographical area under forests. Land put to non-agricultural uses account for 9.11%, Permanent pastures, grazing lands and miscellaneous tree crops occupy 0.96%. Fallow lands account for 4.37% and the Net Sown Area of the State is 57.71%.

The land use pattern of individual districts vary significantly from the State averages. Idukki and Pathanamthitta districts have more than 40% of the total geographical area under forests. Land put to Non-Agricultural uses range from 3.93% in Wayanad district to 17.67% in Alappuzha. Pathanamthitta, Idukki, Malappuram and Wayanad districts have less area under this category than the State average value of 9.11%. The area under Pastures, Grazing lands and Miscellaneous tree crops in most of the districts are less than the State average of 0.96%. Idukki, Kannur, Palakkad, Kasargod and Wayanad are the districts which have more area under this category. Relatively high proportion of fallow lands are found in Kasargod, Palakkad, Malappuram and Idukki districts. Seven districts viz., Thiruvananthapuram, Alappuzha, Kottayam, Ernakulam, Kozhikode, Kannur and Kasargod, have more area under cultivation than the State average of 57.71%. Among these, Kottayam district has the highest percentage Net Sown Area (82.79%).

The second Section of this Chapter is devoted to the land use changes that have taken place at the State level during the period 1961 to 1991.

Forests occupied 22.37% of the total geographical area of the State during 1961 and marginally increased to 22.89% in 1991. The area under non-agricultural uses has not shown any significant change during the three decades. However, area under pastures, grazing lands and miscellaneous tree crops steadily declined from 6.38% in 1961 to 0.96% in 1991. This decline may be due to the fact that these marginal lands were brought under cultivation. Fallow lands declined from 6.51% to 3.23% during the three decades, while the net area sown increased from 50.67% to 57.71%.

The third Section of this Chapter focuses on the land use changes in the various districts of the State. The major land use changes that has taken place in Thiruvananthapuram district for the last three decades is that the area under non-agricultural uses has increased to 9.84%, while fallow lands have significantly declined.

Kollam district recorded major decrease of 13.1% in the area under forests. Correspondingly large increase of 12% was noticed in the net sown area. The land put to non-agricultural uses also showed significant increase.

One of the noticeable features of land use pattern of Alappuzha district is the absence of forests. While the land put to non-agricultural uses increased by 10.75%, the net sown area decreased by 7.25% in the district.

Kottayam district has the distinction of having the highest net sown area (82.79%). The land under forests decreased by as much as 36%, while the net sown area increased by 27%.

In Ernakulam district net sown area increased by about 13.37% and land put to non-agricultural uses by 6% during the three decades. Significant decrease was noticed in area under forests and pastures.

Like many other districts Thrissur district also show a decline in area under forests (-10.6) and increase in net sown area (+12.3%). The land put to non-agricultural uses also increased by about 3.4% during the last three decades.

One peculiar feature of Palakkad district is the substantial increase in the area under forests by about 11.5%. The land put to non-agricultural uses declined by 8% and pastures by about 5.6%.

Kozhikode district show a notable jump in the net sown area, by 20.7%, while experienced sharp fall in the area under forests (-11.6%). the area under pastures and fallows also decreased considerably in the district.

The net sown area of Kannur district increased by 24.3%, while the area under forests increased by 5%. This was compensated by decrease in pastures (-17.4%), fallow lands (-8.8%), and land put to non-agricultural uses (-3%).

The overall changes of land use is discussed in the section four of the Fifth Chapter. It is seen that the State had an overall gross land use change of 10.54% during the period 1961-1991. Of this 5.99% of changes occurred during the first decade (1961-1971), and can be considered as the most dynamic period with respect to land use changes. In the second decade (1971-1981), the gross overall change was 2.88%, followed by 1.67 % during the third decade (1981-1991). This clearly shows that the land use pattern of the State has almost stabilised during these periods.

The Sixth Chapter of this thesis is devoted to the discussion of the agricultural land use over the State and its spatio-temporal variations in relation to rainfall fluctuations. The first Section of this Chapter presents a detailed description about the cropping pattern of the State and its sptio-temporal variations. The second Section describes the influence of short term fluctuations of rainfall in the agricultural land use of the State.

The favourable climate and topographic conditions of the State allows a wide variety of crops to be cultivated. Agriculture in Kerala is unique with respect to its homestead farming, which is practised in all parts of the State.

The crops cultivated in the State include cereals such as paddy, jowar and ragi, pulses, sugar crops, spices and condiments such as pepper, ginger, chilli, clove, cardamom, turmeric and arecanut. Also cultivated are fruits and vegetables like banana, pineapple, jack, mango and cashew. The major non-food crops include coconut, coffee, tea, rubber and cocoa.

The State has experienced a shift in cropping pattern in favour of non-food crops. Food crops accounted for 66.2% of the total cropped area of the State in 1961, which declined to 49.5% in 1990, a decrease of 17.1%. At the same time the area under non-food crops registered a corresponding increase (17.1%).

When considering the absolute area it is obvious that there is a phenomenal 94.4% increase in the area under non-food crops and only a marginal decrease of 4.41% under food crops. The increase of total cropped area during this period was 28.6%.

The derived combination vary from two crops in Alappuzha, Thrissur and Kozhikode districts to five crops in ldukki district. Coconut forms the first ranking crop in nine districts, while rice is the first ranking crop only in Palakkad district. Idukki has pepper as the first ranking crop, followed by rubber, cardamom, tea and coffee. This indicates that the district has predominantly plantation crops. Another noticeable combination is in the Palakkad district where groundnut forms one of the major crops, which occupies the fourth position.

In the northern districts of Kannur and Kasargod, cashew forms a predominant crop occupying the second position. Malappuram district also has cashew, as the fourth ranking crop.

A significant proportion of coffee is grown in Wayanad district where it is the first ranking crop. Tapioca appears in.the combination only in the southern districts of Pathanamthitta, Kollam and Thiruvananthapuram.

Four major crops, paddy, tapioca, coconut and rubber have been selected to study their regional concentration and spatio-temporal variations. Of these, paddy is cultivated mainly during the following three seasons.

1.Virippu - Autumn (first) crop. April / May to September / October

2.Mundakan - Winter (second) crop. September / October to December / January

3.Punja - Summer (third) crop. December / January to March / April.

The highest concentration of paddy is found in Alappuzha and Thrissur districts. Inspite of the fact that rice is the staple food of the people of Kerala, the area under paddy reduced drastically in the State. From 752690 hectares in 1961 it decreased to 541327 hectares in 1991. Alappuzha and Kozhikode districts have high productivity levels.

The area under tapioca in the State declined from 236670 hectares in 1961 to 140881 hectares in 1991. Tapioca is mainly concentrated in the southern districts. High concentrations are found in Thiruvananthapuram and Kollam districts. In consequence to the high concentration of tapioca in the southern districts, they also have high productivity levels.

Coconut is extensively grown through out the State In 1961 the State had 504820 hectares of coconut land, which increased to 863061 hectares in 1991. The productivity levels of coconut are high in Thiruvananthapuram, Alappuzha and Kozhikode districts.

Rubber registered remarkable increase in area. It increased from 133080 hectares in 1961 to 425768 hectares in 1991- an outstanding increase of 220%. Kottayam district has highest concentration of rubber, where it accounts for 34.4% of total cropped area. Rubber productivity follows the general concentration pattern. Kottayam district has the highest productivity level.

Agricultural efficiency of a region depends on the inputs such as the number and types of crops cultivated, their areal extent, climatic and edaphic conditions agricultural practices, and the output in the form of yield per hectare of various crops. Hence an index which takes into account both the per hectare yield and the areal extent of crops, is a most useful tool for assessing the agricultural efficiency.

In this study the Weighted Composite Index of regional inequality in Agricultural efficiency proposed by Singh et.al.(1994), is followed.

The Weighted Composite level of Agricultural Efficiency (V_W) values range from 83 in Palakkad to 584 in Idukki.

Five regions of different levels of efficiency have been identified. Out of the 14 districts in the State, 5 districts have very high and high efficiency levels. Six districts have low to very low levels and the remaining three districts have medium level. This clearly indicates that those districts where the number of crops are more, with almost equal share of crop lands, the efficiency is high. This invariably is found in the hilly districts of the State, where the efficiency level is remarkably very high.

The second Section of this Chapter discusses the influence of rainfall fluctuations on the agricultural land use. Like in many other States of the country, Kerala's agriculture also depends heavily on the monsoon rainfall. Even though the mean annual rainfall of Kerala is much higher than the national average, the inter-annual variations often affect the agricultural production. One way of combating this is by providing adequate irrigation facilities and proper water management practices. Of the total 3021116 hectares of total cropped area in the State, only 387411 hectares are irrigated which accounts for 12.8%. This clearly indicates the degree of dependence of the State's agriculture on rainfall.

Only two districts, Ernakulam and Thrissur, have more than 25% of total cropped area under irrigation. Six districts have only less than 5%. This emphasises that the cultivation in these districts are practically rainfed.

Simple linear regression analysis has been done in this investigation to study the influence of annual rainfall fluctuation on the area production and yield of selected crops. Towards this end data from seven stations have been utilised in this study, assuming that these stations are representative of the districts in which they are located. The summary of the results of this analysis are as follows.

At Attingal in Thiruvananthapuram district, 41.5 % of annual variations in area and 55% of variations in the production of paddy is determined by the annual variations in rainfall. This clearly indicates the heavy dependence of the district on the annual rainfall for paddy cultivation. Similarly, 34.5% of variation of area and 29.8% of variation of production of rubber are determined by the variation of the district's annual rainfall. The dependability of the area and production of tapioca and coconut on rainfall are much lesser.

At Cherthala in Alappuzha district, influence of rainfall on the production of paddy and tapioca are very small. The production of coconut and rubber are influenced to a large extent. The coconut area is also highly influenced by the variation of rainfall.

At Kottayam less than 10% of the area and production of any of the four crops is affected by rainfall variation.ie. the majority of inter-annual fluctuations in the area production and yield of major crops in the district are due to factors other than rainfall.

At Malayattoor in Ernakulam district and Kodungalloor in Thrissur district, the dependability of crops on rainfall are comparatively less. This can be explained as due to the fairly good irrigation facilities available in these districts.

Palakkad district, for which Mannarakkad is the representative station, produces about one third of the total paddy output in Kerala. The district also has fairly good irrigation facilities and hence the dependability of crops on rainfall is less.

At Kannur 21% of the variations of paddy productions may be attributed to the fluctuations of annual rainfall, while 19% changes in the yield of tapioca and 14% variation in the area are caused by the inter-annual variation of rainfall.

It is observed from this study that the rainfall fluctuations do cause significant changes in agricultural land use. The total production and yield of major crops are determined to a large extent by the rainfall values. However where ever sufficient irrigation facilities are available, the degree of dependability of crops on rainfall is much lower.

It is clear from the above results that the State as a whole, experience heavy rainfall and large water surplus while water deficits are not altogether absent Further more, the rainfall over the State seems to be decreasing and the water surplus is getting reduced at a much faster rate than the rainfall, when, at the same time, water deficits are increasing. This means, from the agricultural point of view, the irrigation potential is getting reduced along with the availability of water. Water conservation is therefore not only important but also necessary, critical and urgent.

By a proper management of surface water, when available, the deficits in the other seasons can be reduced. A large quantity of utilizable surface water flows to the Arabian Sea unexploited and unharnessed This can be avoided to a large extent by the construction of dams and reservoirs at proper locations. However, since the State is densely populated and most of the land is exploited, construction of large dams could give rise to rehabilitation problems and environmental degradation. It is therefore advisable to plan comparatively smaller and ecologically viable projects at suitable locations. Heavy rainfall during the monsoon months leads to intensive soil erosion . Therefore soil conservation is an important aspect of land use planning. Terracing, contour bunding and afforestation are generally suggested techniques for soil conservation.

The broad agroclimatic zonation followed in this study suggests that in general the land has been exploited with a fairly high degree of efficiency. However, inorder to arrive at most suitable land use pattern for the State, it is essential that detailed maps of soil, physiography and geology of the State are superimposed on maps depicting the agroclimatic zones. This technique should be adopted and a comprehensive and optimum land use map be prepared with the help of Geographical Information System (GIS). It is also important that once the area are demarcated for specific agricultural land use, they are further studied in detail to evolve the optimum crop combination and cropping pattern, so that the highest levels of agricultural productivity in the area may be achieved. With such an approach, sustainable agriculture can be developed ensuing long term progress of the region.

The analysis of agroclimatological parameters, climatic shifts and droughts and their influence on the major crops revealed that climatic parameters influenced agriculture significantly. Further agroclimatological features are also important determinants in the choice of appropriate land use strategies and cropping pattern, though in this study it has not been possible to quantify their exact influence. Future work is necessary in this direction to determine the finite relationship between variation in climate and meteorological parameters and agricultural land use variability. Towards this end it may be essential to use appropriate crop-climate and crop-weather models along with the information generated by the GIS mentioned above. Such an effort would be a significant step forward in planning optimum land use over the State.

In conclusion, it may be said that the development of the State is inextricably linked to the availability of water through rainfall, with all its inherent inter-seasonal, intra-seasonal and spatial variabilities. Formulation of most suitable land use strategy is important through the co-ordination of various users of precious natural resources of land, water and atmosphere. It is hoped that the results of the present investigation would help in the judicious planning for the optimum use of available resources.