CHAPTER VI

SUMMARY AND CONCLUSIONS

The State of Kerala lies in the southwestern part of the country, along the west coast. The diverse physiographic features of the State are very significant in influencing the climate, vegetation and land-use of the region. Within a short distance of 120 km from the coastline to the Western Ghats, a variety of climates is observed due to the diversity of physical features. The most conspicuous feature of the climate of Kerala is the heavy rainfall due to the southwest monsoon. The vagaries of the monsoon - its onset and withdrawal, active and break conditions, space and time variations - are all very complex.

The State has a well-distributed drainage network consisting of 44 rivers. Due to effluent seepage, rivers of the State are perennial and they possess high potential for hydel-power generation, irrigation and transportation.

A knowledge of what happens to the large amount of the water that reaches the earth surface as rainfall is a pre-requisite for the study of many surface and subsurface water problems and for the efficient control and management of water resources. For a State such as Kerala, whose welfare depends very much on agriculture, a quantitative knowledge of water requirements of the region and the availability of water for plant growth and supplemental irrigation, etc. on a monthly or seasonal basis is an essential requirement for agricultural development. Increasing population
in recent decades and the resultant higher demands for food have led to many attempts aimed at optimal exploitation of water resources. Since the power generation of the State depends totally on hydel projects, a quantitative measure of the water surpluses of the region is a very useful parameter, since it provides a rough estimate of the utilisable water for the power projects.

In this context, a study of the water balance of the State has been found to be very relevant and useful. The derived parameters of water balance, especially water surplus and water deficit, on a seasonal basis give very essential information useful for various agricultural activities, such as choosing the variety of crops, adjusting the farming operations, assessing the irrigation potential of the region and scheduling the irrigation operations. Study of water surplus is especially important for the development of river basins for water supply, power generation, irrigation, flood control and drainage, among other things.

The spatial distributions together with seasonal variations of the water balance parameters help us to delineate the optimal regions for the development of agriculture and hydel-power projects and to assess the economic feasibility of different activities connected to water resources management.

Studies on large scale temporal changes in the hydrometeorological parameters, especially rainfall and temperature are important for planning the development of a country's natural resources. There is also a general opinion that rainfall of Kerala is decreasing and temperature is increasing.
In Kerala, whose economy is very much dependent on water availability, fluctuations in rainfall affect human welfare, through their effects on agriculture, power generation and industrial activities. Power cuts and load shedding have become a common feature in the State during the last decade, due to the deficiency of power. This again affects agricultural and industrial production and thereby the economy. Even though well-developed irrigation facilities reduce the risk in agricultural activities, prolonged drought conditions will affect the irrigation system itself. Salt water intrusion through the rivers is another problem in Kerala, especially during pre-monsoon months, which indirectly affect agriculture. Since the population density is very high, and is further increasing, the water requirements for domestic purposes too, would be increasing.

In the present context, a detailed study of time series of rainfall and other water balance parameters such as actual evapotranspiration, water surplus and water deficit to detect the trends and periodicities in the series, seems to be very relevant. Therefore, the spatial and temporal variabilities of some important hydrometeorological parameters over the State have been analysed in the present study. The thesis consists of six Chapters with a general introduction as the first one. The first Section of the Second Chapter explains the concepts of hydrologic cycle and water balance, various methods of estimation of potential evapotranspiration, the book-keeping procedure of water balance of Thornthwaite (1948) and various applications of water balance techniques. The second Section of this Chapter is mainly concerned with the applications of time series analysis in climatology. Various techniques such as power spectrum analysis, Mann-Kendall statistic test, Student's t-test and filtering methods which are
employed to reveal the temporal variations in time series have been discussed. An exhaustive and relevant review of various hydrometeorological studies are cited in this Chapter.

The third Chapter consists of a discussion of the important physico-climatic features of Kerala State. The location and extent, physiography, drainage, soil types, agricultural pattern and land-use systems over the State are explained in the first Section, while details about temperature, wind and humidity which form the climatological features are discussed in the second.

The seasonal and annual distributions of important water balance parameters namely rainfall, potential evapotranspiration, actual evapotranspiration, water surplus, water deficit, surface flow, underground flow and total discharge over the State have been mapped and discussed to present a broad picture of hydro-climatic background of the region in the fourth Chapter. The spatial distributions of various indices derived from the water balance procedure, such as Moisture Adequacy Index, Aridity Index, Humidity Index, and Moisture Index have also been presented. A classification of climates of Kerala, based on Thornthwaite's scheme has also been depicted in this Chapter. The salient results of the study are given below.

The average annual rainfall for the State as a whole is 294 cm, of which 45% (131 cm) is utilised for evapotranspiration and the remaining 55% (163 cm) is available for utilisation. By segregating the exploitable water, it is found that about 97 cm (33% of rainfall) is available as surface flow and the remaining as underground flow. For the State as a
single unit, the average annual surface flow is greater than underground flow.

Average annual water need for the State is 160 cm. The actual evapotranspiration (A.E.) is 133 cm which is about 83% of the water need, and therefore a deficit (P.E.- A.E.) of 27 cm (17% of the need) is experienced. This indicates that the State as a whole, experiences heavy rainfall and a large water surplus, but water deficits are not altogether absent. The average annual water surplus is about 6 times higher than that of deficit: also water deficit is only about one third of the surface flow. So, by a proper management of the surplus water, the deficit now experienced over the State can be mitigated, even without much exploitation of groundwater.

There are two pockets of very heavy rainfall over the State, having average annual rainfall of more than 500 cm: one in the south and the other in the north. Among the stations selected for the study, the highest mean annual rainfall has been recorded at Neriamangalam (507 cm) and the lowest at Chinnar (60 cm). An interesting feature to be noted is, that, these two stations are only about 35 km apart. The rainfall varies from about 175 cm in the extreme south to about 350 cm in the extreme north. The highest annual point rainfall (842.5 cm) has been recorded at Peermede, in 1968 and the lowest (12.3 cm) at Chinnar in 1939.

The seasonal contributions to average annual rainfall are 1%, 15%, 66% and 18% for the winter, pre-monsoon, monsoon and post-monsoon seasons respectively. The rainfall pattern in the monsoon season also exhibits two regions of very heavy rainfall. The northern pocket has comparatively
higher monsoonal rainfall, though in the case of annual rainfall, the higher value is in the south. The maximum rainfall in the monsoon season occurs at Vythiri (347 cm), which is about 80% of its annual value, and the lowest at Chinnar (17 cm), where it is only 28% of the annual rainfall. The percentage contribution of monsoon rainfall to the annual is more than 80% in the northern parts, and gradually decreases to about 45% in the extreme south, where post-monsoon rainfall is comparatively higher (about 30% of annual). The heavy rainfall pockets observed in the annual and monsoon rainfall patterns in the north are not seen in the post-monsoon rainfall pattern. The north–south gradient of monsoon season rainfall is in a direction opposite to that of annual values and that of the other three seasons.

The mean annual rainfall over the State is about two and a half times the rainfall of India. The rainfall over Kerala in pre-monsoon, monsoon and post-monsoon seasons are more than twice the national average. Only in the winter months, the seasonal value over the State is less than that of the rainfall over the country. The percentage contribution of the monsoon season to the annual total is less for the State than for the country. The years of extremes of rainfall over the State and the country are not identical.

Stations in the southern parts of the State have their highest monthly rainfall in June, but over the northern parts, the maximum occurs in July. The heaviest mean monthly rainfall of 140 cm occurs at Vythiri, followed by Kuttiyadi (130 cm), both in July and in the northern heavy rainfall pocket. In the northern parts, the major contributions to annual
rainfall are in the months of June, July and August, but in the southern parts, the rainfall is more widely distributed among the months. A double maximum exists in the monthly rainfall pattern all over the State, except in the extreme north. Here, the variability pattern of monthly rainfall shows a trimodal structure for most of the stations.

The highest weekly rainfall (35 cm) occurs at Vythiri during the 29th week. This station experiences weekly rainfall of more than 30 cm over four consecutive weeks, and more than 25 cm each during six consecutive weeks. Almost all stations have shown a secondary maximum corresponding to the post-monsoon season, a fact which is not evident from the monthly distribution pattern over northern parts of the State.

Isolines of potential evapotranspiration are nearly parallel to the Ghats, but there exist a few pockets of low annual values (less than 90 cm) corresponding to hill stations. The average annual P.E. for the State as a whole is 160 cm, 15% of which is in winter, 29% in pre-monsoon, 32% in the monsoon and 24% in the post-monsoon seasons. The distribution of annual P.E. for different seasons are more uniform compared to the rainfall distributions, and it is this factor that determines the water balance of the State.

The spatial distribution pattern of mean annual A.E. has a resemblance to that of P.E. distribution. But, an increasing trend towards the south in annual A.E. has been observed, in contrast to the annual P.E. pattern. The highest value of annual A.E. of 165 cm (more than 95% of annual P.E.) is at Kanjirapally. During winter and pre-monsoon seasons, the distribution patterns of A.E. are quite different from that of P.E.,
but have a similarity to the corresponding rainfall patterns.

A salient feature of the seasonal distribution of A.E. is that during monsoon season it equals P.E. all over the State except over a very small area surrounding Chinnar.

The moisture adequacy index for most parts of the State is very high - more than 70% - indicating that almost all parts of the State are suitable for a wide variety of agricultural crops.

The mean annual water deficit increases from 24 cm in the south-west to about 47 cm in the north-western parts of the State, with certain areas having higher values. This may appear to be paradoxical, considering the fact that the mean annual rainfall also increases in the same direction. The highest value of annual deficit of about 77 cm occurs over Chinnar region, while Devikulam region experiences the lowest value of only 2 cm. The winter and pre-monsoon seasons each contribute about 45% of the annual deficit. During monsoon season, there are no deficits over the State, except over Chinnar region. A general decrease of deficit towards south and east is observed in all the seasons.

The mean annual water surplus varies from 0 cm at Chinnar to 358 cm at Neriamangalam. During winter season no station has any surplus. Furthermore, almost all stations, except those in the southern heavy rainfall pocket do not have any surplus during pre-monsoon season too. Even though 15% of the State's average annual rainfall is contributed by pre-monsoon season, it adds only about 1% of the surplus to the annual value. About 85% of the surplus is during the monsoon season, though the percentage contribution of the monsoon rainfall to the annual is only 66%.
Even though rainfall is widely distributed over the year, surplus is observed only between June and November. The highest monthly surplus over the extreme south of the State occurs in October, though the heaviest monthly rainfall is in the month of June.

Annual surpluses are very high for all stations compared to annual deficits, except at Chinnar, where there is no surplus, but exists the highest annual deficit. In general, both annual surplus and deficit decrease towards south, with the exception of a few isolated pockets. All stations north of Cranganore (except high altitude stations) have annual deficits more than the average for the State: stations south of Cranganore except Chinnar have deficits less than the State average.

Climatic classification shows that there is no arid climate over the State, while a small area surrounding Chinnar belongs to the semi-arid type, and most parts of the State have humid type of climate. Northeast Kerala and an area surrounding southern pocket of heavy rainfall enjoy perhumid type of climate. The thermal regime of classification shows that, except the eastern high altitude stations, the State has megathermal type of climate, and can support the most luxuriant forms of vegetation.

The spatial distribution patterns of surface flow on an annual and seasonal basis are similar to that of surplus. The monsoon and post-monsoon seasons contribute about 99% of the surface flow.

The State average annual groundwater flow is distributed as 11%, 8%, 50% and 31% respectively among four seasons. Even though there is no significant surplus in winter and pre-monsoon seasons, there is underground
flow. Rainfall is least in winter, but the underground flow is least in the pre-monsoon months: also, the winter season groundwater flow is more than that of rainfall for that season. The spatial distribution patterns of groundwater flow on both annual and seasonal bases are very much different from that of surplus pattern, with high values being observed in the northwestern part of the State. The western parts of the State have comparatively high values of groundwater flow than the eastern parts. Chinnar region does not have any groundwater flow in any season, on a climatic basis. For the State as a whole, annual surface flow is about one and a half times the groundwater flow. But, on a seasonal basis, underground flow is more than surface flow, except in the monsoon season.

On a monthly basis, even though there is no surplus till June, there is groundwater flow (which is more than monthly rainfall) during the months of January and February. Rainfall and surplus are maximum in June or July, but the highest monthly groundwater flow occurs in August for most of the stations, indicating a lag of at least one month. The secondary maximum observed in the monthly rainfall and surplus values are not much pronounced in the case of groundwater flow.

On a climatic basis, total discharge is the same as that of total annual water surplus, but surplus is concentrated in monsoon and post-monsoon seasons, while the total discharge is distributed among all seasons. On a monthly basis, the least total discharge occurs in May as does groundwater flow, but the highest values are observed in June or July as in the case of surface flow.
The fifth Chapter deals with the time series analysis of rainfall, actual evapotranspiration, water deficit and water surplus over the State as revealed by power spectrum analysis and trend aspects as indicated by Mann–Kendall statistic, Student's t-test and low pass filtering techniques. The analysis has been carried out on a seasonal basis for nine selected stations.

Trend analysis of annual rainfall has shown that some stations in the southern half of the State exhibit a significant decreasing trend, but only two stations in the northern half of the State have shown such a trend. None of the stations in the State has shown any significant increasing trend. The stations which have shown significant decreasing trends appear to be randomly distributed. The departures of half-period averages vary from +21 cm at Perintalmanna to -165 cm at Neriamangalam. A conspicuous feature is that the region of maximum decrease in annual rainfall corresponds to the region of heaviest annual rainfall for the State. Three pockets have shown a decrease of more than 50 cm. It is worth noting that a slight increasing tendency in half-period averages has been observed over Palghat Gap, and an area extending to the north through the coastal tracts of the State and the leeward side of the Western Ghats in the southern half. The percentage ratio of departure is maximum over Neriamangalam (-28%). Marayur, a station on the leeward side of the Ghats has shown a positive departure of more than 15%.

For the monsoon season, only Punelur has shown a significant decreasing trend in rainfall. Half period averages have shown that both stations in the high ranges – Peermede and Vythiri – also exhibit a
decreasing tendency. It is interesting to note that all the other six stations show a slight increasing tendency in monsoon rainfall. For the post-monsoon season, all stations except Palghat have shown a decreasing tendency. Punelur, Peermede and Vythiri have shown a decreasing tendency in monsoon, post-monsoon and annual rainfall. On the other hand, Palghat has shown an increasing tendency in all the three cases. For all coastal stations, the departure of means for monsoon rainfall is much more than the annual rainfall.

Filtered series of rainfall have shown that variations are oscillatory with peaks and dips. Although Punelur has shown a significant decreasing trend, the filtered series does not indicate a continuous decrease. The filtered series of rainfall of various stations do not exhibit many common features. But, it is observed that the annual rainfall of all stations were near normal during 1978-1979: after that, a sharp decrease has begun. This feature has been observed to a certain extent in monsoon rainfall also. This decreasing trend ceases by 1986-1987 and then onwards an increasing trend is noted and the rainfall becomes above normal by about 1988.

About one third of the stations have shown a significant decreasing trend in annual A.E.. Almost all stations which have shown a significant decreasing trend in rainfall, have shown a decreasing trend in A.E. too. Many of the stations which do not exhibit any significant decreasing trend in annual rainfall or even some stations which have shown an increasing tendency have shown very significant decreasing tendencies in annual A.E.. Only Karikode has shown a significantly increasing trend in A.E. values.
Stations in the northern half of the State which do not exhibit any significant decrease in annual rainfall or increase in P.E., exhibit a significant decreasing trend in annual A.E.. This implies that seasonal distributions of both rainfall and P.E. play a major role in these cases. It is to be noted that a small decreasing trend in winter or pre-monsoon rainfall will certainly affect the A.E. values, but need not have much effect on annual rainfall. Similarly, a decreasing trend in annual or post-monsoon rainfall need not have much effect on annual A.E. values.

Cochin and Peermede have shown an increasing trend in A.E. of monsoon period, but do not show any significant change in annual A.E.. All the other seven stations do not show any significant trend in monsoon, post-monsoon and annual A.E. series.

Trend analysis of annual deficits has shown that two-third of the stations exhibit significant increasing trends and none of the stations except Perintalmanna shows any significant decreasing trend. It is to be remembered that, for a third of the stations the decreasing trend is significant at 99% level. Stations which exhibit significant trends appear to be distributed at random. A few of the stations which do not exhibit any decreasing trend either in rainfall or in A.E. show an increasing trend in annual deficit. Similarly, some of the stations in the southern half of the State which exhibit significant decreasing trends in rainfall have not shown any increasing trend in annual deficit.

Departure of half-period means have revealed that most of the areas in the State show an increasing tendency with comparatively higher values in the southwestern parts of the State, with a maximum of 22 cm at
Nedumangad. Neriamangalam which shows the maximum decrease in annual rainfall (165 cm) has shown a departure of only 4 cm in annual deficit. The northwestern parts of the State which experience a decreasing tendency in annual rainfall do not show a corresponding increasing tendency in annual deficit. Stations on the leeward side of the Western Ghats show a slight decreasing tendency in deficits.

The percentage departure of annual deficit is maximum around Nedumangad region (more than 90%). It is to be noted that the increase in the percentage ratio of annual deficit is more than twice the decrease in the percentage ratio of annual rainfall for most of the stations. The area of increasing tendency of annual deficit is much more than the area of decreasing tendency of annual rainfall.

Deficits in the monsoon season for many stations have shown statistically significant decreases by Mann-Kendall statistic test, though this is not of much practical significance, since actual values themselves are very low. But, none of the stations has shown any increasing trend in this season. It is interesting to note that, during post-monsoon season, Peermede, and Vythiri have shown a decreasing tendency in water deficits.

For all stations, high values of annual deficits occurred in 1982 or 1983: at the same time the filtered values were above normal from 1975 onwards, except at Palghat. The series of annual values of rainfall and deficit do not appear to be correlated for Calicut and Trivandrum. This seems to be paradoxical, since one expect an increase in deficit as the rainfall decreases. This again implies that changes in the distribution pattern of rainfall are important.
All stations which exhibit significant trends in annual rainfall have shown trends in annual surplus too. Many stations in the southern half of the State reveal the presence of highly significant decreasing trends. None of the stations has shown any increasing trend. This indicates reduction in hydrologically available water and also the reduction of flood severity over the State especially in the southern half.

Many stations in the southern half of the State exhibit significant trends, both in annual surpluses and annual deficits. But, in the northern half, many stations have shown significant increasing trends in annual deficits, but only two stations have shown significant decreasing trends in annual surplus.

The percentage departures of annual surplus are very high compared to that of annual rainfall for almost all stations, and it varies from -49% at Chinnar to +12% over Palghat Gap, with three pockets of more than 20%. This gives a very important conclusion that the hydrologically available water is getting reduced much faster than actual rainfall itself.

During the monsoon season, only one station has shown a significant decreasing trend in surplus values, but, for post-monsoon season, six out of nine stations have shown a decreasing trend. It is to be noted that for all coastal stations, increase in monsoon surplus during the second half over the first half is more than the corresponding increase in annual values. This implies that coastal stations have shown an increase in rainfall during the monsoon season and a decrease in other seasons.
Time series of annual values of rainfall, A.E., water deficit and water surplus for all stations have been subjected to power spectrum analysis, to find out significant periodicities present in the series. It is found that none of the time series of different parameters of any stations exhibits Markov linear type persistence. High-frequency oscillations become more prominent in the case of filtered series of all parameters.

About half of the stations have shown persistence in rainfall series, significant at 99% level for about one fifth of the stations. About two third of the stations in the southern half of the State have shown persistence, while in the northern half, only a few stations have done so.

A periodicity of infinite wavelength has been observed at Punelur. Six stations shown a quasi-periodicity in one or more harmonics in the wavelength range 10.3-24.0 years. Thirteen stations, mostly in the southern half of the State, have shown a quasi-periodicity in the medium wavelength range of 2.9-4.3 years and in this, a periodicity of 3.1-3.4 years was significant for 11 stations. Another salient feature of the time series of rainfall is that none of the stations exhibit any periodicity at 99% significant level.

Persistence has been observed in the time series of annual A.E. for 10 stations, in which half of them are significant at 99% level. Significant spectral concentration corresponding to an infinite wave length has been observed at Kayamkulam. About half of the stations exhibit a quasi-periodicity of 3.4-5.5 years. Another quasi-periodicity observed in the time series is 2.2-2.5 years (8 stations). Significant periodicities
at 99% level have been observed for 2.2-2.5 years at Irrikur and 3.4-3.8 years at Perintalmanna. A.E. series of Attingal has shown significance for a wide spectrum of wavelength corresponding to 4th and 9th harmonic (3.8-10.3 years). It is observed that the periodicities observed in the annual rainfall series are not reflected in A.E. series.

More than one third of the stations have shown significant persistence in the case of annual water deficits. Deficit series of Cranganore and Kayamkulam have shown the presence of significant trends in the series, but only 5 stations have exhibited periodicities beyond 6.5 years. Major quasi-periodicities observed are 2.2-2.9 and 3.1-4.8 years. About one third of the stations have shown periodicity in one or more harmonics in the wavelength range of 2.2-2.9 years; more than half of the stations exhibit periodicity in one or more harmonics in the wavelength range of 3.1-4.8 years. Periodicities of 3.4-3.8 years and 3.8-4.3 years are significant at 99% level for Perintalmanna, 2.3-2.5 year at 99% level for Irikkur and Vythiri, and 2.5-2.7 and 4.8-5.5 years (99% level) over Neriamangalam and Muvattupuzha respectively. Periodicities observed for rainfall series and that of deficit series are not correlated.

Analysis of annual water surplus has shown that Punelur exhibits significant trend or long term periodicity. Major quasi-periodicities observed in annual water surplus series are 3.1-3.8 years and 10.3-24.0 years. One third of the stations exhibit periodicities in the 3.1-3.4 year wavelength range and about one fourth of the stations show periodicity in 3.4-3.8 year wavelength. A few stations have shown periodicities in very short wavelengths too. High significance (99% level) has been observed at
Malayattur (2.2-2.3 years) and Devikulam (2.5-2.7 years). Most of the periodicities observed in annual rainfall series are reflected in annual water surplus series. Almost all stations which have shown quasi-periodicities for 3.1-3.8 years and 8.3-24.0 years in rainfall series have shown the periodicity in annual water surplus series too. However, some stations exhibit these periodicities in annual water surplus but not in rainfall series.

A comparison of the periodicities observed for different parameters shows that the 10\textsuperscript{th} harmonic corresponding to a wavelength of 3.4-3.8 years has shown significant periodicities for comparatively larger number of stations for all parameters. Large wavelength periodicities are more for rainfall and surplus series. A correlation between the periodicities of A.E. series and water deficit series has been observed for some stations.

Periodicity analysis carried out for 9 selected stations have shown that during the monsoon season, two major quasi-periodicities of 3.1-3.8 and 6.5-14.4 years are observed in time series of rainfall, A.E. and water surplus. None of the stations has shown any periodicity higher than 14.4 years for any parameter. The quasi-periodicity of 3.1-3.8 years is observed at 6 out of 9 stations. The major quasi-periodicities observed in deficit series are 2.5-3.1 and 4.2-4.8 years.

It is clear from all the above results that the State as a whole experiences heavy rainfall and large water surpluses, but water deficits are not altogether absent. The average annual water surplus is about 6 times the water deficit, which is only about one third of the surface flow.
There are regions having large surpluses as also regions without any surplus. Water surplus occurs only in a few months: about 85% of the surplus occurs in the monsoon season and during winter there is no surplus anywhere in the State. The annual water deficit over the State varies from 2 cm to more than 75 cm. The winter and pre-monsoon seasons experience about 45% of the annual deficit. The co-existence of both water surplus and water deficit at different times of the year in different parts of the State is an important aspect of the hydrometeorology of the State.

By a proper management of the surplus water, the deficit now experienced over the State can be mitigated. A large quantity of the surplus water flows to the Arabian Sea unexploited; sometimes such flow causes damage to the river banks by flooding. This can be avoided to a large extent by the construction of dams and reservoirs at proper sites. Since the State is densely populated, construction of large dams will give rise to rehabilitation problems, cause environmental degradation and also affect the stability of the Ghats. Since the State is narrow, being confined to the area between the coast and the Ghats, all rivers in the State are very short in length and have steep flows. It is, therefore advisable to plan comparatively smaller projects at suitable locations for conserving the valuable surface flow. Since rainfall in the northern parts of the State, is concentrated in the monsoon season, it is imperative to impound as much water as possible in these areas, by comparatively bigger dams, if necessary. The present study clearly indicates the regions, periods of the year of large surplus and deficits.
In order to get the maximum utility of the hydel-projects, siltation in the rivers has to be reduced. Intense soil erosion will result in the reduction of the capacity of rivers and reservoirs. Therefore soil conservation is an important aspect of water conservation. Because of the rugged and steep topography of the State, the soil erosion will be naturally very high, augment by unwise human activities. Terracing, contour bunding and afforestation are some of the usually suggested techniques for soil conservation. Judicious agricultural and other land-use practices are very important for the proper management of the soil.

The study points out that, apart from surface flow, the State has large groundwater resources. For the State as a whole, underground flow is about 1.5 times the surface flow. Even though on an annual basis, surface flow is more than the underground flow, on a seasonal basis, underground flow exceeds surface flow, except in the monsoon season. In order to avoid lowering of the water table and intrusion of saline water it is necessary to recharge the groundwater during the monsoon months. For this, percolation ponds and wells can be planned. Highland regions of the State are comparatively steep, and so the infiltration rates are less. This can be solved to a certain extent by bunding and terracing of the slopes. Afforestation of the slopes is also a method suggested to reduce the runoff and thereby increase the infiltration rate.

By judicious management of water resources - both surface and subsurface water- and optimum utilisation of the available water, it is possible to convert large areas of cultivable wasteland into productive agricultural lands. Agricultural development can then be achieved by
increasing the area of cropping, increasing the number of crops, and employing multiple cropping methods.

It is well recognised that, climate is always varying, and that climatic variability influences man's natural environment and his welfare. However, the practical importance of climatic changes may not always be revealed by statistical significance tests. This does not mean that the study of climatic variability is without practical applications. If it is true that a practically significant change of climate need not be a statistically significant change, the converse, that a statistically significant change of climate may be of practical importance is much less likely to be true. The practical value of any study of variability is in its potential applicability to future planning. Climatic variations are very important because they affect human beings in myriad ways and touch upon the most fundamental aspects of life. Interannual climatic variability can have radical effects on agricultural productivity and food supply, and also profound impact on water resources.

In the time series analysis carried out, it has been seen that some series contain statistically significant trends or cycles in relatively brief periods of time. But, if longer periods of observations are considered, these trends or periodicities may become less distinct. Similarly, relatively larger trends or cycles that did in fact exist in the climate may not be indicated in short-period analysis. It should be remembered that a fluctuation which lacks statistical significance during the period of study may be continuing in the same direction, so as to acquire statistical significance in the near future.
It is observed that rainfall over the State is decreasing, and the water surplus is getting reduced at a much faster rate than rainfall, while at the same time water deficit over the State is increasing. From the agricultural point of view, the irrigation potential is getting reduced along with the actual available water. Water conservation is therefore becoming more important, critical and urgent.

From the spectral analysis, it is seen that some series exhibit periodicity, but we do not have any idea about the phase of the oscillation. This phase difference of oscillation between different pairs of stations or of the different parameters of the same station can be obtained from co-spectrum and quadrature spectrum of the time series.

Water resources do not have political or administrative boundaries and should be considered as a national resource. A regional water grid as a part of national grid has to be developed, in order to fully exploit the natural wealth for the development of the State and the country.

In conclusion it may be said, the development of the State is linked to the conservation of surplus water during the monsoon season through appropriate storages and the utilisation through regulated release during the drier part of year for irrigation, power generation, navigation, fish culture and tourism. Coordination of the various needs and uses of the available water has to be secured through an integrated approach to the management of the precious natural resource.