CHAPTER IV

RAINFALL VARIABILITY AND AGROCLIMATIC DROUGHTS OVER KERALA

A detailed analysis of the rainfall pattern over the State is presented in the first section of this Chapter, while the drought climatology of the region has been discussed in the second section.

4.1 Spatial and temporal distribution of rainfall over the State:

The results of the studies pertaining to spatial and temporal distribution of annual as well as seasonal rainfall over the State carried out by James (1991) are presented in this Section.

Analysis of data pertaining to the period 1931-1980 for 42 stations distributed uniformly over the State reveals that the average annual rainfall of Kerala is 294.3 cm; it is about 2.5 times the average rainfall of India and about thrice the world average rainfall.

There are two pockets of very heavy rainfall over the State (Fig 4.1), having average annual rainfall of more than 500 cm: one in the south and the other in the north. Among the stations selected for this study, the highest mean annual rainfall (507 cm) has been recorded at Neriamangalam and the lowest (60 cm) at Chinnar The rainfall varies from about 175 cm in the extreme south to about 350cm 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.

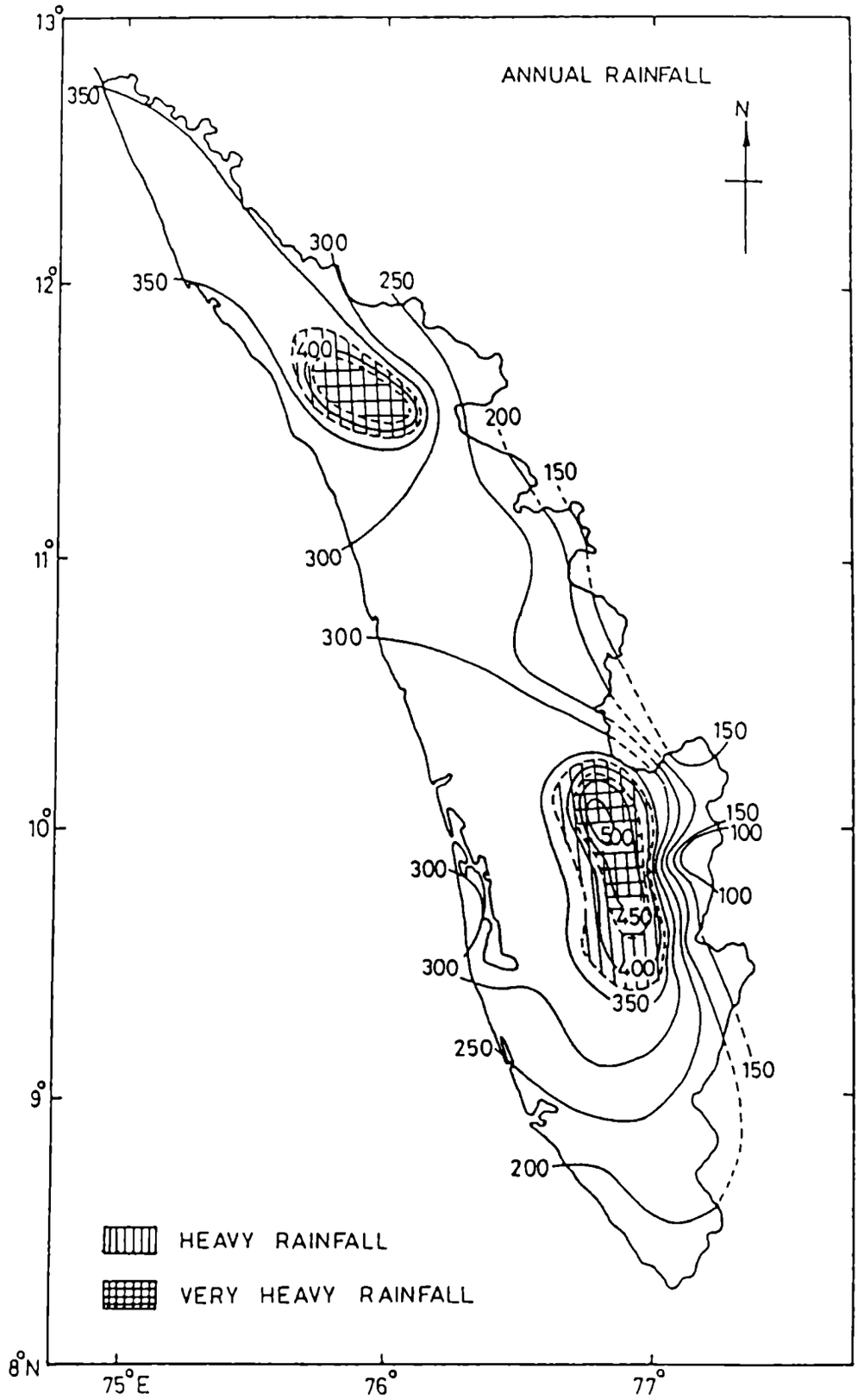


Fig 4.1 Spatial distribution of annual rainfall of Kerala (cm) (After James (1991)

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 pockets of very heavy rainfall (Fig 4.2) 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.

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. Over the northern parts, the major contributions to annual rainfall are in the months of June, July and August, and 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.

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

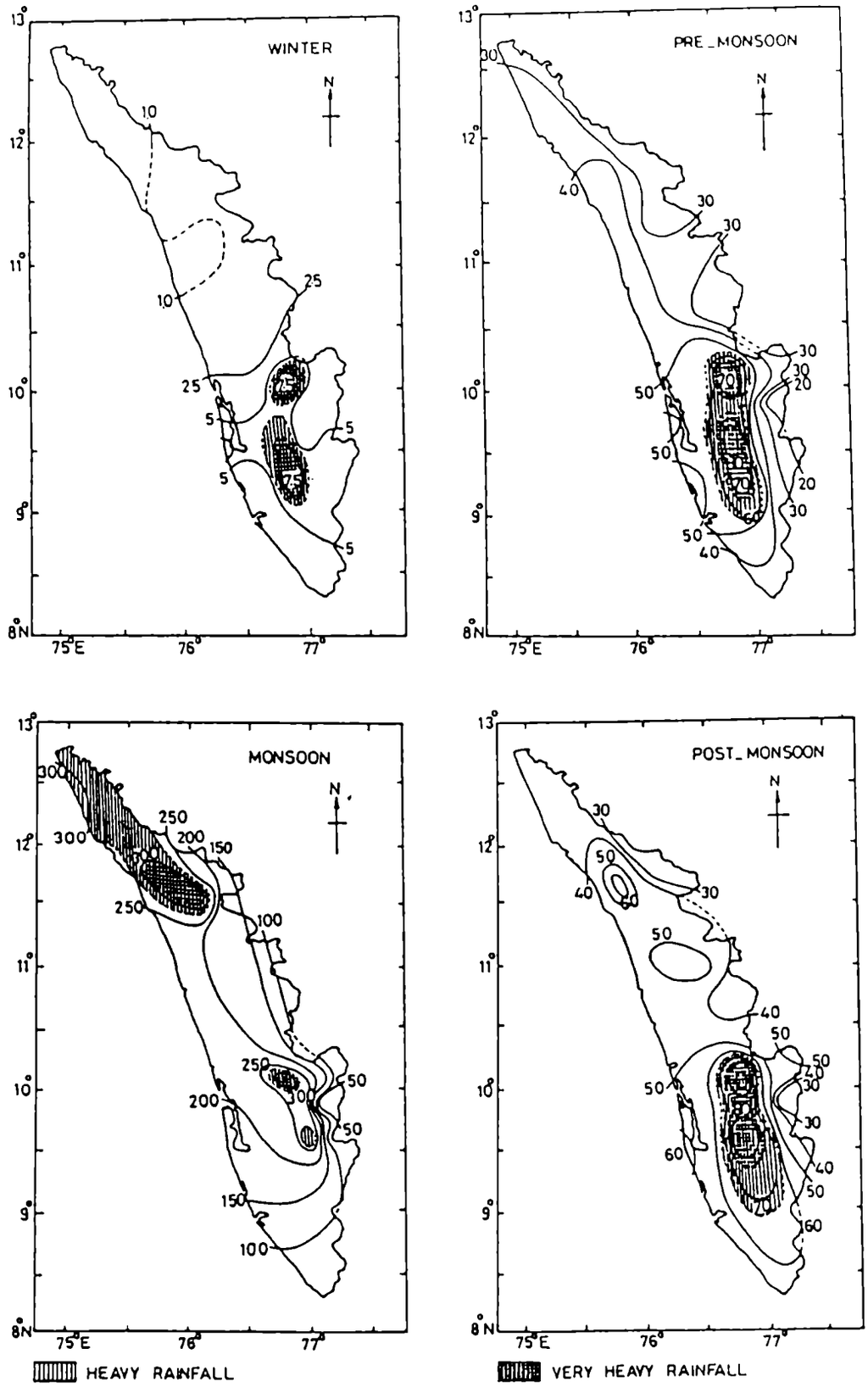


Fig 4.2 Spatial distribution of seasonal rainfall of Kerala
(After James (1991)

a secondary maximum corresponding to the post-monsoon season.

Trend analysis of annual rainfall (Fig 4.3) has shown that some stations in the southern half of the State exhibits a significant decreasing trend, but only two stations in the northern half of State has 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.

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. All the other 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.

Time series analysis of annual rainfall over State employing power spectrum analysis gave the following results. A periodicity of infinite wave length was observed at Punelur. Some stations showed a quasi-periodicity in one or more harmonics in the wavelength range 10.3-24.0 years, while most of the stations in the southern half of the State showed a quasi-periodicity in the 2.9-4.3 years wavelength range.

It is clear from the above discussions that the State as a whole experiences large spatial and temporal variation both in

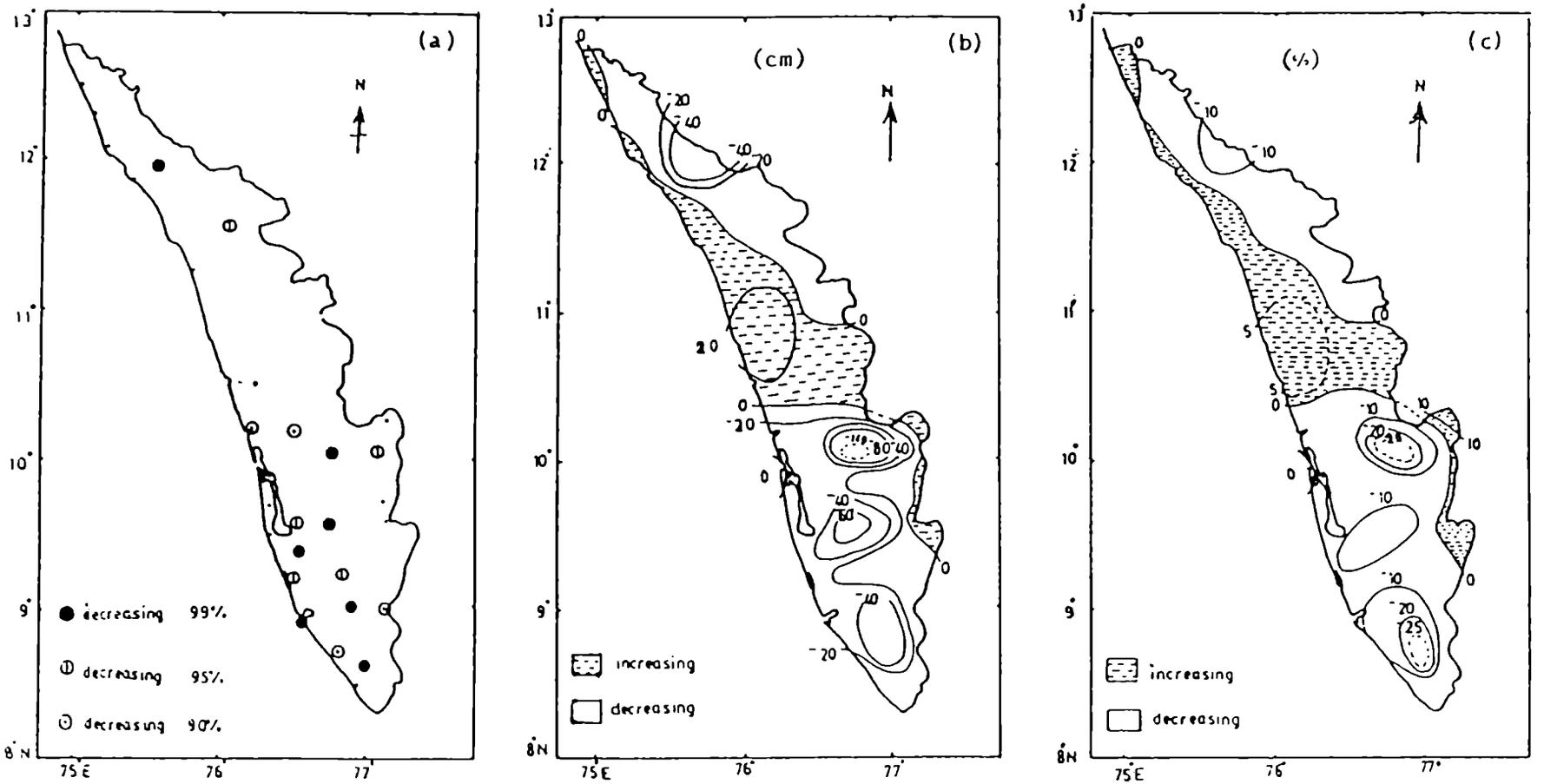


Fig 4.3 Trend aspects of annual rainfall series of Kerala
(After James (1991)

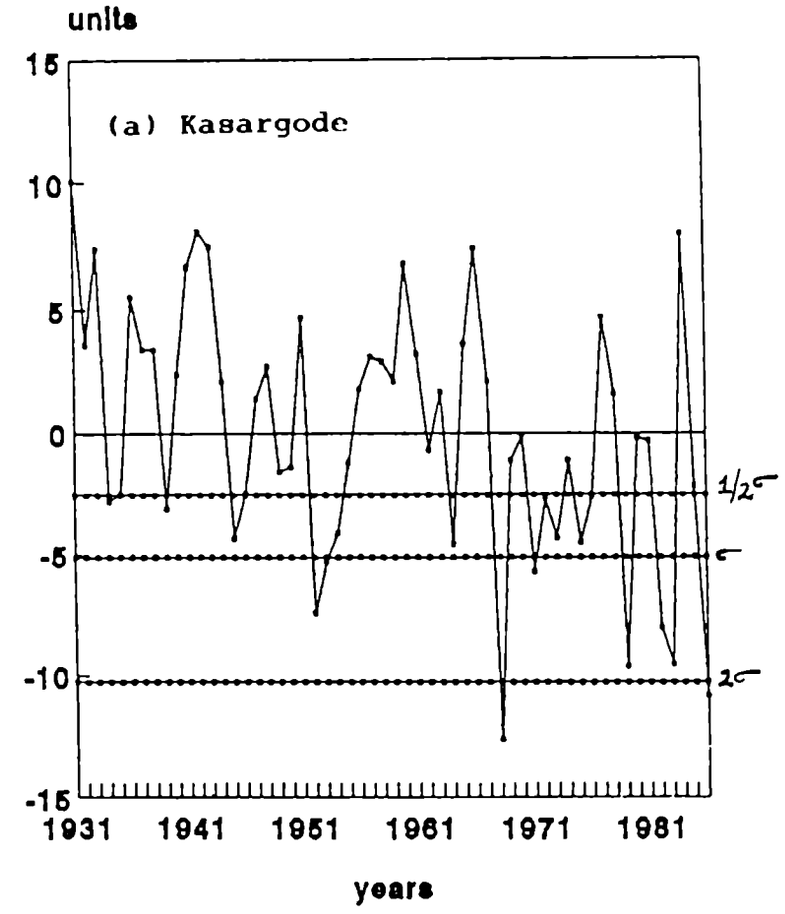
annual and seasonal rainfall. This variation in rainfall is in a way responsible for the occurrence of floods and droughts. While rainfall alone cannot be held responsible for the occurrence of floods, droughts are generally understood as a period of dryness due to lack of rain.

4.2 Agroclimatic droughts over Kerala:

4.2.1 Categorization of droughts

Fig 4.4 presents the march of percentage departures at 6 selected stations of Index of Moisture Adequacy (I_{ma}) from the climatic normals on an annual basis. As discussed in section three of chapter II, whenever the departures were negative droughts were categorized in relation to the standard deviation. The results of this study is presented in Table 4.1. Table 4.1 which shows the total number of drought years and number of droughts of various categories experienced by the stations.

Alleppey experienced the least number of droughts (19) and Kasargode the most (30) Vythiri was free from disastrous droughts during the entire study period. Konni experienced the largest number of moderate droughts (13), followed by Sherthala and Cranganore (12) Kasargode experienced the most number of large droughts (12) Trivandrum, Cochin and Trichur experienced 10 large droughts each. Alathur and Calicut experienced 10 severe droughts during the study period. The stations which experienced largest number of disastrous drought years (3) are Thiruvalla, Sherthala, Marayur, Cranganore, Kuttiyadi and Irikkur.



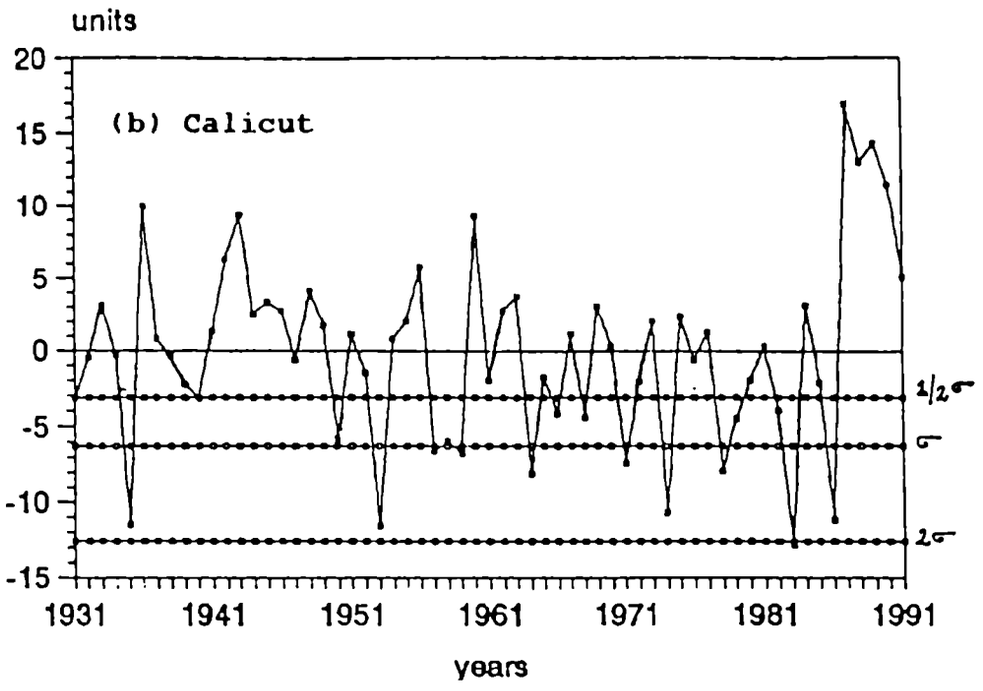
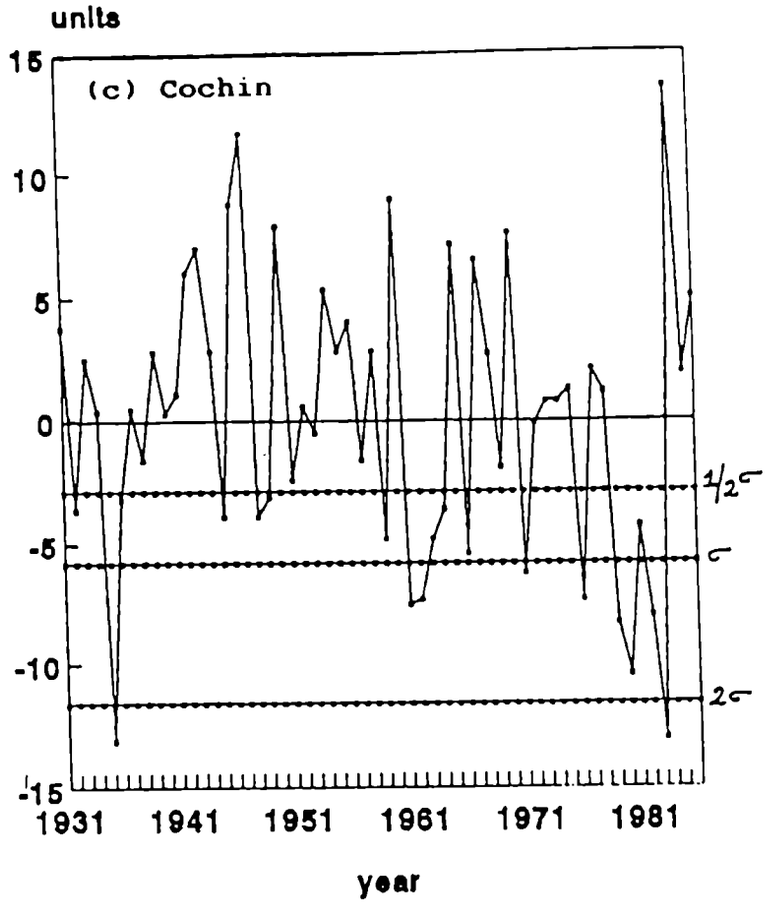


Fig 4.4 Yearly march of Index of Moisture Adequacy (%)



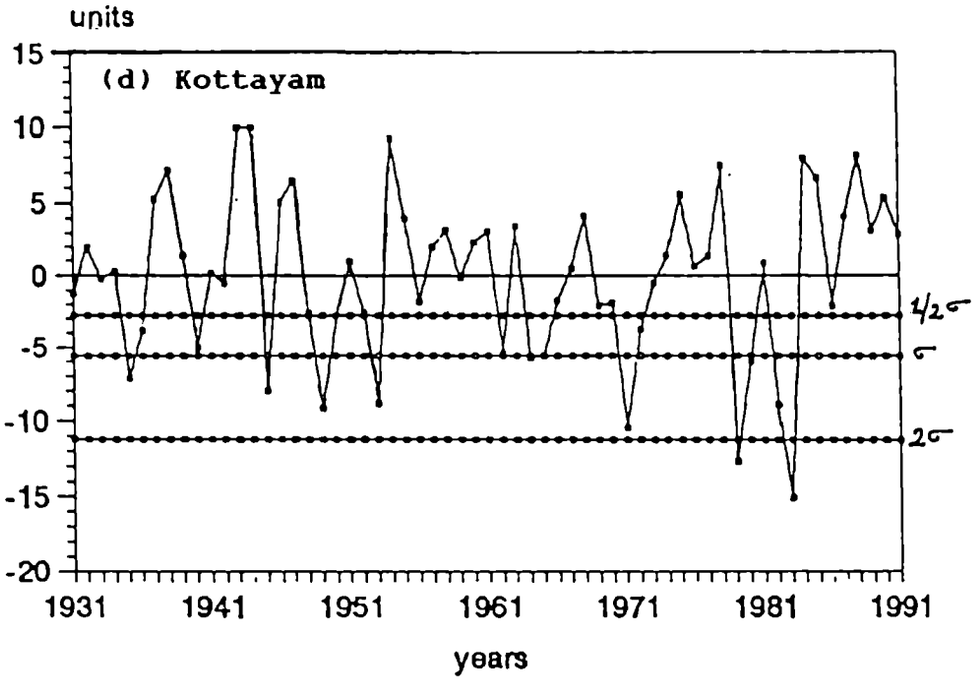
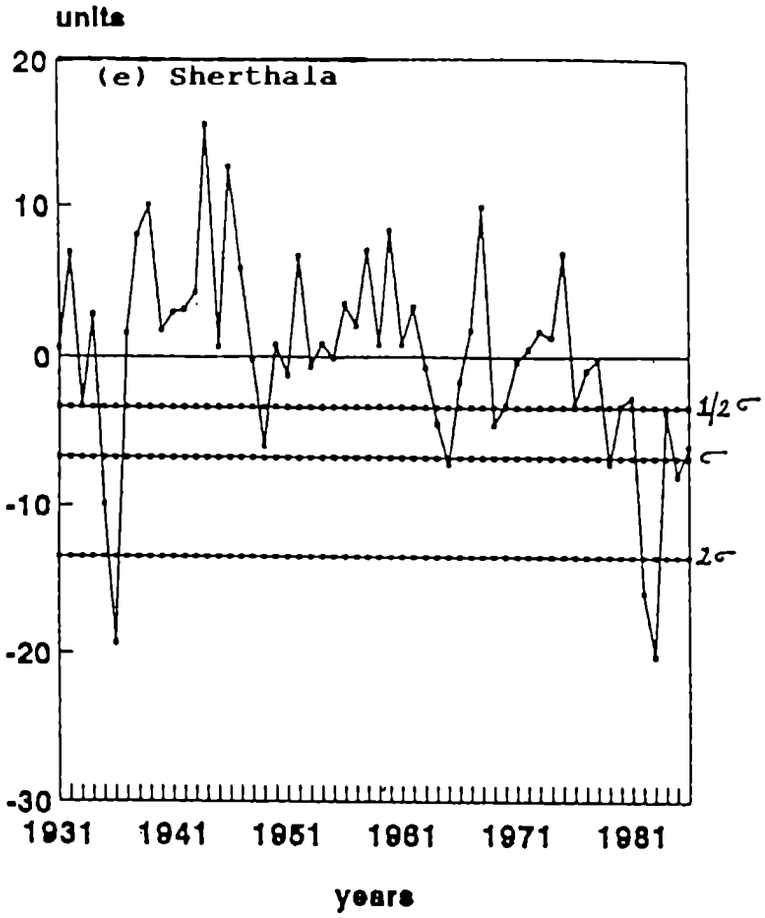


Fig 4.4 Yearly march of Index of Moisture Adequacy (%) (contd.)



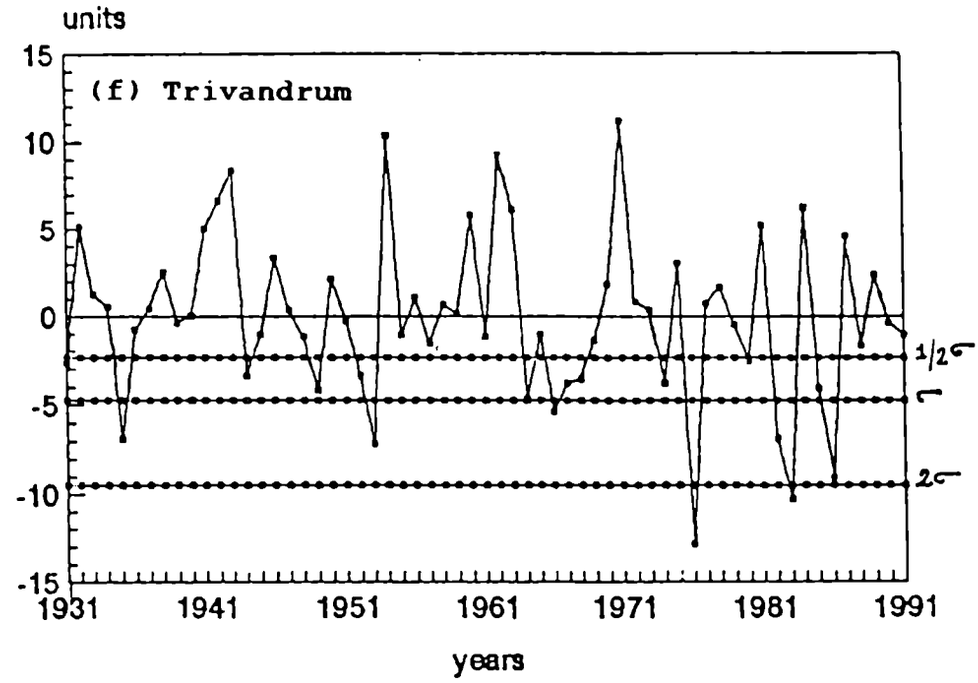


Fig 4.4 Yearly march of Index of Moisture Adequacy (%) (contd.)

STATION		NO OF YEARS STUDIED	NO OF DROUGHT YEARS	NO OF MODERATE DROUGHT YEARS	NO OF LARGE DROUGHT YEARS	NO OF SEVERE DROUGHT YEARS	NO OF DISASTROUS DROUGHT YEARS
Trivandrum	(TVM)	@ 60	20	11	10	5	2
Quilon	(QLN)	@ 60	27	11	6	9	1
Kayamkulam	(KYM)	55	24	11	6	6	1
Konni	(KNI)	55	27	13	5	8	1
Thiruvalla	(TVL)	55	22	9	5	5	3
Alleppey	(ALP)	55	19	7	5	5	2
Kottayam	(KTM)	@ 60	26	11	7	6	2
Sherthala	(STL)	55	24	12	5	4	3
Karikode	(KKD)	55	25	10	8	5	2
Cochin	(CHN)	55	25	6	10	7	2
Devikulam	(DVM)	* 49	23	10	6	5	2
Marayur	(MYR)	* 49	19	10	5	1	3
Cranganore	(CGR)	55	26	12	7	4	3
Trichur	(TCR)	55	26	9	10	6	1
Alathur	(ATR)	55	23	8	4	10	1
Mannarghat	(MRT)	55	26	9	8	5	2
Perinthalmanna	(PRM)	* 49	22	8	7	6	1
Calicut	(CLT)	@ 60	25	10	4	10	1
Vythiri	(VYT)	55	23	7	9	7	0
Kuttiyadi	(KTD)	* 49	19	6	6	4	3
Manantoddy	(MTY)	55	24	9	5	8	2
Cannanore	(CNR)	* 49	24	9	4	9	2
Irikkur	(IRK)	* 49	20	10	3	4	3
Kasargode	(KSD)	55	30	10	12	6	2

@ (1931 - 1991)
* (1931 - 1980)

Table 4.1 Incidence of drought years Kerala

4.2.2 Frequency of droughts

Fig 4.5 gives the occurrence of droughts of different categories at the selected stations in Kerala State during the period 1931- 1986 It is seen that droughts of some category or the other occur every year at least at a few stations in the State: there is no drought free years during the study period. As is to be expected, moderate droughts are most frequent, while disastrous droughts are experienced in a few years only. Large and severe droughts occur more often than disastrous droughts. There is no specific frequency in the occurrence of droughts nor is there any regular geography pattern.

From the figure, it is evident that the frequencies of occurrence of severe and disastrous droughts are more in the sixth, seventh and the first half of eighth decade. The early eighties, were the most drought affected period in the State. In 1981, Thiruvalla experienced a disastrous drought while Karikode and Vythiri experienced severe droughts and a few other stations had moderate and large droughts. In the year 1982, Alleppey and Sherthala experienced disastrous droughts with a majority of stations having droughts of severe intensity. In 1983, all the stations studied, except Alathur, experienced either a severe or disastrous drought: stations especially in South Kerala experienced disastrous droughts. Significantly, the year 1984 was in strong contrast to the previous year: only Mannarghat had a disastrous drought, with most of the stations being drought-free. None of the stations experienced a disastrous drought in 1985 while in 1986 only Kasargode and Alathur experienced disastrous droughts. The exceptionally large number

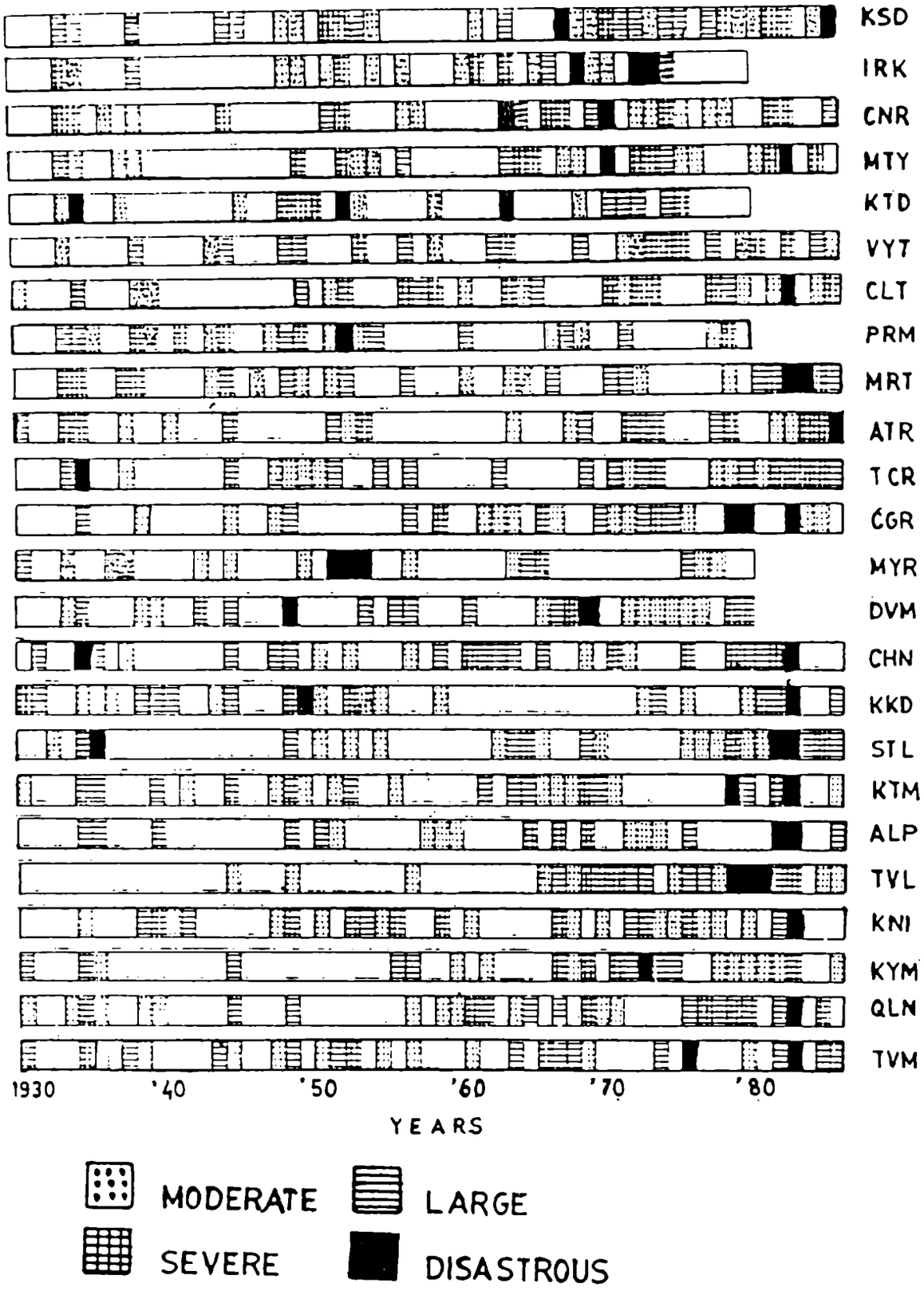


Fig 4.5 Categorisation of droughts on an annual basis - Kerala

of disastrous and severe droughts in these few years deserve detailed analysis of their exact duration and severity.

4.2.3 Duration and severity of droughts

Widespread droughts conditions of 1982 and 1983 and the drought-free year of 1984 were analyzed on a monthly basis by studying data for the period 1982-1984. As discussed in section - Three of chapter II the ratios of departures of the monthly I_{ma} values from their climatic normals to the standard deviations of the corresponding months were plotted (Fig 4.6) Drought spells are indicated by negative values while their severities are indicated by the magnitude of the negative departures from the normal. It is seen that a long duration spell spanning from September 1982 to June 1983 was experienced at most of the stations. For example, Trivandrum experienced seven drought spells between the years 1982 to 1984 The first one extends from January 1982 to April 1982, with the maximum intensity in February 1982. The second one with a short duration was limited to the month of September 1982. The third one extends from December 1982 to May 1983 and the fourth is also of a short duration, July 1983. The fifth spell extends from October 1983 to November 1983, the sixth from August 1984 to September 1984 and the seventh from November 1984 to December 1984(Table 4.2) From the table, it is seen that the drought spells which occurred in the year 1982 and 1983 were of longer durations than the other years.

On analyzing the weather sequences during the period, it is found that the State had received below normal rainfall from

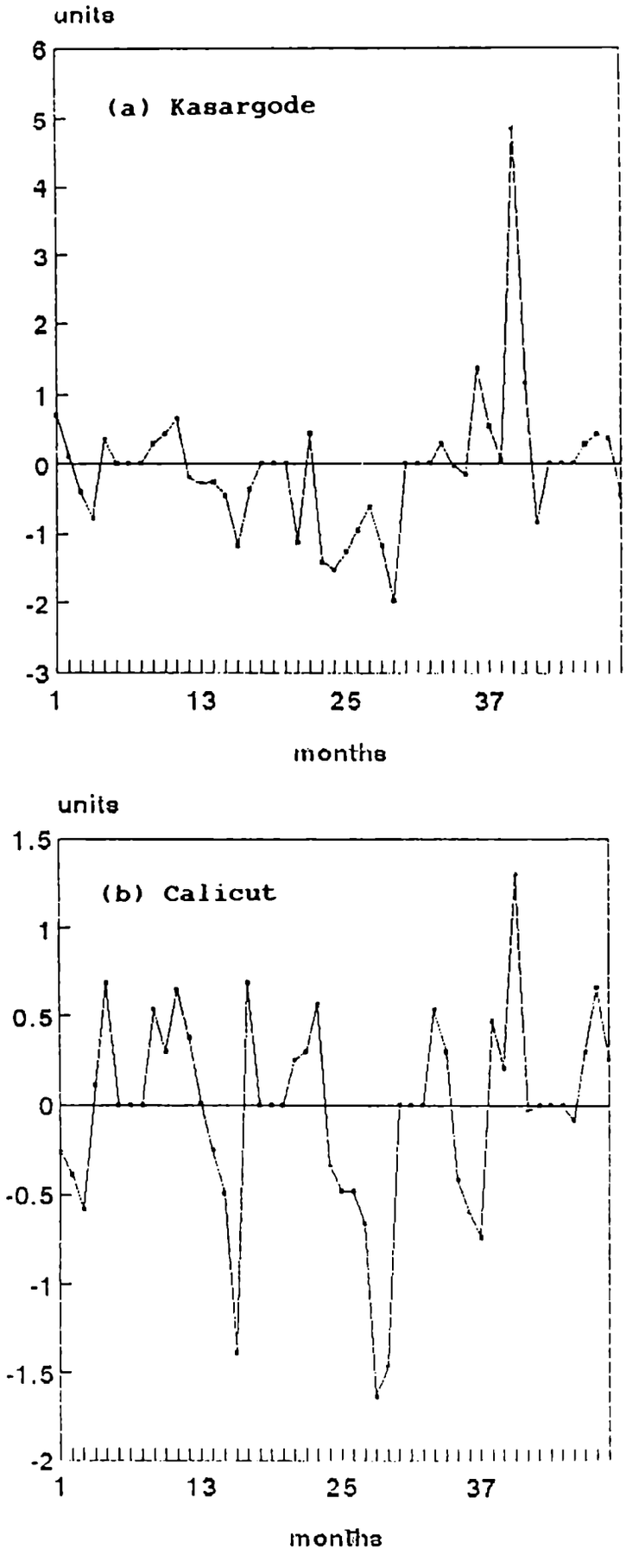
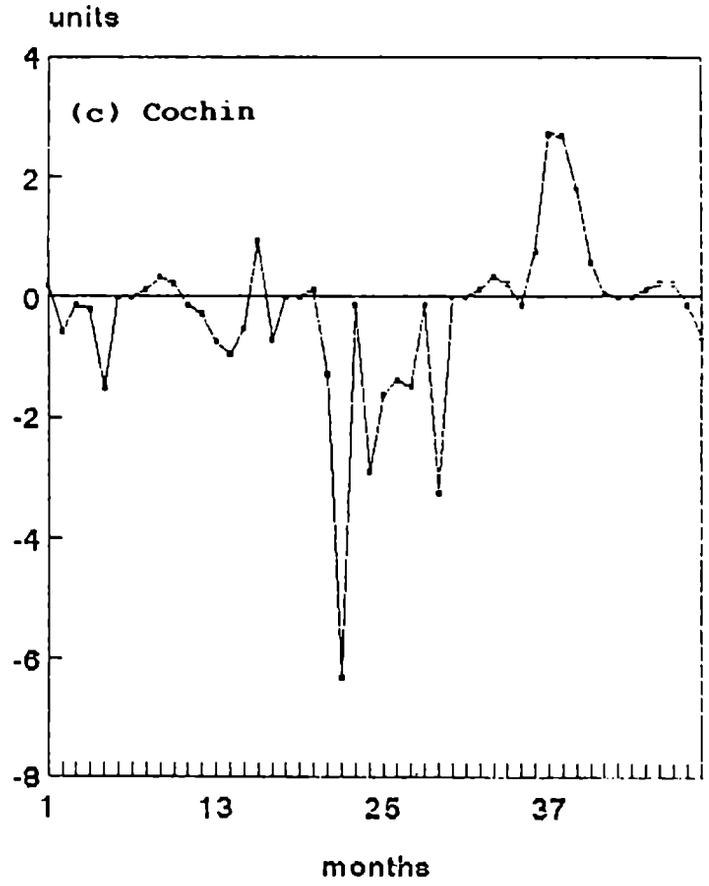


Fig 4.6 Severity and duration of drought spells (1982 - 1984)



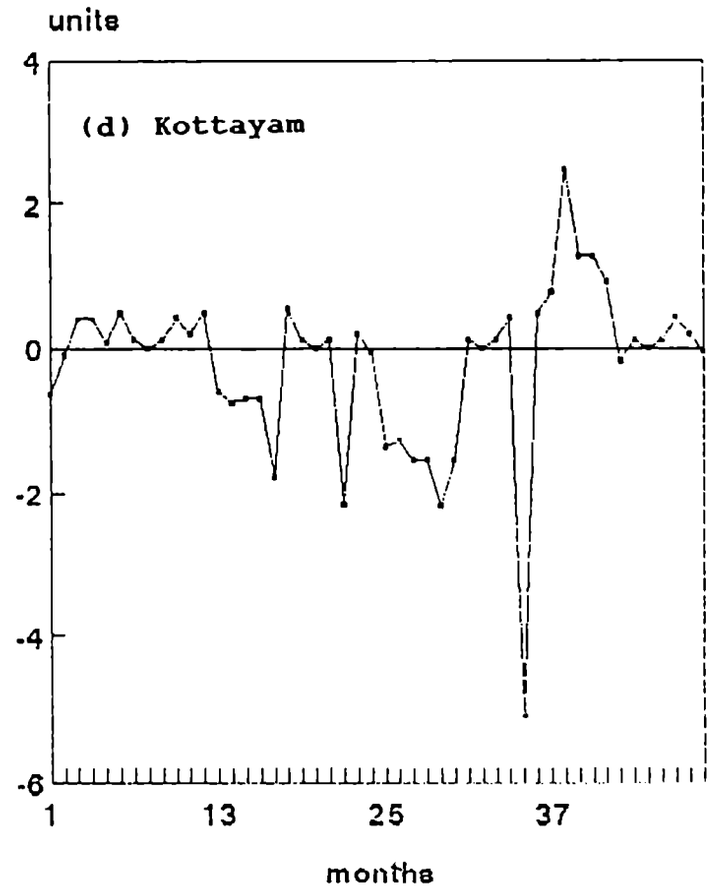


Fig 4.6 Severity and duration of drought spells (1982 - 1984) (contd.)

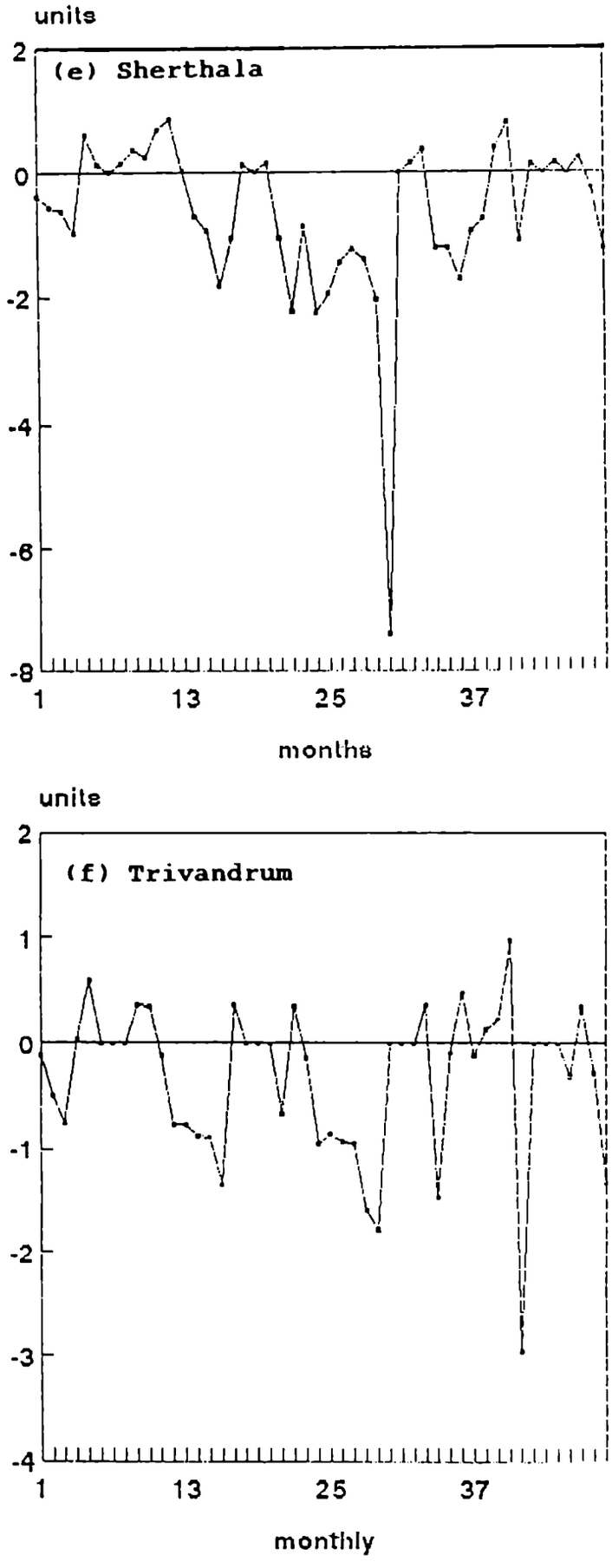


Fig 4.6 Severity and duration of drought spells (1982 - 1984) (contd.)

DRY SPELLS

STATION	1	2	3	4	5	6	7
Trivandrum	Jan. 1982 to Apr. 1982	Sep. 1982	Dec. 1982 to May 1983	July 1983	Oct. 1983 to Nov. 1983	Aug. 1984 to Sep. 1984	Nov. 1984 to Dec. 1984
Month with most severe drought	May 1982	Oct. 1982	May 1983	Nov. 1983	June 1984	Dec. 1984	
Kottayam	Jan. 1982 to May 1982	Oct. 1982	Dec. 1982 to June 1983	Nov. 1983	June 1984	Dec. 1984	
Month with most severe drought	May 1982	Oct. 1982	May 1983	Nov. 1983	June 1984	Dec. 1984	
Sherthala	Feb. 1982 to May 1982	Sep. 1982 to June 1983	Oct. 1983 to Feb. 1984	May 1984	Nov. 1984 to Dec. 1984		
Month with most severe drought	Apr. 1982	June 1983	Dec. 1983	May. 1984	Dec. 1984		

Table 4.2 Duration of drought spells - (1982 - 1984)

(Contd...)

DRY SPELLS

STATION	1	2	3	4	5	6	7
Cochin	Nov. 1981 to Mar. 1982	May 1982	Sep. 1982 to May 1983	Oct 1983 to Nov. 1983	Nov. 1984 to Dec. 1984		
Month with most severe drought	Feb. 1982	May 1982	Oct. 1982	Oct. 1983	Dec 1984		
Calicut	Jan. 1981 to Mar. 1981	Feb. 1982 to Apr. 1982	Dec. 1982 to May 1983	Nov 1983 to Jan. 1984	May 1984	Sep. 1984	
Month with most severe drought	Mar. 1981	Apr. 1982	Apr. 1983	Jan. 1984	May 1984	Sep. 1984	
Kasargode	Dec. 1981 to May 1982	Sep. 1982	Nov. 1982 to May 1983	Oct. 1983 to Nov. 1983	May 1984	Dec. 1984	
Month with most severe drought	Apr. 1982	Sep. 1982	May 1983	Nov. 1983	May 1984	Dec. 1984	

Table 4.2 Duration of drought spells - (1982 - 1984)

September 1982 to May 1983 The northeast monsoon was not active enough over the State during October November 1982 and the systems in the easterlies which in normal conditions give rain or thundershowers from January to May were less active. The cyclonic storms which formed, either decayed as soon as they crossed the coast or had a more northward displacement. Further, the onset of Southwest monsoon was on June 12th in the year 1983, a delay of 12 days from the normal date.

On the other hand, the northeast monsoon was active over the State during October and November 1983. The systems in the easterlies generally caused widespread rain or thundershowers on most of the days in December 1983. Rainfall during the months January to May 1984 was normal over the State: a number of systems developing in the easterlies affected the weather over Kerala. In the months April and May, the equatorial trough extending from South Andaman sea to South East Arabian sea across extreme south peninsula and Comorin area was quite active in which several moving or quasi-stationary cyclonic circulations in the lower troposphere were observed. Rain and thundershowers were widespread on a number of days during these months over the State. The onset of the southwest monsoon was on May 30th in the year 1984. Therefore, the heavy rainfall between December 1983 and April 1984 and an early onset of South west monsoon, elevated most stations to the drought free category.

4.2.4 Spatial coherence of droughts

The spatial coherence of droughts at all the nineteen stations was calculated for droughts of all the four categories

as detailed in the methodology discussed earlier (Section Three of Chapter II) In the study, only probabilities above 50% were considered to be significant - values between 50% and 75% denoting moderate spatial coherence and values above 75%, high coherence.

(a) Probabilities of spatial coherence of moderate droughts

Table 4.3a presents the probabilities of spatial coherence of moderate droughts of all the stations considered for the study. In the study, only probabilities above 50% were considered to be significant - values between 50% and 75% denoting moderate spatial coherence and values above 75%, high coherence.

Among the stations considered for the study, when Kasargode, Karikode and Thiruvalla experienced moderate droughts, the probabilities of drought occurrence in the other area of the State are comparatively high.

When Kasargode is the key station, 13 other stations show moderate coherence. In the case of Karikode 10 other stations and in the case of Alleppey 12 other stations show moderate coherence.

Among the stations considered for the study, when Manantoddy, Calicut, Mannarghat, Kottayam, Konni and Quilon experience moderate droughts, the probabilities of drought occurrence in the other areas of the State are generally low. When Mannarghat is the key station, only Kottayam shows moderate coherence.

Auxiliary stations

KEY STN.	NO OF DROUGHTS AT KEY STN.	KSD	CNR	MTY	VYT	CLT	MRT	ATR	TCR	CGR	CHN	KKD	STL	KTM	ALP	TVL	KNI	KYM	QLN	TVM
KSD	10		20	60	60	40	30	30	60	50	50	60	60	60	30	60	50	50	60	60
CNR	9	55.5		30.3	55.5	66.6	33.3	44.4	44.4	66.6	33.3	44.4	33.3	11.1	44.4	55.5	22.2	55.5	44.4	44.4
MTY	9	44.4	33.3		55.5	11.1	22.2	44.4	44.4	22.2	44.4	22.2	55.5	22.2	11.1	22.2	55.5	33.3	33.3	55.5
VYT	7	57.1	42.9	28.6		71.4	71.4	42.9	71.4	57.1	57.1	57.1	42.9	42.9	42.9	57.1	42.9	57.1	42.9	28.6
CLT	9	33.3	22.2	33.3	22.2		44.4	44.4	44.4	33.3	22.2	44.4	33.3	55.5	44.4	33.3	55.5	22.2	77.7	66.6
MRT	9	33.3	44.4	44.4	33.3	77.7		33.3	11.1	33.3	33.3	33.3	22.2	55.5	33.3	22.2	22.2	11.1	44.4	44.4
ATR	7	71.4	71.4	85.7	28.6	42.9	57.1		42.9	28.6	71.4	57.1	42.9	71.4	28.6	42.9	71.4	42.9	42.9	85.7
TCR	9	55.5	22.2	33.3	55.5	22.2	44.4	44.4		22.2	66.6	44.4	44.4	44.4	33.3	55.5	55.5	44.4	22.2	33.3
CGR	12	58.3	50	33.3	50	33.3	66.6	41.7	50		66.6	16.7	33.3	50	25	50	41.7	41.7	41.7	58.3
CHN	6	33.3	33.3	50	50	50	33.3	66.6	66.6	33.3		33.3	33.3	33.3	50	33.3	50	33.3	33.3	83.3
KKD	10	60	40	50	50	30	30	30	50	50	50		60	20	50	30	80	30	30	60
STL	12	50	33.3	41.7	41.7	33.3	16.7	16.7	50	41.7	58.3	41.7		8.3	16.7	58.3	58.3	25	33.3	50
KTM	11	45.5	45.5	36.4	27.3	45.5	45.5	27.3	45.5	36.4	27.3	23.7	18.2		27.3	45.5	45.5	54.5	27.3	63.6
ALP	7	42.9	57.1	28.6	42.9	85.7	42.9	57.1	57.1	57.1	14.3	42.9	14.3	14.3		28.6	57.1	57.1	28.6	14.3
TVL	9	55.5	66.6	44.4	55.5	55.5	55.5	55.5	66.6	55.5	44.4	22.2	44.4	55.5	22.2		33.3	55.5	55.5	66.6
KNI	13	61.5	38.5	46.2	38.5	23.1	15.4	38.5	53.8	46.2	38.5	46.2	53.8	385	23.1	46.2		46.2	46.2	61.5
KYM	10	70	50	30	40	50	40	40	60	30	60	40	60	60	30	60	40		70	40
QLN	11	36.4	45.5	36.4	54.5	63.6	45.5	27.3	18.2	45.5	45.5	36.4	18.2	54.5	36.4	27.3	36.4	36.4		27.3
TVM	9	55.5	33.3	44.4	55.5	44.4	44.4	22.2	77.7	55.5	77.7	55.5	33.3	44.4	22.2	33.3	66.6	44.4	55.5	

Table 4.3a Spatial coherence of Moderate Droughts (%)

Out of the 19 stations, only 4 stations (Calicut, Mannarghat, Alathur and Cochin) show high coherence in the occurrence of moderate drought, simultaneous with other stations. When Calicut is the key station the probability of occurrence of moderate drought in Quilon is 77.7%. When Mannarghat is the key station the probability of occurrence of moderate drought in Calicut is 77 7%. Cochin has high coherence (83.3%) with Trivandrum, Alathur has high coherence (85.7%) with Manantoddy and Trivandrum.

(b) Probabilities of spatial coherence of large droughts

From Table 4.3 b it is observed that when Mannarghat, Trichur and Kayamkulam are considered as the "key" stations, moderate coherence is observed at 14, 12 and 12 stations respectively, while in the case of Kottayam, only Cranganore and Cochin show moderate coherence. 7 stations in the State show high coherence with Quilon. No station showed high coherence with occurrence of large droughts in Cochin, Karikode, Kayamkulam or Trivandrum. The stations Mannarghat, Trichur, Kayamkulam and Quilon exhibit high coherence with a larger number of stations in the northern parts of the State than in the south.

(c) Probabilities of spatial coherence of severe droughts

Trichur exhibited moderate spatial coherence with 14 stations, the highest for any key station. Kasargode and Cochin had moderate coherence with 12 other stations (Table 4.3c)

Similarly Trivandrum and Sherthala experienced high spatial coherence with 10 other stations. At the other extreme when

Auxiliary Stations

	NO OF DROUGHTS AT KEY STN.	KSD	CNR	MTY	VYT	CLT	MRT	ATR	TCR	CGR	CHN	KKD	STL	KTM	ALP	TVL	KNI	KYM	QLN	TVM
KSD	12		66.6	66.6	83.3	41.6	50	66.6	41.6	66.6	41.6	41.6	33.3	25	33.5	50	66.6	50	50	41.6
CNR	4	75		25	25	75	75	50	50	25	0	25	75	100	75	50	25	25	50	50
MTY	5	80	100		80	40	80	60	60	80	60	20	20	40	20	40	40	60	80	60
VYT	9	44.4	33.3	33.3		44.4	55.5	33.3	77.7	55.5	55.5	44.4	33.3	44.4	22.2	55.5	33.3	44.4	66.6	55.5
CLT	4	50	50	50	25		50	25	50	50	50	25	50	75	0	50	0	25	25	25
MRT	8	62.5	37.5	50	62.5	62.5		37.5	62.5	62.5	75	50	50	62.5	50	87.5	50	62.5	50	62.5
ATR	4	75	50	25	50	75	25		75	0	25	25	25	75	50	50	25	75	50	75
TCR	10	80	60	60	60	60	50	50		50	50	40	40	40	30	60	30	60	50	60
CGR	5	80	80	60	40	40	60	20	60		40	40	40	40	40	80	80	60	60	40
CHN	10	40	20	20	60	30	30	20	40	70		40	50	50	30	30	30	30	50	40
KKD	7	57.1	57.1	28.6	42.9	57.1	42.9	57.1	28.6	28.6	28.6		14.3	42.9	42.9	28.6	42.9	42.9	42.9	57.1
STL	5	60	20	20	80	40	40	60	40	60	40	80		40	60	40	60	20	40	40
KTM	7	57.1	42.9	28.6	28.6	42.9	28.6	14.3	14.3	57.1	57.1	28.6	42.9		28.6	28.6	42.9	42.9	100	28.6
ALP	7	42.9	57.1	28.6	42.9	85.7	42.9	57.1	57.1	57.1	14.3	42.9	14.3	14.3		28.6	57.1	57.1	28.6	14.3
TVL	5	60	60	60	40	40	60	40	40	80	40	40	20	20	40		80	60	40	40
KNI	5	80	40	60	60	60	40	60	40	40	40	60	40	40	40	20		20	40	40
KYM	6	50	50	33.3	66.6	50	50	50	50	50	50	33.3	0	50	16.7	33.3	50		50	50
QLN	5	60	80	40	40	60	80	40	60	40	40	40	80	80	80	80	80	60		60
TVM	11	63.6	54.5	54.5	36.4	45.5	63.6	72.7	54.5	45.5	36.4	45.5	27.3	63.6	45.5	45.5	45.5	45.5	45.5	

Table 4.3b Spatial Coherence of Large Droughts (%)

Auxiliary stations

	NO OF DROUGHTS AT KEY STN.	KSD	CNR	MTY	VYT	CLT	MRT	ATR	TCR	CGR	CHN	KKD	STL	KTM	ALP	TVL	KNI	KYM	QLN	TVM
KSD	6		100	66.6	33.3	50	83.3	66.6	83.3	50	83.3	50	66.6	100	50	66.6	50	66.6	50	66.6
CNR	9	88.9		66.6	44.4	22.2	77.8	77.8	55.6	55.6	55.6	55.6	44.4	66.6	44.4	66.6	77.8	77.8	66.6	77.7
MTY	8	62.5	75		25	100	75	62.5	50	50	37.5	62.5	62.5	62.5	50	50	50	37.5	37.5	50
VYT	7	100	21.4	100		28.6	42.9	57.1	42.9	71.4	57.1	71.4	57.1	28.6	42.9	42.9	71.4	42.9	28.6	28.6
CLT	9	77.8	88.8	66.6	77.7		55.5	66.6	66.6	66.6	44.4	55.5	44.4	44.4	44.4	55.5	55.5	66.6	55.5	55.5
MRT	7	57.1	42.9	71.4	42.9	42.9		85.7	85.7	57.1	57.1	57.1	42.9	42.9	28.6	42.9	42.9	42.9	85.7	85.7
ATR	10	80	60	60	50	50	70		90	80	40	40	50	20	40	40	50	60	50	40
TCR	6	83.3	66.6	66.6	50	50	66.6	100		83.3	50	66.6	66.6	50	66.6	66.6	50	50	66.6	83.3
CGR	4	50	50	75	50	75	25	25	50		75	75	75	50	75	25	75	50	50	75
CHN	7	71.4	57.1	28.6	42.9	71.4	57.1	28.6	57.1	71.4		42.9	57.1	71.4	28.6	71.4	57.1	71.4	85.7	57.1
KKD	5	80	40	60	40	60	80	60	60	20	80		80	80	40	60	60	60	60	80
STL	4	75	75	75	0	75	100	75	75	75	50	25		75	25	50	25	50	100	50
KTM	6	100	66.6	66.6	66.6	33.3	83.3	83.3	83.3	50	100	83.3	66.6		66.6	66.6	66.6	66.6	83.3	100
ALP	5	40	40	40	40	40	60	20	40	40	40	40	40	100		60	60	40	100	60
TVL	5	100	80	80	40	40	60	60	80	60	80	40	40	100	60		60	80	100	60
KNI	8	50	50	37.5	37.5	50	50	25	25	62.5	37.5	75	50	62.5	75	50		25	50	50
KYM	6	83.3	83.3	83.3	66.6	33.3	66.6	66.6	83.3	83.3	66.6	50	33.5	83.3	83.3	66.6	66.6		83.3	83.3
QLN	9	66.6	33.3	44.4	33.3	44.4	44.4	44.4	66.6	55.5	77.7	33.3	55.5	66.6	22.2	66.6	44.4	66.6		66.6
TVM	4	75	75	75	25	75	75	75	50	50	75	75	100	100	25	50	50	50	25	

Table 4.3c Spatial coherence of Severe Droughts (%)

Cochin and Quilon are key stations, only one station exhibits high spatial coherence. In general, the spatial coherence of severe droughts is higher than the coherence of severe droughts is higher than the coherence of large and moderate droughts.

(d) Probabilities of spatial coherence of disastrous droughts

Disastrous droughts, though the least frequent, exhibit the highest spatial coherence among all the categories of droughts (Table 4.3d) In other words, when any station experienced a disastrous drought, the probability of occurrence of a drought at any station was very high. From the study it is seen that when Kayamkulam was the key station, 12 stations showed 100% spatial coherence of disastrous droughts. While Thiruvalla exhibited 100% coherence with 5 stations and moderate coherence with 7 others. However when Sherthala was the key station, 15 auxiliary stations exhibited 100% coherence and 3 other stations moderate coherence. Vythiri did not experience any disastrous drought during the study period. Kasargode, Mannarghat, Trichur and Kayamkulam have high probability of drought occurrence when other stations have disastrous droughts.

Comparing the spatial coherence of all categories of droughts, it is seen that moderate droughts have the least coherence, though they are the most frequent. On an average, when any station experiences moderate droughts there is a moderate possibility of drought occurrence at 6 stations, however there are exceptional cases: Kasargode has 13 stations and Mannarghat only 1 station experiencing drought simultaneously In the case of large droughts, coherence is higher with 7

Auxiliary Stations

	NO OF DROUGHT IN KEY STN.	KSD	CNR	MTY	VYT	CLT	MRT	ATR	TCR	CGR	CHN	KKD	STL	KTM	ALP	TVL	KNI	KYM	QLN	TVM
KSD	2		100	50	50	50	50	100	50	0	0	50	50	100	50	100	50	100	0	100
CNR	2	100		100	0	100	100	50	50	100	100	0	0	100	0	50	0	50	100	50
MTY	2	100	100		100	50	100	50	100	100	100	50	50	100	50	100	50	100	100	50
VYT																				
CLT	1	100	100	100	0		100	100	100	0	100	100	100	100	100	100	100	100	100	100
MRT	2	50	50	50	50	0		100	100	100	50	50	100	50	50	50	50	50	50	50
ATR	1	100	100	0	100	100	100		100	0	0	100	100	100	100	100	0	100	0	100
TCR	1	100	100	100	0	0	100	100		100	100	100	100	100	100	0	100	100	100	100
CGR	3	100	66.6	33.3	66.6	66.6	66.6	66.6	100		100	66.6	100	66.6	33.3	100	66.6	100	100	66.6
CHN	2	100	100	100	50	0	100	100	100	100		100	100	100	100	50	100	100	100	100
KKD	2	100	50	100	100	0	100	100	100	100	50		100	100	100	50	100	100	100	100
STL	2	100	100	100	50	50	100	100	100	50	100	100		100	100	100	100	100	100	100
KTM	2	50	100	100	50	50	100	100	100	100	100	50	100		50	100	50	100	100	50
ALP	2	100	100	100	50	50	100	100	100	50	100	100	100	100		100	100	100	100	100
TVL	3	100	33.3	33.3	66.6	66.6	66.6	33.3	100	66.6	100	66.6	100	66.6	0		33.3	100	66.6	0
KNI	1	100	100	100	100	0	100	100	100	100	100	100	100	100	100	100		100	100	100
KYM	1	100	100	100	0	100	100	100	100	100	0	100	0	0	100	100	100		0	0
QLN	1	100	100	100	100	0	100	100	100	100	100	100	100	100	100	100	100	100		100
TVM	2	100	100	100	100	0	50	50	50	100	100	100	100	50	100	100	100	50	50	

Table 4.3 d Spatial Coherence of Disastrous Droughts (%)

stations having moderate possibility of simultaneous drought incidence and atleast 1 station, high probability (>75%) When severe droughts affect any station, there is moderate coherence at 8 other stations and atleast 1 station shows high probability of drought incidence. Disastrous droughts have the highest spatial coherence: 3 stations, on the average, show moderate probabilities and as many as eleven stations, high probabilities.

Moderate droughts have the least spatial coherence since such droughts are a result of minor fluctuations or departures of the actual moisture regime from the average or climatic level of water balance. Large and severe droughts that exhibit increasing spatial coherence in that order, results due to water deficiency arising out of anomalies in the circulatory patterns of the atmosphere affecting the areas. Disastrous droughts, least frequent but with the highest spatial coherence, occur due to wide fluctuations of the water balances onto the drier side, arising out of very large water deficiencies and these must be the result of large-scale anomalies in the general circulation over the region as a whole: considering the widespread drought conditions of 1982-83 almost all the stations exhibited 100% spatial coherence

4.2.5 Climatic shifts

As a result of wide fluctuations of water budget parameters - both water deficiency and water surplus it is quite likely that the normal climatic regime are occasionally shifted into more humid or less humid categories. In order to study this aspect, climatic shifts have been studied by plotting the inter-

annual variations of moisture index (I_m) for all the stations.

Of the 24 stations included in this study, results of only six representative stations representing per-humid, humid and moist-sub humid categories of climate are presented here (Table 4.4 & Fig 4.7 (a) to (f)) Kasargode had a total number of 21 shifts into the other climatic types. Of these, 20 were to the humid climates of different categories and one to the moist sub humid type.

Among the humid stations, Kottayam had 49 shifts, while, Calicut, Cochin and Alleppey had 47, 43 and 41 respectively. All these four stations had larger number of climatic shifts into the drier categories of the humid climate. In addition, Kottayam had two shifts into the moist sub humid climate while Alleppey had one.

Trivandrum, the only moist sub humid station studied here, had a total of 42 shifts of which 24 were to the dry subhumid and 1 to the semi arid category.

An overall study of the climatic shifts in the region in comparison to the occurrences of droughts reveals interesting results. As is to be expected during many of the years when the climate shifted to a drier category due to deficient rainfall, the stations experienced droughts of one or the other categories. However, there were many occasions when several stations did not experience droughts eventhough shifts in the climate to drier categories were observed. Similarly,there have also been years when droughts have occurred even when rainfall had been above normal and the climatic shifts were in the wetter directions.

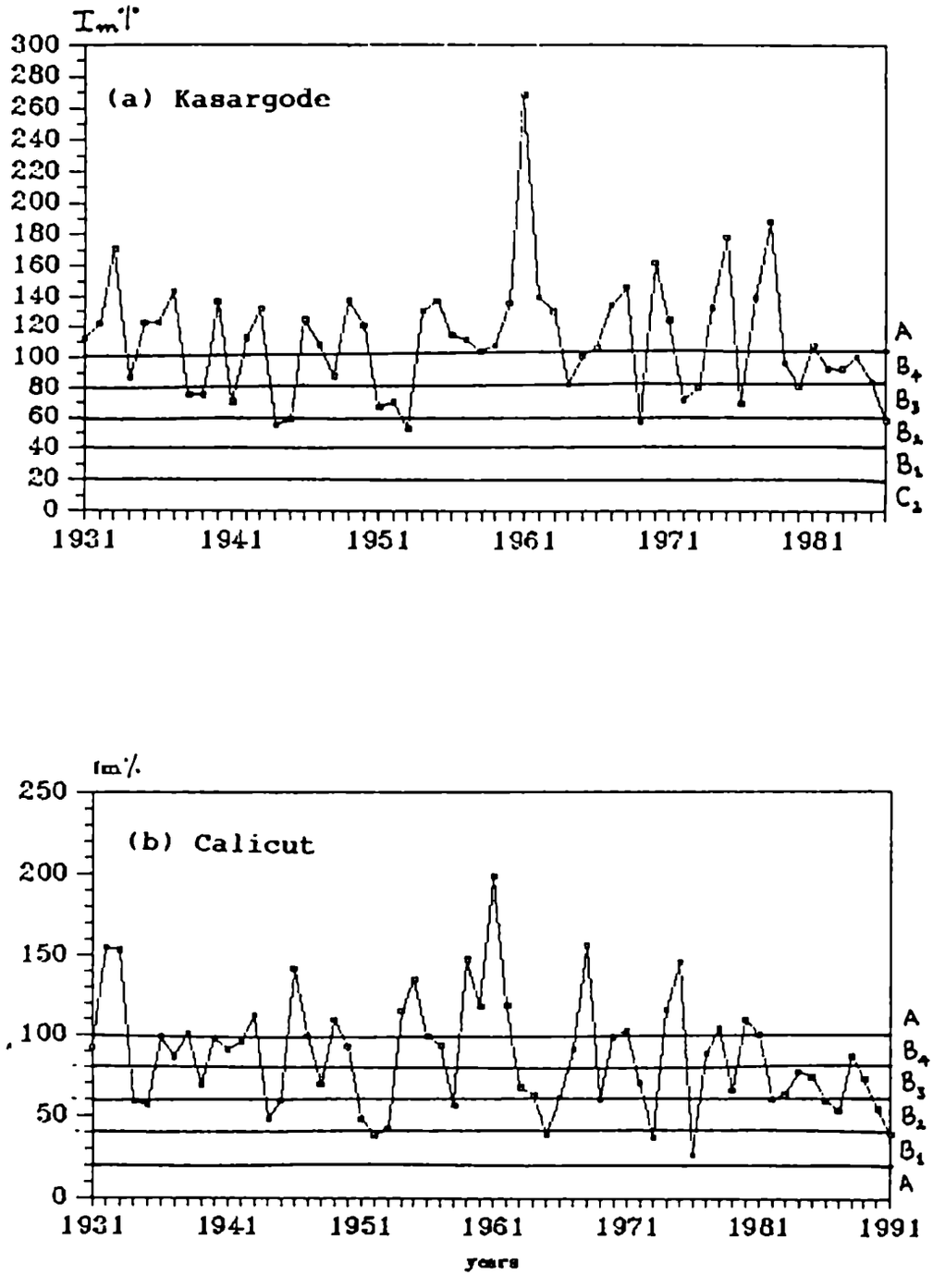
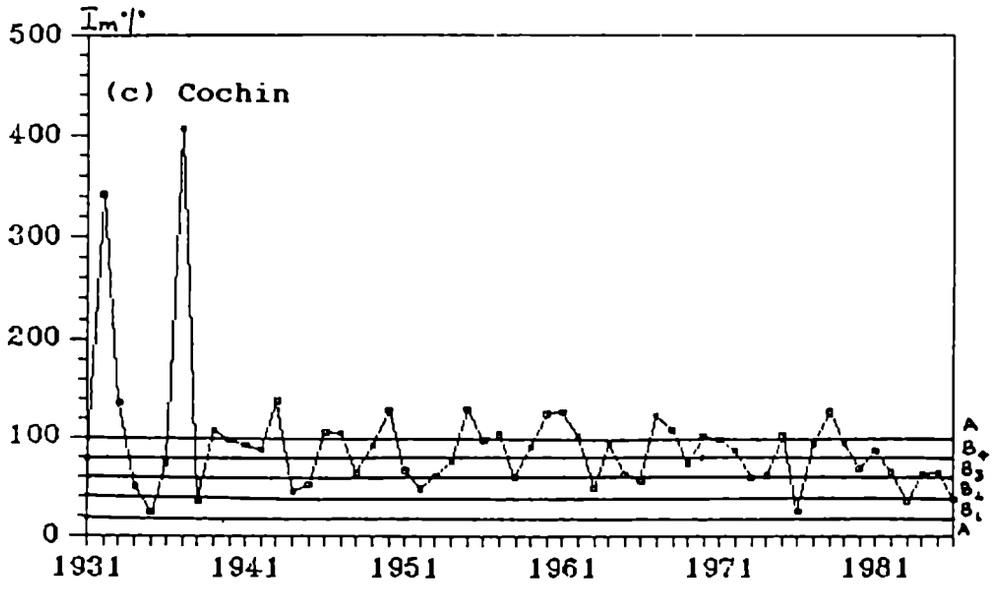


Fig 4.7 Yearly march of Moisture Index and climatic shifts



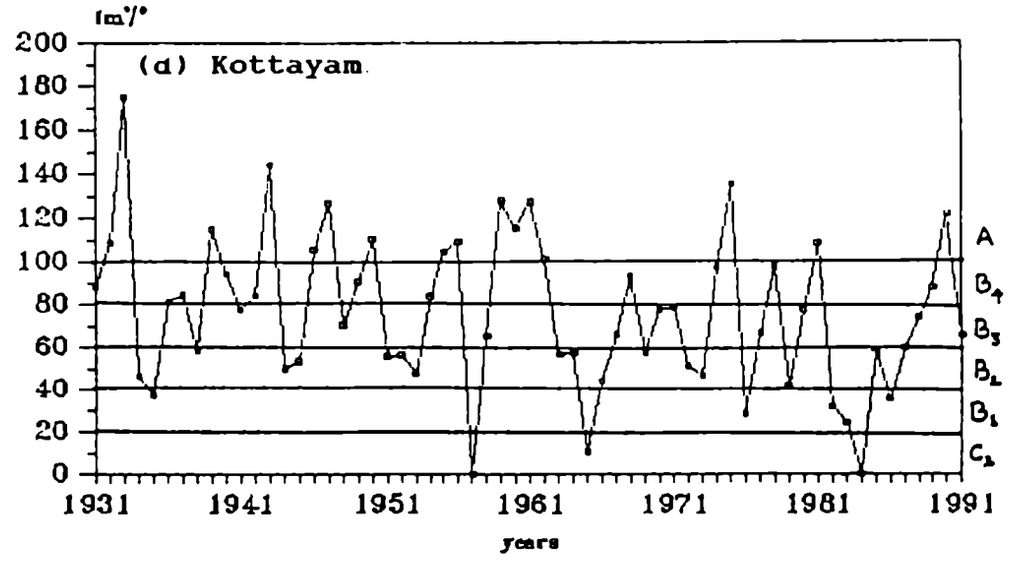


Fig 4.7 Yearly march of Moisture Index and climatic shifts (contd.)

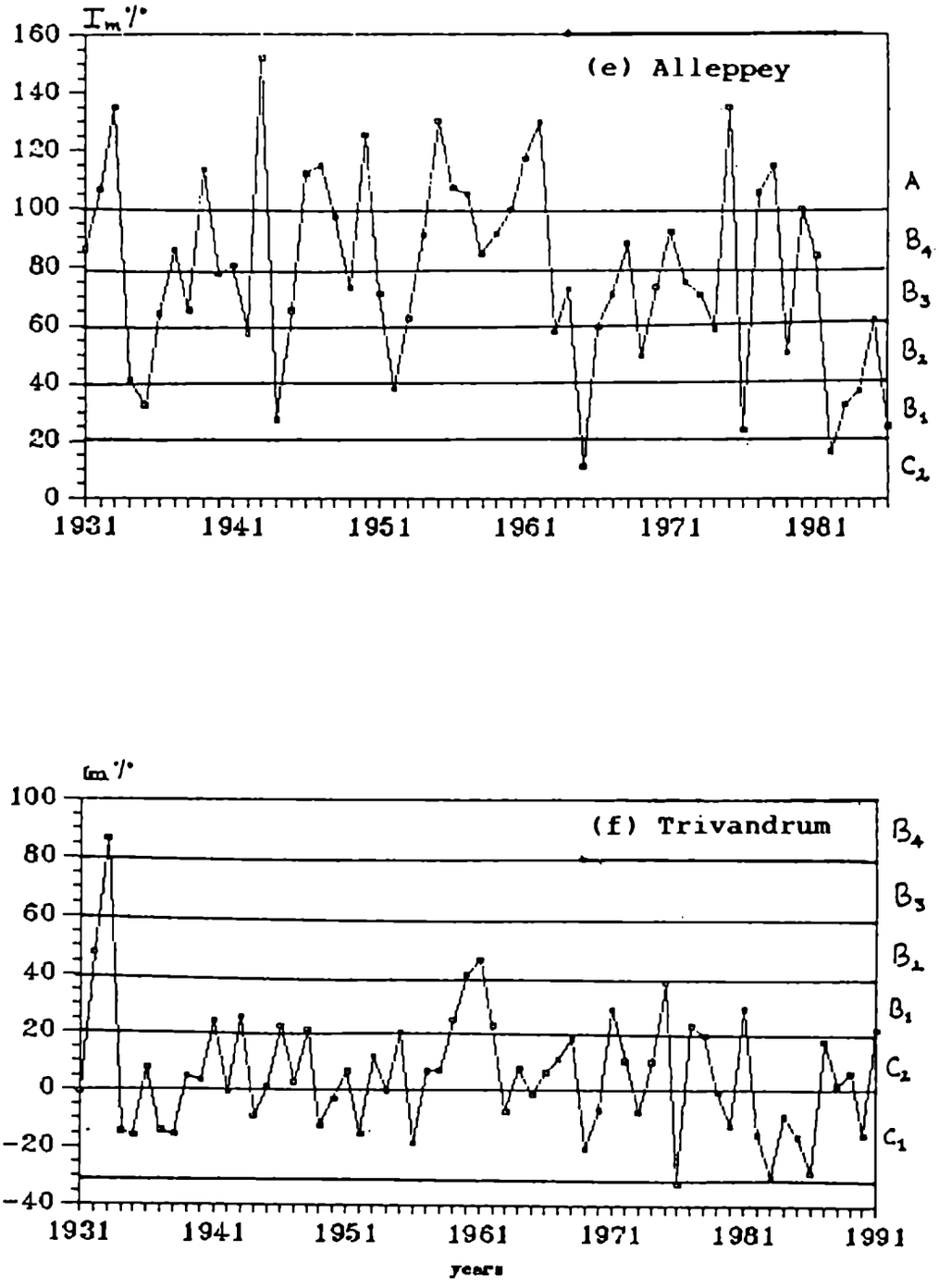


Fig 4.7 Yearly march of Moisture Index and climatic shifts (contd.)

	CLIMATIC TYPE								
Stations	A	B 4	B 3	B 2	B 1	C 2	C 1	D	Total
A Kasargode		B	7	5		1			21
B Calicut	21	1	11	11	3				47
Cochin	28		12	7	5				44
Kottayam	16	1	18	15	5	2			49
Alleppey	17		6	12	5	1			41
C Trivandrum		1		3	12	1	24	1	42

Table 4.4 Number of occasions of climatic shifts

These observations point to the inadequacy of rainfall data alone in delineating droughts. It is not monthly or the annual deficiency in rainfall that has to be considered in categorizing droughts, but rather its distribution in comparison to the water need of the place. As was seen in the study of the water budget elements, is the irregular distribution of rainfall that causes water deficiencies (and therefore droughts) and water surpluses. The water balance technique of comparing perception with the water need on a monthly, weekly or daily basis is thus well suited to the study of droughts and climatic shifts.

4.2.6 Moisture regime during climatic shifts

The study of the water balances of different locations in years of extreme climatic shifts is of immense practical utility in agroclimatology and hydrometeorology. A critical examination of the comparative values of elements of water balance would reveal the variability of water surplus and water deficit in years of such shifts. As all the stations studied in the State belong to the humid climates, analysis of water deficits is more important than water surpluses. Table 4.5 summarises the main elements of water balance at all the important stations in Kerala through a comparison of the important water budget parameters in the normal year with those of wettest year, driest year and disastrous drought years.

For example, during a normal year at Kasargode, a perhumid station, rainfall is 361cm., water deficit is 57cm. and surplus is 240cm. During the wet year 1961 the rainfall was above 170% of the normal and the water surplus was double the climatic

Kasargode

Category of year	Water need(cm)	Rainfall (cm)	Water deficit(cm)	Water surplus(cm)	Moisture index	Climatic type
Normal year		360.9	56.6	246.9	109.8	A
Wettest year (1961)	167.6	613.1	50.36	500.0	468.3	A
Driest year (1938)	169.3	358.1	239.3	238.8	75.6	B_3
Disastrous drought years i (1968)	169.38	413.8	77.52	324.34	145.7	A
ii (1986)	174.03	273.91	76.52	177.58	58.1	B_2

Calicut

Category of year	Water need(cm)	Rainfall (cm)	Water deficit(cm)	Water surplus(cm)	Moisture index	Climatic type
Normal year	172.0	324.4	46.9	200.2	90.1	B_4
Wettest year (1961)	167.9	495.2	47.5	381.4	198.8	A
Driest year (1976)	171.4	216.3	46.1	91.9	26.7	B_1
Disastrous drought years i (1976)	171.41	216.27	46.14	91.85	26.7	B_1
ii (1982)	175.53	279.38	53.16	158.91	60.2	B_3

Table 4.5 Variability in water budget elements during climatic shifts.

value. However, water deficit decreased only marginally while the moisture index shot up to 468% On the other hand, during the driest year 1938, rainfall and water surplus were almost equal to the normal values but water deficit was about 420% of the climatic value and the climate shifted to B_3 humid category. In 1968 when a disastrous drought occurred at the station, rainfall was 15% above normal and water surplus increased by 31% However, water deficit was also higher by about 35% Paradoxically, the station exhibited a higher moisture index (145.7%) In an other disastrous drought year (1986) the climate shifted to B_2 category as a consequence of rainfall being only 76% of the normal. Water surplus was about 72% of the normal value while deficit was one third more than climatic.

Similarly, detailed analysis of the water budget elements in years of climatic shifts at other stations too has been made. As is to be expected during dry years, water deficits increased and water surpluses fell below normal, while in the case of wet years surpluses increased and deficits fell below normal. However, such simple relations are not always true. In the example detailed about Kasargode experienced higher rainfall and water surplus but also had larger water deficits resulting in a disastrous drought in 1968. It is thus possible that increased water surpluses can coexist with increased water deficits even in disastrous drought years.

It is also observed that values of water deficits and water surpluses in years of extreme climatic shifts are not proportional to the changes in rainfall amounts. That is, increases or decreases in rainfall do not result in proportionate

changes in water surpluses or water deficits. For example, at Calicut in the wettest year 1961, rainfall was 53% above normal and water surplus was 90% above normal. However, water deficit remained constant while the climate jumped to the perhumid category. Such a behaviour of the moisture regime is because water surpluses and water deficits are not determined by the magnitudes of rainfall but rather by its distribution through the year.