CHAPTER - 2
PHYSIOGRAPHY, CLIMATE AND GEOLOGY

2.1. Introduction

The controlling effect of physiography and climate on weathering and soil development was recognized as early as 1941 by Jenny, who proposed the 'five-factor model' in which soil is perceived as a function of topography, nature of bed rock, time, climate and organic activity. In other words, Climate directly exerts a control on weathering through rainfall and temperature and indirectly through organic matter (Faniran and Jeje, 1983). Effect of climate on weathering and soil development has been has been studied in depth by Carroll (1970); Hay and Johns (1972); Singer (1980); Nesbitt and Young (1984); Colman and Dethier (1986); White and Blum (1995); Nesbitt et al. (1996); Kelly et al. (1998); Brady et al. (1999); Stewart et al. (2001). Identification of various parameters viz., relief, climate, lithology and vegetation and quantification of their influence is essential for modeling of physical and chemical weathering (Olivia et al. 1999). Curtis and Spears (1971) offered numerical solutions to problems related to the stability of mineral phases in weathering profiles in differing climates. Sheldon et al., (2002) quantified the relationship between mean annual precipitation, mean annual temperature and weathering using major element distribution. In the present study addresses the roles of climate, physiography and lithology on weathering and mineral transformations.

Physiographic attributes (altitude, slope and relief), climate and geology of Kerala and Tamil Nadu in general and NB and TB in particular are dealt with in this chapter. NB and TB, almost at the southern tip of India, share the same mountain divide, and the two are set on the western and eastern slopes Western Ghats (WG).

2.2. Physiography of Kerala and Neyyar Basin (NB)

Kerala with a more or less 'vertically asymmetrical spindle' like outline is located at the SW part of the Indian Peninsula (N. Lat. 8°17'30" & 12°27'40" and E. Long. 74°51'57" & 77° 24'47"; length = 560 km.; width= 11-124 km.; area= 38,863 km^2).

Based on physiography, three zones are identified (viz., highland, HL= >75m, area=48.15 %.) midland (ML; 7.5-75m.) and lowland (LL; <7.5m.) (Anon, 1974). Of the

total area of this State, 48.15% belong to HL, 41.76% belong to ML and 10.09% belong to LL. Highland falls on the WG and foot hills, extending for almost the entire length of Kerala. High rising spurs, vast number of ravines and dense forest, with abundant tropical flora and fauna, are very special to the WG. The highest peak in Kerala (elev. = 2690 m) is Anaimudi, Idukki district. Drainage network in highland is expressly controlled by lineament geometry of basement rocks. The control by lineament appears prominently in the plan view of stream channels and is discernible from the SOI toposheets, aerial photos and satellite imageries. The jagged shoreline and reservoir arms joining at or near right angles are another case in point.

Midland comprises a swath of land between HL and LL, with undulating hills and separating valleys, like a trochoidal wave in profile view, bounded by gentle slopes. The hills have a core of crystalline rocks; sometimes these rocks are exposed at the summit, flanks or valley floors. It supports luxuriant vegetation and plantations and is cut across by west flowing rivers, whose courses are influenced by the geometry (at least in the higher midland) by the general orientation of lineaments.

The lowland is mostly coastal tract with 'kayals' inlets, barrier spits, beaches and beach ridges, coastal plains, and cliffs made up of either crystalline rocks of Precambrian age (e.g., Kovalam, Ezhimala) or sedimentary rocks of Tertiary age (e.g., Karichal, Varakala) also occur at places. The 'Kuttanad' adjoining the Vembanad estuary to the east and south and the 'Kolelands' (i.e. wetlands) of Thrissur district belong to this category (Chattopadhyay and Chattopadhyay, 1995). A number of beach dunes, oriented parallel / subparallel to the coast are seen, especially in Alappuzha - Cherthala sector. In general lowland is wider in central Kerala whereas it is narrow in the north and south.

Lowland is dotted by several 'kayals' (a.k.a backwaters), connected by intracoastal water way with a break in Malappuram and portions of Kozhikode district. Based on the plan-forms, orientation of long axis, geologic settings, age relationships and evolutionary history, these kayals are classified into three categories, viz., shore parallel (eg: Vembanad kayal), shore perpendicular (e.g., Ashtamudi kayal) and shore distant kayals (e.g., Sasthankotta kayal) (Chattopadhyay and Chattopadhyay, 1995; Joseph and Thrivikramaji, 2002).

2.2.1. The Neyyar Basin

Neyyar river rising from Agasthyamalai (elev. = 1866 m.) in WG and flows westerly through Thiruvananthapuram district and debouches into the Laccadeeve sea at Puvar in the west coast. The Neyyar basin (NB) lies on the western slope of the WG. All the three physiographic domains (HL, ML and LL) are represented in the basin. Aerially 2.27% of the NB falls in HL, 11.17% in ML and 86.56% in LL.

Among the 18 profiles selected for study in NB, 11 are located in ML and 7 in HL (see Section 3.3; Table 3.3).

2.3. Physiography of Tamil Nadu and Tambraparni Basin (TB)

Tamil Nadu, located in the SE part of peninsular India (N. Lat. $8^0$00' & $13^0$30' and E. Long. $76^0$00' & $80^0$18'; Area = 130058 km^2), is bordered by the Bay of Bengal to the east and the Western Ghats to the west. The States of Karnataka and Andhra Pradesh are on the north while the Lakshadweep Sea fringes the southern shore of Tamil Nadu in Kanyakumari district.

Tamil Nadu is divided into three domains, viz., upland (>300 m.); inland plain (10-300 m.) and coastal plain (<10 m.). Upland comprises of the Western Ghats and its slopes. The Western Ghats trend roughly N-S and stand out as almost continuous hill range commencing from Nagercoil in the south up to Nilgiri – Biligirirangan hills in the north and extends northwards through Karnataka. The elevation of Western Ghats ranges from 1275 to 2640 m. The prominent peaks are Mahendragiri, Agasthyarmalai, Anamalai, Palani and Nilgiris. Dodabetta hills (elev. = 2640 m) the tallest peak in WG is in the Nilgiris. The major physiographic break in Western Ghats is the Palghat Gap (Anon, 1998).

The inland plain - an extensive swath of dissected pediplain - exhibits gentle easterly slopes towards the low lying coastal plain. Tambraparni Ar and Chittar have developed flood plains in the inland plains.

The coastal plains of Tamil Nadu consists of associated tidal flats, beach ridges, estuaries, lagoons, relatively narrow, but fairly continuous modern beaches and the modern and ancient coastal dunes. A number of cusps, spits, wave-cut platforms

and palaeo-shorelines are present here (Anon., 1998). Prominent beach ridges with complimentary swales are present in the coast of Tamil Nadu; each ridge denotes a palaeo-sea level. Swales are occupied by coastal lakes and backwaters. Different types of marine terraces – coral terrace at Pamban, sandstone terrace at Valinokkam, calcareous sandstone (beach rock) at Tiruchendur and Manappad and sandstone terrace at Kanyakumari - are found along the coast (Loveson et. al., 1987).

2.3.1. The Tambraparni Basin

Tambraparni Ar, is a perennial river (length = 126 km.; basin area = 5969 km^2) rising in the eastern flanks of the WG, flows easterly draining large area of the Tirunelveli (formerly Nellai–Kattabomman) and Thoothukudi (formerly Chidambaranar) districts and enters Gulf of Mannar at Punnakayal a village south of Thoothukudi. (see Section 1.5.2).

Tributaries of the Tambraparni river are Manimuttar, Gatana Nadi, Chittar and Pachaiyar. The main stream originates on the flanks of the Papanasam hill ranges where the tallest peak is Agasthyamalai (=1866 m.). Tambraparni Ar is structurally controlled by the Achankovil-Tambraparni shear (ATS) - a NW-SE to WNW-ESE trending lineament (Ramachandran, 1991). Several lagoons parallel to the coast occur in the coastal plain closer to the mouth of Tambraparni river. Many tidal inlets are also present here.

2.4. Slope

Classification of slopes proposed by Miller and Summerson (1960), and quoted in Fairbridge (1968) is followed in this study. They suggested a fourfold numerical (1 to 4) classification of slopes based on four equal divisions of mathematical function $\sqrt{Sin\,A}$, where A is the slope in degrees. In this study, numerical classes have been converted to four arbitrary verbal classes viz. 'Very gentle' (VG), 'Gentle' (G), 'Steep' (S) and 'Very steep' (VS) (Table 2.1). According to this scheme, among the 18 profiles selected in NB, locations of 4 profiles belong to 'VG', 13 to 'G' and one to 'S'. Similarly, out of 19 profiles selected in TB, 18 belongs to 'VG' and one to 'S'. The locations belonging to 'steep' category (one each in NB and TB) registered a slope of 18° (see Section 3.3; Tables 3.3 and 3.4).

Table 2.1: Numerical slope classes and equivalent verbal divisions after Miller and Summerson (1960) quoted in Fairbridge (1968). Verbal divisions added in this study.

Numerical Slope Class	Slope Angle (A)	$\sqrt{Sin\,A}$	Verbal Slope Class (this study)
1	$0 - 3^{U}\,35'$	0.0 – 0.25	Very Gentle
2	$3^{0}\,36' - 14^{0}\,29'$	0.25 – 0.50	Gentle
3	$14^{0}\,30' - 34^{0}\,14'$	0.5 – 0.75	Steep
4	$34^{0}\,15' - 90^{0}$	0.75 - 1	Very Steep

Table 2.2: Classification of Relative Relief (after Mc Donald et. al., 1990)

Relative Relief Class	Range in Relative Relief (m)
Plains	0 - 9
Rises	9 - 30
Low Hills	30 - 90
Hills	90 - 300
Mountains	> 300

Sheeja (2011) has analyzed the slope characteristics of NB by using a different classification and identified seven classes of slope categories. It was estimated that ~52% of the total basin area is 'Level to very gently sloping' with a slope of 0-4°. About 14% of the total area of NB belongs 'Very gentle to Gently sloping' category with a slope of 4-12°. 'Gently to moderately sloping' terrain with a slope of 12-20° constitute ~15% of this basin. Judging from these two lines of approach, it may be argued that a large chunk Neyyar Basin belongs to 'very gentle to steep' category of Miller and Summerson (1960).

2.5. Relative Relief

Relative relief (RR) refers to the numerical difference between points of highest and lowest altitudes. Steeper the terrain, higher will be the RR. Classification of relative relief is given in Table 2.2 (McDonald et.al., 1990). Five classes have been suggested viz., Plains (0-9 m), Rises (9-30 m), low hills (30-90 m), Hills (90-300), mountains (>300 m). Among the 18 profiles in NB, 7 belong to low hills, 10 belong to Rises and one belongs to Hill. On the other hand, iln TB, out of 19 profile, 18 belong to Rises and one (TB 38) belong to Hill.

2.6. Climate

Meteorological data (rainfall, temperature and relative humidity) of Kerala and Tamil Nadu in general, and Neyyar and Tambraparni Basins in particular are given in this section. This is based on data sourced from India Meteorological Department (IMD).

In the data set for Kerala covers rainfall data for 1901-1950 and temperature and relative humidity for the period 1931-1960 (Das, 1986). Neyyattinkara and Parassala meteorological stations within Neyyar Basin are taken to represent NB. As no data on temperature and relative humidity of these stations were available, the data (1931-1960) of Thiruvananthapuram i.e. the nearest meteorological station is used.

IMD's data at five stations - Kanyakumari, Madurai, Tondi (period= 1988-1995), Palayamkkottai and Thoothukudi district (period= 1969-1989) were used to represent the climate of southern Tamil Nadu. Data of Palayamkottai and Thoothukudi

meteorological stations, both falling in TB, were taken to represent the climate of the Tamraparni Basin.

As meteorological data of sampling station TB-38 (close to Shencottah, TN) was not available, rainfall data of Aryankavu (E. Long: $77^0$9'12"; N Lat: $8^0$58'40"; 58H/1) and temperature and relative humidity data of Punalur (E. Long: $76^0$55'32"; N. Lat: $9^0$01'13"; metereological stations, both in Kerala nearer to Shencottah were used in this analysis. Aerial distance from Shencottah to Aryankavu is 3 km. and to Punalur is 27.5 km.

Aryankavu *pass,* across the Western Ghats is a swath of relatively lower elevation. Due to this orographic low regions in Tamil Nadu lying close to Aryankavu *pass* receive an average annual rainfall close to that of Kerala.

2.6.1. Kerala and Neyyar Basin

Meteorological data of Kerala in general and Neyyar basin in particular is portrayed below (Tables 2.3 to 2.8; Figs. 2.1 to 2.5).

2.6.1.1. Rainfall

Kerala receives two spells of rain viz., SW monsoon (June – September) and NE monsoon (October – December). Hot season is from March to the end of May. The SW monsoon rains contributes ~73% of the annual rainfall. July is the rainiest month (695.50 mm; ave. of 50 yr.) and February is the driest month (17.30 mm; ave. of 50 yr.). The average annual rainfall is 3001.00 mm (Table 2.3). Neyyar Basin registered an average annual rainfall of 1580.70 mm with a maximum of 284.55 mm in June and minimum of 17.15 mm in February (ave. of 50 yr; Table 2.4; Fig. 2.1a).

2.6.1.2. Temperature

The mean daily maximum temperature in Kerala ranges from 28.50^0C in July to 33.30^0C in March (ave. of 30 yr.) and mean daily minimum temperature varies between 22.50^0C in January and 25.50^0C in April (ave. of 30 yr.). The mean annual temperature (MAT) of Kerala stands at 27.33 ^{0}C (Table 2.3; Fig. 2.2a). It is observed that the mean daily maximum temperature in Kerala is lowest during SW monsoon.

Table 2.3: Mean monthly rainfall (1901-1950), mean daily temperature (1931-1960) and relative humidity (1931-1960), Kerala (Source: IMD).

Month	Mean monthly rainfall (mm)	Mean Daily Temperature (°C)			Relative Humidity (%)	
		Max.	Min.	Average	8.30	17.30
Jan	18.10	31.80	22.50	27.15	72.00	60.00
Feb	17.30	32.40	23.40	27.90	73.00	60.00
Mar	42.90	33.30	24.80	29.05	74.00	63.00
Apr	111.60	33.10	25.50	29.30	77.00	70.00
May	244.90	32.00	25.30	28.65	82.00	76.00
June	676.30	29.30	23.70	26.50	89.00	84.00
July	695.50	28.50	23.20	25.85	91.00	85.00
Aug	417.20	28.80	23.50	26.15	90.00	83.00
Sep	234.60	29.50	23.60	26.55	86.00	80.00
Oct	305.20	30.00	23.70	26.85	85.00	79.00
Nov	187.90	30.60	23.50	27.05	81.00	74.00
Dec	49.50	31.30	22.60	26.95	74.00	63.00
Total	**3001.00**					
Mean	**250.08**	**30.88**	**23.78**	**27.33**	**81.16**	**73.08**

Table: 2.4: Mean monthly rainfall (1901-1950), mean daily temperature (1931-1960) and relative humidity (1931-1960), Neyyar Basin (Source: IMD).

Month	*Mean monthly rainfall (mm)	+Mean Daily Temperature (°C)			+Relative Humidity (%)	
		Max.	Min.	Average	8.30	17.30
Jan	25.00	31.30	22.30	26.80	77.00	63.00
Feb	17.15	31.70	22.90	27.30	79.00	63.00
Mar	42.80	32.50	24.20	28.35	80.00	66.00
Apr	100.70	32.40	25.10	28.75	81.00	73.00
May	177.55	31.60	25.00	28.30	84.00	77.00
June	284.55	29.40	23.60	26.50	90.00	82.00
July	165.85	29.10	23.20	26.15	89.00	81.00
Aug	110.35	29.40	23.30	26.35	88.00	78.00
Sep	114.90	29.90	23.30	26.60	86.00	77.00
Oct	255.15	29.90	23.40	26.65	87.00	80.00
Nov	217.65	30.10	23.10	26.60	87.00	78.00
Dec	69.05	30.90	22.50	26.70	80.00	69.00
Total	**1580.70**					
Mean	**131.73**	**30.68**	**23.49**	**27.11**	**84.00**	**73.92**

* **Mean** data of Neyyattinkara and Parasala (falling in Neyyar Basin)
+ Average data of Thiruvananthapuram district.

Table 2.5: Mean monthly rainfall, mean daily temperature and relative humidity in southern Tamil Nadu (av. of 3 stations, 1988-1995 & 2 stations, 1969-1989) (Source: IMD)

Month	Mean monthly rainfall (mm)	Mean Daily Temperature (°C)			Relative Humidity (%)	
		Max.	Min.	Average	8.30	17.30
Jan	35.10	30.24	21.56	25.89	74.53	65.40
Feb	14.00	31.72	22.44	27.08	74.70	64.00
Mar	37.70	33.02	24.04	28.53	72.13	63.30
Apr	54.50	34.60	26.02	30.31	73.10	67.30
May	79.80	35.24	26.77	31.01	70.83	68.23
June	42.60	34.86	25.99	30.43	73.27	67.77
July	28.20	33.69	25.34	29.51	71.63	66.80
Aug	28.70	33.90	25.37	27.64	71.53	68.17
Sep	60.30	33.67	25.05	29.36	71.23	70.47
Oct	160.40	32.29	24.35	28.32	77.60	75.50
Nov	194.20	30.66	23.38	27.02	79.77	74.70
Dec	75.60	29.10	21.83	25.47	75.13	68.17
Total	**811.10**					
Mean	**67.59**	**32.75**	**24.35**	**28.38**	**73.79**	**68.32**

Table 2.6: Mean monthly rainfall, mean daily temperature and relative humidity in Tambraparni basin (av. of 2 stations, 1969-1989) (Source: IMD)

Month	*Mean monthly rainfall (mm)	*Mean Daily Temperature (°C)			*Relative Humidity (%)	
		Max.	Min.	Average	8.30	17.30
Jan	19.90	30.05	21.75	25.90	78.00	68.00
Feb	30.05	31.70	22.70	27.20	78.50	63.50
Mar	40.10	32.70	23.70	28.20	73.50	60.00
Apr	57.20	35.05	25.95	30.50	72.00	64.50
May	55.90	36.50	27.00	31.75	64.00	59.50
June	5.20	36.05	26.75	31.40	61.50	54.00
July	8.20	34.60	25.65	30.13	59.50	54.00
Aug	9.85	35.20	26.10	30.65	62.00	57.00
Sep	42.15	35.00	25.65	30.33	63.50	61.50
Oct	159.05	33.35	24.65	29.00	73.50	69.50
Nov	184.65	31.10	23.60	27.35	79.00	73.50
Dec	85.60	28.05	21.25	24.65	75.00	68.50
Total	**697.85**					
Mean	**58.15**	**33.28**	**24.56**	**28.92**	**70.00**	**62.79**

*Mean data of Palayamkottai and Tuticorin (stations falling in Tambraparni Basin)

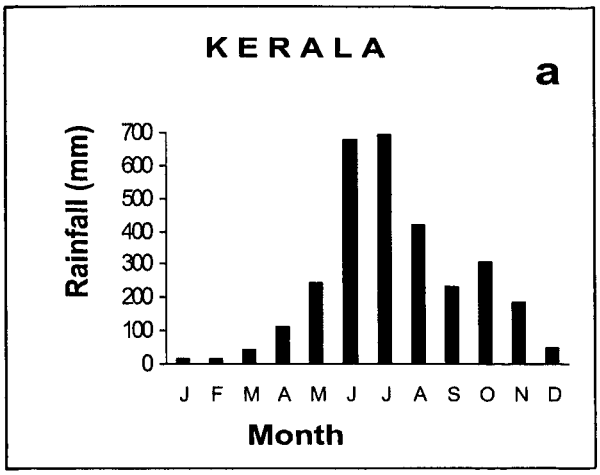
Table 2.7: Mean monthly rainfall at Aryankavu* (1901-1950) and mean daily temperature (1931-1960) and relative humidity (1931-1960) at Punalur*, Kerala (Source: IMD)

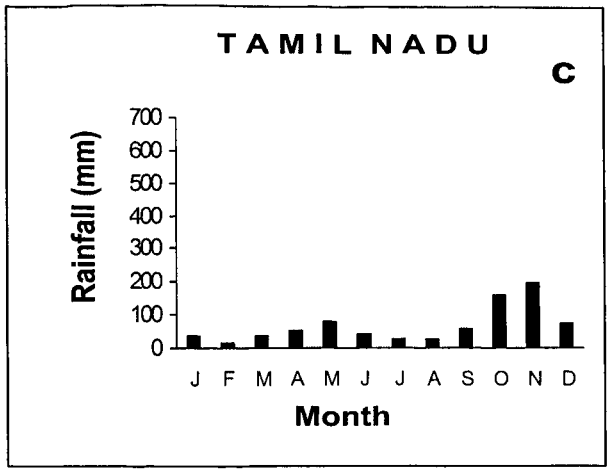
Month	Mean monthly rainfall (mm)	Mean Daily Temperature (°C)			Relative Humidity (%)	
		Max.	Min.	Mean	8.30	17.30
Jan	45.20	33.40	20.80	27.10	79.00	53.00
Feb	30.20	34.80	21.00	27.90	77.00	46.00
Mar	78.20	35.60	22.70	29.15	81.00	54.00
Apr	89.10	35.00	23.80	29.40	85.00	69.00
May	156.50	32.90	23.90	28.40	89.00	75.00
June	485.70	30.70	23.30	27.00	92.00	78.00
July	431.00	29.80	22.80	26.30	93.00	79.00
Aug	290.10	30.00	22.80	26.40	92.00	79.00
Sep	204.20	30.60	22.70	26.65	91.00	75.00
Oct	350.80	30.60	22.10	26.35	92.00	79.00
Nov	285.00	31.10	21.60	26.35	88.00	74.00
Dec	96.50	32.30	20.30	26.30	82.00	62.00
Total	**2542.50**					
Mean	**211.88**	**32.23**	**22.32**	**27.28**	**86.75**	**68.58**

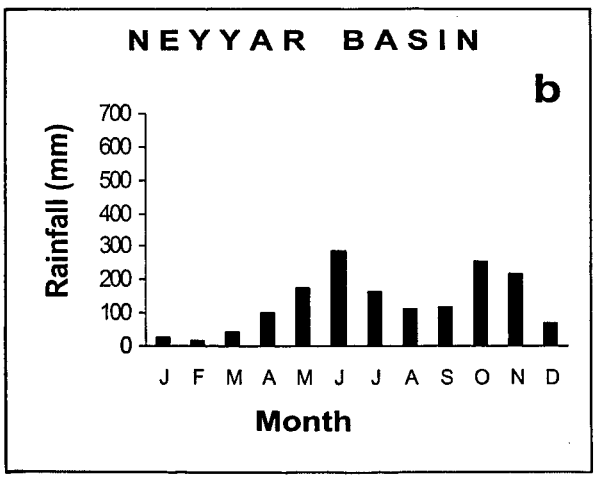
*Rainfall data of at Aryankavu and temperature data at Punalur, the meteorological stations nearest to location of profile TB-38 at Shencottah has been adopted as surrogate data.

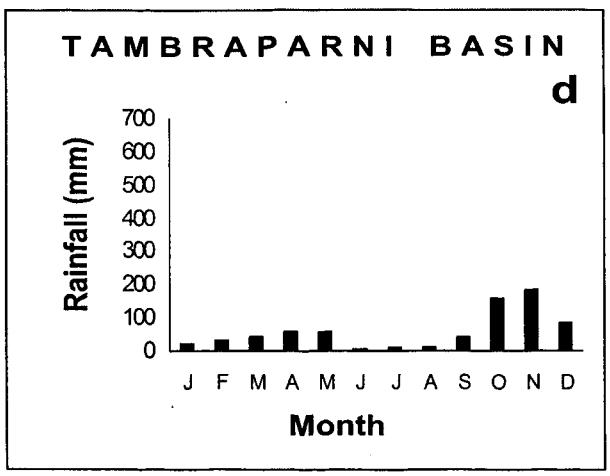
Table 2.8: Summary of climatic parameters of Kerala, Neyyar Basin, Tamil Nadu, Tambraparni Basin and at Aryankavu/ Punalur (IMD data)

Domain	Annual rainfall (mm)	Mean annual temperature (°C)	Relative humidity (%)	
			8.30	17.30
Kerala	3001.00	27.33	81.16	73.08
Neyyar basin (Kerala)	1580.70	27.11	84.00	73.92
Tamil Nadu	811.10	28.38	73.79	63.32
Tambraparni basin (Tamil Nadu)	697.85	28.92	70.00	62.79
Aryankavu / Punalur (surrogate for TB-38)	2542.50 (Aryankavu)	27.28 (Punalur)	86.75 (Punalur)	68.58 (Punalur)









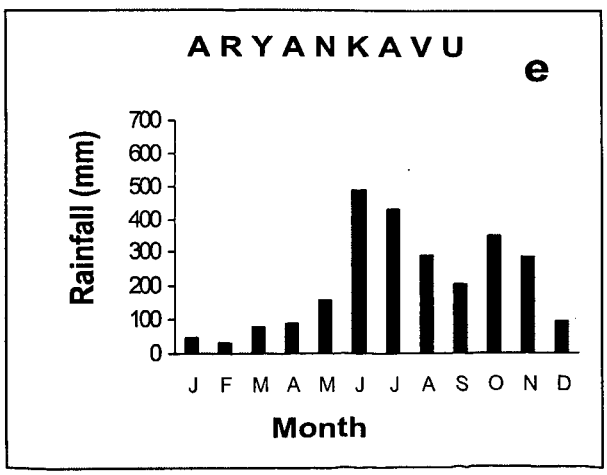
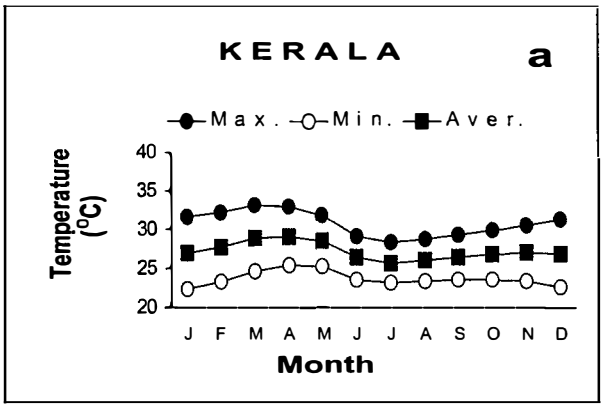
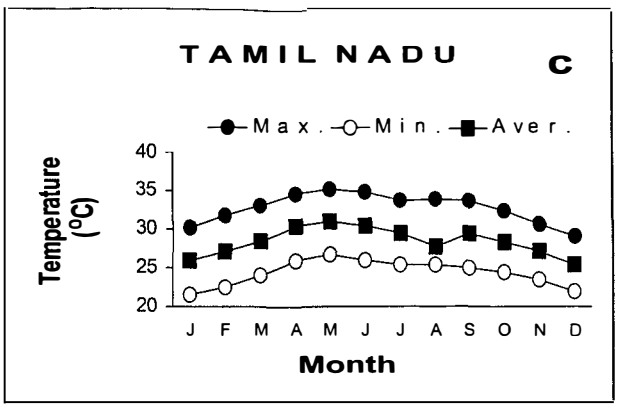
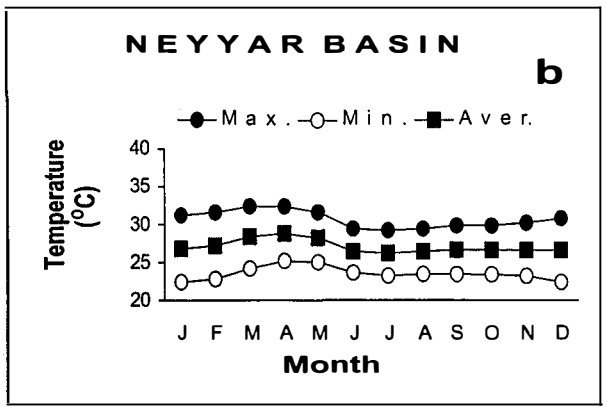
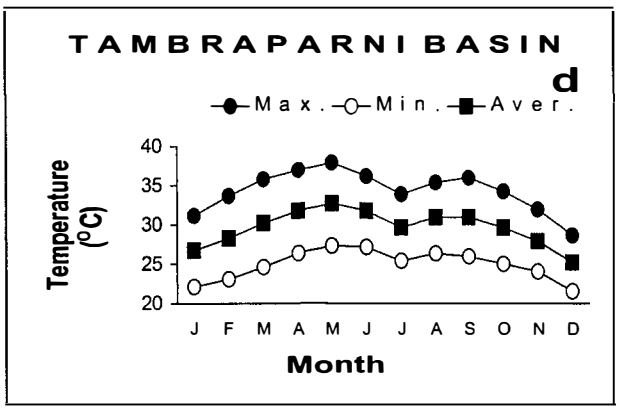


Fig. 2.1 Variation in monthly rainfall in (a) Kerala (1901-1950), (b) Neyyar Basin (1901-50), (c) Tamil Nadu (av. of 3 stations, 1988-95 & 2 stations, 1969-89), (d) Tambraparani Basin (av. of 2 stations, 1969-89) and (e) Aryankavu (1901-31).









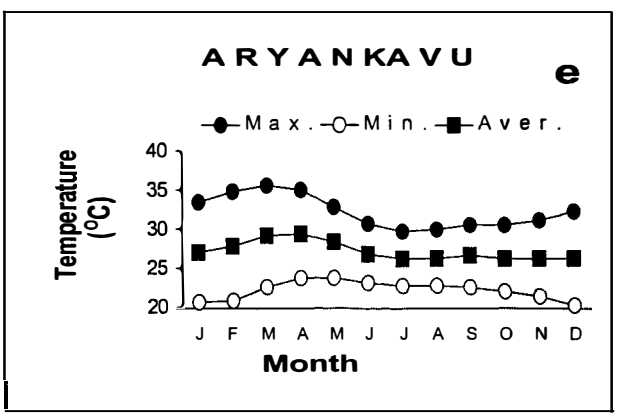
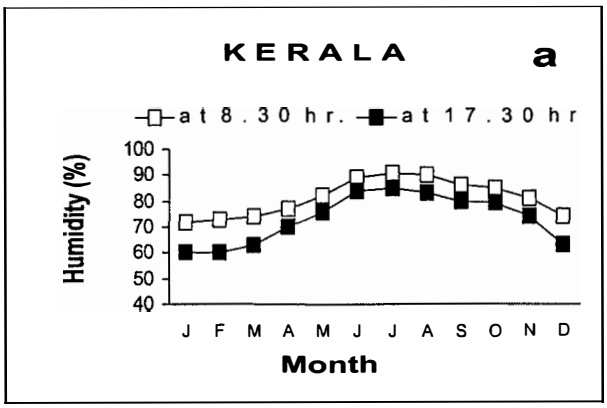
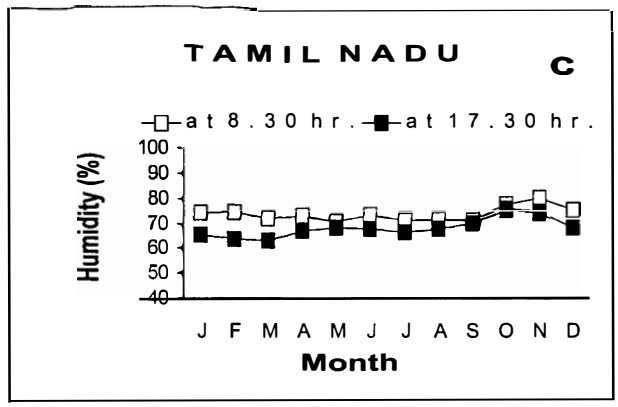
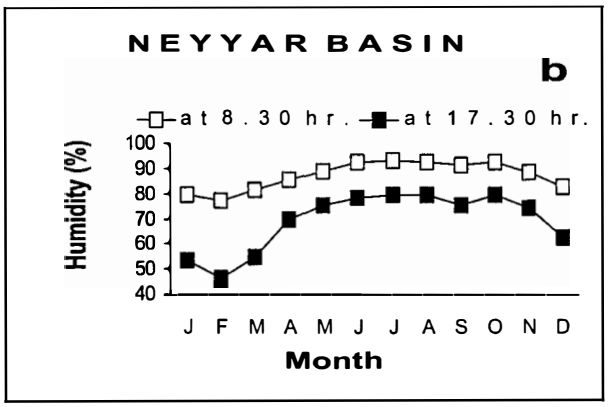
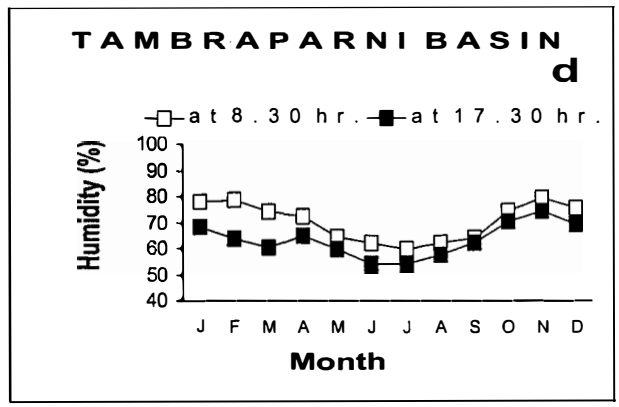


Fig. 2.2 Variation in monthly temperature (C) in (a) Kerala (1931-60), (b) Neyyar basin (1931-60), (c) Tamil Nadu (av. of 3 stations,(1988-95 & 2 stations,1969-89) , (d) Tambraparani basin (av. of 2 stations, 1969-89) and (e) Aryankavu (1931-60).









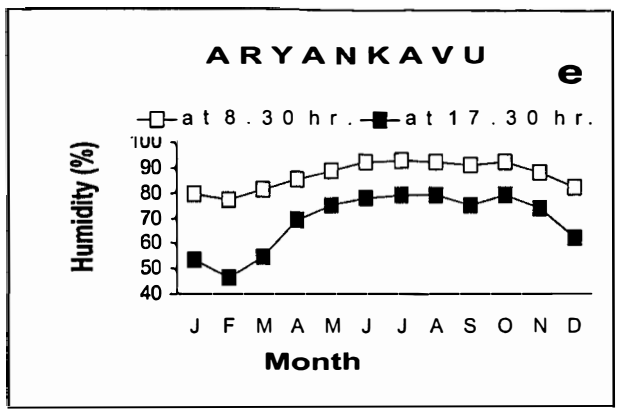


Fig. 2.3: Variation in monthly relative humidity (%) (a) Kerala (1931-60), (b) Neyyar basin (1931-60), (c) Tamil Nadu (av. of 3 stations, 1988-95 & 2 stations 1969-89), (d) Tambraparni basin (av. of 2 stations, 1969-89) and (e) Aryankavu (1931-60).

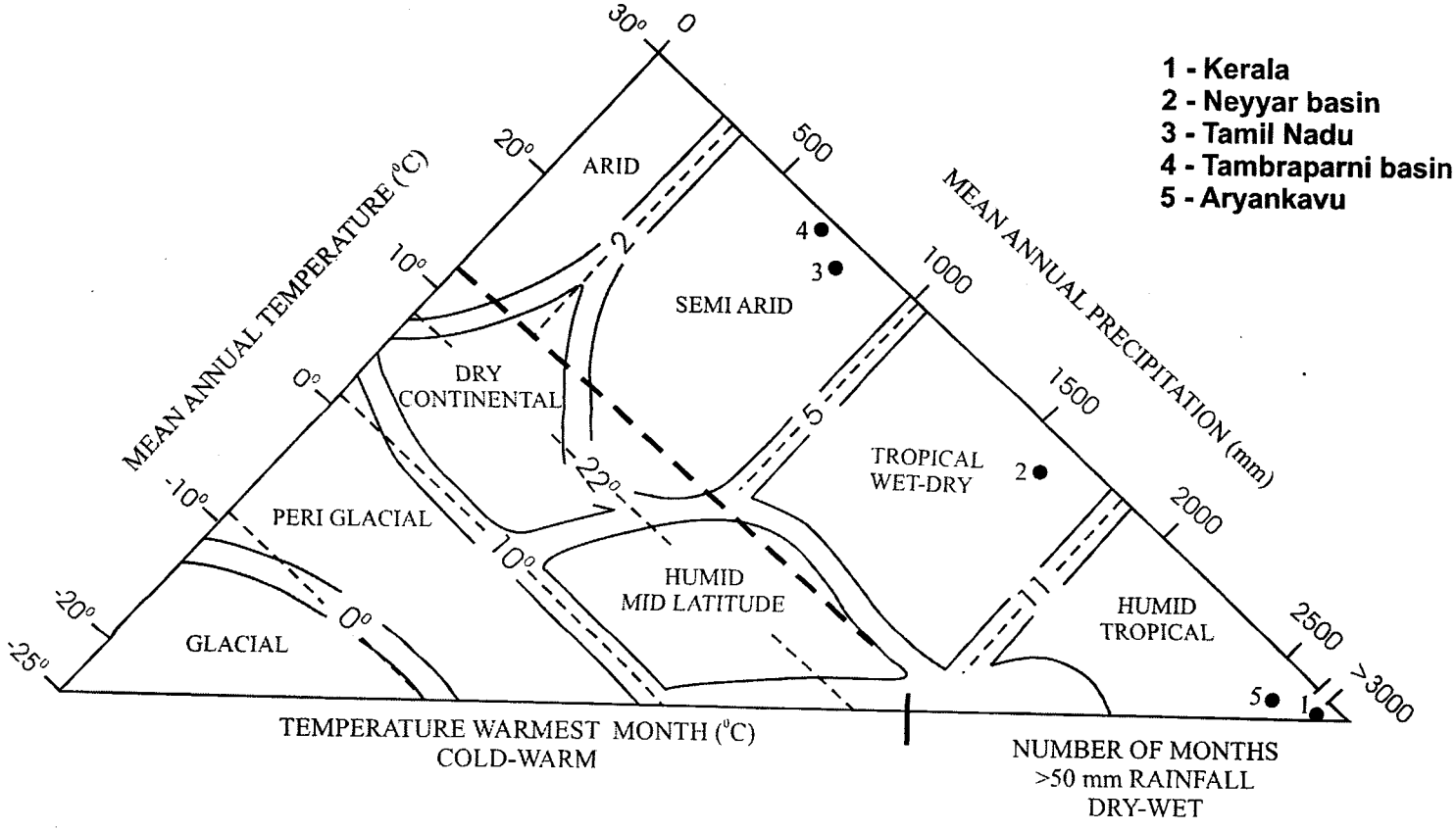


Fig. 2.4: Climatic classification of the study area
(Modified after Chorley et al., 1984)

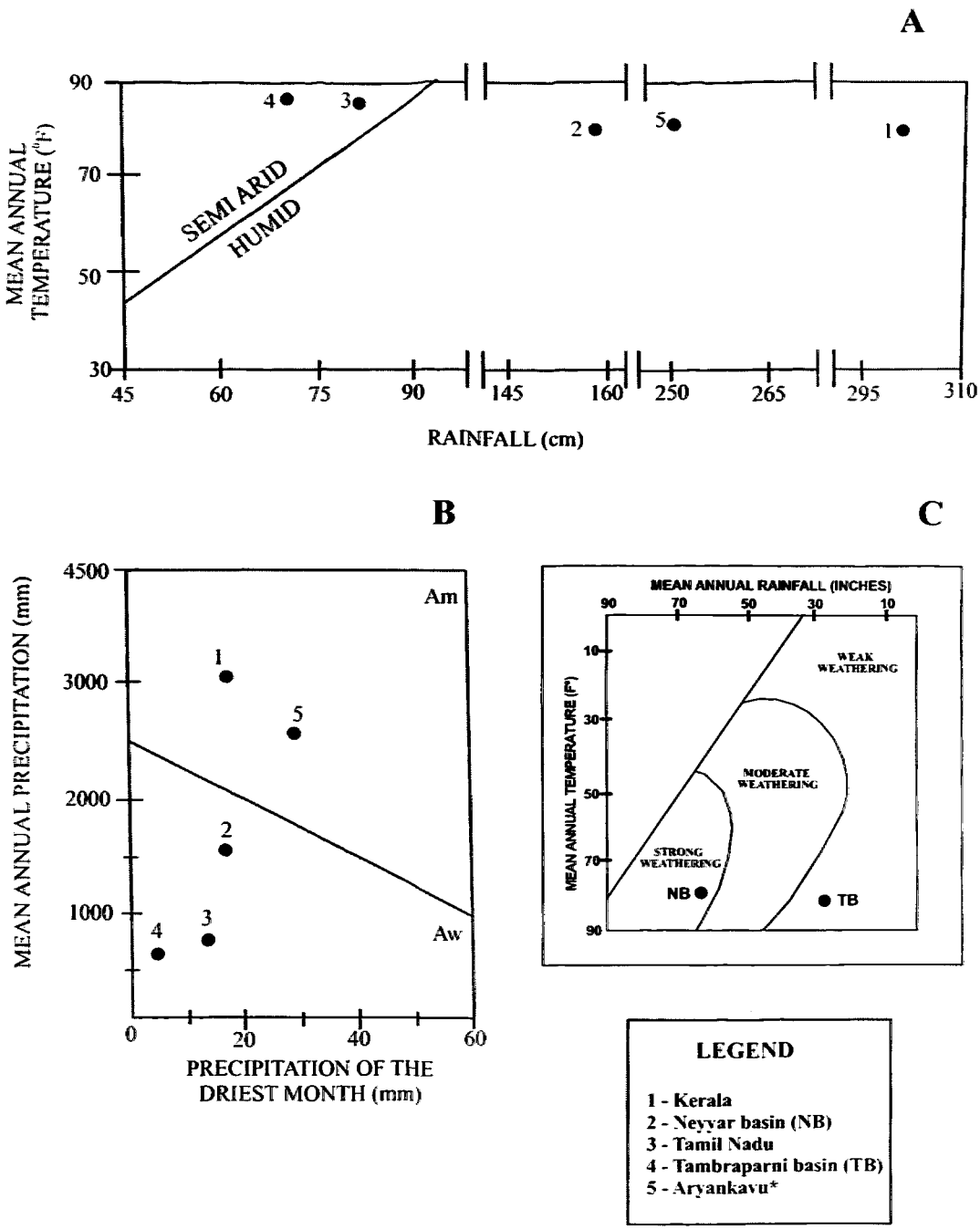


Fig: 2.5 Climatic classification of the study area on the basis of rainfall and temperature from different meteorological stations in Kerala and Tamil Nadu to
(A) semiarid and humid (modified after Trevartha, 1954) and
(B) tropical 'Am' and 'Aw' (after Koppen,)
(C) Climate-chemical weathering relationship (modified after Brunsden, 1979)
***Data for Aryankavu is taken as surrogate for sampling station TB-38.**

In NB, mean daily maximum temperature spans between 29.10 ^{0}C in July to 32.50 ^{0}C in March (ave. of 30 yr.) and mean daily minimum temperature ranges between 22.30 ^{0}C in January and 25.10 ^{0}C in April (ave. of 30 yr.). The MAT is 27.11 ^{0}C (Table 2.4; Fig. 2.2b).

2.6.1.3. Relative Humidity

In Kerala, relative humidity, RH, remains high due to proximity to the Lakshadweep Sea. The RH at 8.30 hr. ranges from 72% in January to 91% in July (ave. = 81.16%) and at 17.30 hr. it is 60% in January and 85% in July (ave. = 73.08%; Table 2.3; Fig. 2.3a).

In NB, relative humidity at 8.30 hr. ranges from 77% in January to 90% in June (ave. = 84%) and at 17.30 hr. it is 63% in January to 82% in June (ave. = 73.92%; Table 2.4; Fig. 2.3b).

2.6.2. Tamil Nadu and Tambraparni Basin

An illustration of meteorological data of Tamil Nadu and Tambraparni basin (Sebastian, 1999), in particular is given in Tables 2.5 to 2.7 and Figures 2.1 to 2.3.

2.6.2.1. Rainfall

Maximum rainfall in southern Tamil Nadu is in the month of November (194.20 mm) and minimum in February (14.00 mm). The data shows that the major share of precipitation (= 60%) is out of NE monsoon (October – December), followed by a long spell of hot and dry season. Rainfall received in the months of October and November account for approximately 60% of NE monsoon. Contribution by SW monsoon (June – October) is only marginal. The average annual rainfall in Tamil Nadu is 811.10 mm (Table 2.5; Fig. 2.1c).

The rainfall in Tambraparni basin shows maximum (184.65 mm in November) and minimum (5.20 mm in June), but the annual average is 697.85 mm (Table 2.6; Fig. 2.1d).

2.6.2.2. Temperature

In southern Tamil Nadu, mean daily maximum temperature varies between 29.10^{0}C in December and 35.24 ^{0}C in May and mean daily minimum temperature ranges from 21.56 ^{0}C in January to 26.77 ^{0}C in May. The MAT is 28.38 ^{0}C (Table 2.5; Fig. 2.2c).

In Tambraparni basin, mean daily maximum temperature varies between 28.05 ^{0}C in December to 36.50 ^{0}C in May and mean daily minimum temperature ranges from 21.25 ^{0}C in December to 27.00 ^{0}C in May. The MAT is 28.92 ^{0}C (Table 2.6; Fig. 2.2d).

2.6.2.3. Relative Humidity

Relative humidity in southern TN in the morning (8.30 hr.) ranges from 70.83% in May to 79.77% in November with an average of 73.79%. But humidity in the evening (17.30 hr.) varies from 63.30% in March in to 75.50% in October and averages at 68.32% (Table 2.5; Fig. 2.3c).

In Tambraparni basin, relative humidity at 8.30 hr. ranges from 59.50% in July to 79.00% in November with an average of 70.00% whereas at 17.30 hr. it is between 54.00% in June and July and 73.50% in November (ave. of 62.79%; (Table 2.6; Fig. 2.3d).

2.6.3. Climate of Aryankavu (for location TB 38, near Shencottah)

The average annual rainfall in Aryankavu, stands at 2542.50 mm with a mean monthly maximum (485.70 mm) in June and mean monthly minimum (30.20 mm) in February (Table 2.7; Fig. 2.1e).

Here, mean daily maximum temperature varies between 29.80^{0}C in July and 35.60^{0}C in March and mean daily minimum temperature ranges from 20.30 (December) to 23.90 ^{0}C (May) with a MAT of 27.28 ^{0}C (Fig. 2.2e).

In Aryankavu, relative humidity at 8.30 hr. is 77.00% in February and 93.00% in July (av. =86.75%) and at 17.30 hr., 46.00% in February and 79.00% in July and August with an average of 68.58% (Table 2.7; Fig. 2.3e).

The pattern of rainfall, temperature and humidity in Aryankavu and adjoining areas, including Shencottah, indicate that climate is very much akin to that in NB and other parts of Kerala.

2.7. Vegetation

Vegetation in Kerala is typical of a tropical humid environment. The highland is blanketed with thick forests, including patches of tropical, wet, evergreen forests (e.g., Silent Valley) known for their diverse fauna and flora. The hill tract support extensive plantations of tea (*Thea sinensis*) coffee (*Coffea arabica*), cardamom (*Eleteria cardamomum*) and rubber (*Hevea brasiliensis*). Midland has Coconut (Cocos nucifera) plantations and other crops whereas rice (Oryza sativa) is cultivated extensively in the lowlands. Other crops include banaana (Musa paradisiaca), pepper (Piper nigrum), arecanut (Areca catechu) and tapioca (Manihot sp.)

In NB almost the entire highland comes under the Reserved Forest and hence plantations are absent. Midland and lowland have crops of banana, rubber, coconut, paddy and a variety of vegetables.

Vegetation in Tamil Nadu (except along the hill tract) displays a semiarid flora. Palmyra palm (*Borassus flbellfer*) and the thorny acacia (Acacia horida) are ubiquitous. Cashew (Anacardium occidentale), banana (*Musa paradisiaca*), coconut (*Cocos nucifera*), mango, banana, groundnut chilly, paddy, sunflower etc. are cultivated in the plains. Groundwater is utilized more than surface water for farming purposes.

2.8, Geology of Kerala and Neyyar Basin

Southern India comprises of Proterozoic high-grade metamorphic rocks of dominantly upper amphibolite to granulite grade which are welded onto an Archean craton in the north (Drury et al., 1984). The southern part of South India comprises a vast supracrustal sequence of granulites termed as the Kerala Khondalite Belt (Chacko et al., 1987) or the Trivandrum Granulite Block (Santosh, 1996). The major lithounits in this block are garnet–sillimanite–cordierite–spinel bearing aluminous granulites (khondalites), garnet–biotite gneisses (leptynites), and orthopyroxene-

bearing anhydrous granulites (charnockites) with subordinate pyroxene granulites and calc-silicate rocks.

Although crystalline rocks constitute the dominant lithounits of the area, the Cenozoic sediments fringe the coastal tract overlying the Precambrian rocks (Soman, 1997). The coastal sedimentary basins also occur, located in the offshore, among which the Kerala–Konkan Basin forms the southernmost segment, the land extension of which is known as the South Kerala Sedimentary Basin-SKSB (Nair et al., 1998). The SKSB comprises both Quaternary sediment fill and ridge–runnel system formed by Holocene sedimentary events (Jayalakshmi et al., 2004). Various clay deposits constitute part of the Cenozoic sediments.

A large chunk of the NB is made up of crystalline rocks of Precambrian age comprising of granulites with a thick cover of laterite, alluvium and soil. The main lithounits are khondalite with veins of pegmatite, migmatite, charnokite, sandstone and clay with lignite, sand and silt and laterite. Discordant dolerite dykes have been reported from several places (Soman, 1997). Most of the highlands of NB are covered by pyroxene granulites, charnockite and garnet biotite gneiss (with/without sillimanite) and quartzite.

2.9. Geology of Tamil Nadu, and Tambraparni Basin

Narayanaswami (1975) studied the charnockite-khondalite suite of the entire south India and suggested that the charnockites of Tirunelveli represent a geosynclinal association of sediments with basic intrusives and ultrabasics. The Precambrian crystallines cover over 80% of the terrain. The Phanerzoic sedimentaries are confined to the eastern coastal region. Lithologically two groups' viz., charnockite and khondalite occupy Tirunelveli and its surrounding regions. The charnockite group consists of charnockite, pyroxene granulite and associated migmatites in the western part. These litho-units occur as thin bands and lenses in other parts of the area. The khondalite group consists of garnetiferous sillimanite -graphite gneiss, and the associated migmatites in southern and western part. Lenses and bands of pink granite and granitic gneisses are associated with both the groups. Thin bands of quarzite and marble associated with gneisses and the khondalite group occurs around Tirunelveli, Kovilpatti and Ambasamudram taluks. Pegmatites and quartz veins are also occasionally present.

Cuddalore sandstone of Mio-Pliocene age (Tertiary) rest over the crystallines unconformably. Red 'teri' sands, beach sands, Kankar and alluvium and soil belong to the Quaternary. Thickness of the sedimentaries varies from 57.6 to 117.5 m.

2.9.1. Teris of Tirunelveli

'Teri' is a term applied to the red dune sands which cover extensive areas (~ 500 sq.km) in the earstwhile Tirunelveli district of southern Tamil Nadu (Joseph and Thrivikramaji, 1998, 1999, 2002) These occur as detached patches-mostly in the coastal tract- within N. lat. 08:05:00 & 09:10:00; E. Long. 77:23:00 &78:28:00. The term "teri" was introduced by Foote (1883) to designate the red sand hills. The surficial matrial is unundurated to partly indurated sand body and is shaped to subaerial dunes, interdune sheets and extensive sheet sands and display sparkling red color on bright sunny days (Joseph, 1996). Teri sands are considered as unconsolidated equivalents of Red beds.

2.9.2. Structural and Tectonic framework of Tirunelveli

Information on the structural and tectonic set up of Tirunelveli is given in Ermenko et al (1970), Grady (1971) and Vemban et al (1977). Five major systems of structural elements like faults/dislocations/lineaments have been recognized here, which trend in a). E-W to WNW-ESE, b). NNE-SSW to NE-SW, c). ENE-WSW, d). N-S and e). NW-SE. The most significant of all is the Cauvery lineament trending WNW-ESE. The E-W trending Bhavani shear separating the Mysore plateau in the north and the plains of Gobichettipalayam in the south is another one of prominence.

The shoreline configuration of Tamil Nadu reflects a good deal of control by tectonics. An important fault in the system lies in the contact between the crystallines and the sedimentary rocks of the coastal land and is roughly parallel to the shore. This zone of contact is affected by other cross faults at a number of places causing displacement to the east. To the east of this fault boundary, there are a number of parallel and sub-parallel faults which at some places coincide with the straight shore line.

2.10. Discussion

Chorley et al. (1984) has identified eight morphogenetic regions – glacial, arid, humid tropical, tropical wet-dry, semi-arid, dry continental, humid mid latitude and periglacial - based on climate type and resultant landform. Parameters taken into account for identifying these are mean annual temperature (^{0}C), mean annual precipitation (mm), mean number of wet months (rainfall > 50 mm.) and mean temperature of the warmest month (^{0}C). Plot of these parameters for Kerala, Neyyar Basin, Tamil Nadu and Tambraparni basin (Fig. 2.4) clearly indicate that NB fits in the field of tropical wet-dry (close to humid tropical) climate, whereas TB (except TB-38) falls in the semi-arid field (Fig. 2.4). TB-38 falls within the humid tropical along with NB.

Plot of these parameters for Kerala, Neyyar Basin, Tamil Nadu and Tambraparni basin (Fig. 2.4) clearly indicate that NB fits in the field of tropical wet-dry (close to humid tropical) climate, whereas TB (except TB-38) falls in the semi-arid field (Fig. 2.4). TB-38 falls within the humid tropical along with NB.

Plot of data in the climate classification diagrams of Trevartha (1954) and Koppen (1936) to analyze the climate of the basins (Figs. 2.5A and 2.5B). Figure 2.5A indicates that NB and Aryankavu fall under humid climate, whereas TB is under semi-arid climate. Fig 2.5c incorporates climatic parameters (rainfall and temperature) and intensity of weathering (after Brunsden, 1979). The plot reveals that NB experiences 'strong' chemical weathering, whereas this process in TB is 'weak'.

2.11. Summary

Physiographic attributes (altitude, slope and relief), climate and geology of the NB, Kerala and TB, Tamil Nadu , both in SW part of India, are dealt with in this chapter. The WG stands aloft as a natural divide between Kerala and Tamil Nadu.

1. Physiographically, Kerala is divided in to three domains viz. LL (altitude<7.5 m.), ML (7.5-75 m) and HL (>75 m). HL consists of the WG and its foothills. ML comprises a swath of land between HL and LL, with undulating hills and separating valleys. The LL is mostly coastal land with 'kayals', inlets, barrier spits, beaches and beach ridges, coastal plains, and cliffs.

2. The NB lies on the western slope of the WG and extends up to Puvar in Thiruvananthapuram district, on the west coast of India. In NB among the 18 selected profiles, 7 belong to HL and 11 belong to ML. Again, 13 gentle, 4 very gentle and 1 steep category of slope.

3. Physiographically, Tamil Nadu is divided into three domains, viz., uplands (>300 m.), inland plains (10-300 m.) and coastal plains (<10 m.). Upland comprises of the WG and its slopes with altitude ranging from 1275 to 2640 m. The inland plains are a swath of dissected land with gentle easterly slopes. The coastal plains of Tamil Nadu consist of tidal flats, beach ridges, estuaries, lagoons, modern beaches and coastal dunes.

4. Among the 19 locations, 6 fall in ML and 13 in HL. Slope 17 very gentle and one steep. Relative relief – 18 Rises and one Hill.

5. The average annual rainfall in Kerala is 3001.0 mm and Neyyar Basin is 1580.70 mm. The MAT, Kerala stands at 27.33^{0}C and that of NB is 27.11^{0}C. In Kerala, the mean relative humidity at 8.30 hr. is 81.16 and at 17.30 hr. is 73.08%. In NB, the corresponding values are 84 and 73.92%.

6. The average annual rainfall in Tamil Nadu (TN) is 811.10 mm and Tamraparni Basin is 697.85 mm. The MAT of TN stands at 28.38 ^{0}C and that of TB is 28.92 ^{0}C. In TN, the mean RH at 8.30 hr. is 73.79% and at 17.30 hr. is 63.32%. In TB, the corresponding values are 84 and 73.92%.

7. The meteorological conditions of at TB-38 in Tamraparni Basin are markedly different from rest of the basin. Here the average annual rainfall is 2542.50 mm MAT is 27.28^{0}C. The RH at 8.30 hr. is 86.75% and at 17.30 hr. is 68.58%.

8. Data when plotted in Threvartha's diagram classifies falls in the tropical humid domain and TB in the semi-arid domain.

9. Data plots in the Brunsden diagram (1979) yields a humid climate experiences strong weathering in the NB, whereas a semi-arid climate with weak weathering in TB.

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