Evaluation of Soil-Site Conditions for Suitability of Rubber

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Abstract: *Six major rubber growing areas supporting excellent, moderate and marginal growth of rubber were selected in the main rubber growing regions in Kerala and Tamil Nadu. Fifteen representative sites were identified and their soil and site conditions were studied. The climatic, soil and site parameters were compared with the yield of rubber for developing the criteria for the soil-site suitability of the crop. The characteristics of each site were compared with the suitability criteria and the soils were evaluated for rubber cultivation, through limitation approach. The kind and degree of major constraints for rubber production were identified. The most striking parameter influencing the yield of rubber is the period of moisture availability (LGP) followed by soil depth, PAWC, slope, winter temperature, and excess rains. (**Key words :** Rubber, soil-site suitability, land evaluation).*

Rubber is a commercial plantation crop, grown for latex that forms natural rubber. It has about 895 plant species, of which Hevea brasiliensis is the only species wherein latex is commercially extracted. It is commonly grown in the intertropical part of the world (Indonesia, Malaysia, Thailand, China, India, Sri Lanka, Libia, Nigeria, Zaire, Ivory Coast, Cameroon, The Phillipines, Burma, etc.). In India, it is cultivated dominantly in the states of Kerala, Tamil Nadu, Karnataka and Andaman and Nicobar Islands. Of the total area under rubber cultivation, almost 88 per cent is in the state of Kerala.

Since it is an industrial cash crop with a remunerative price in the world market, the Rubber Board has been encouraging its cultivation in comparable agro-ecological regions. Other north-eastern states, especially, Tripura, Mizoram, Manipur, Assam, have been exploring the possibility of rubber cultivation as an alternative to the existing cropping systems, in the marginal areas where arable crops have no competition. However, the available literature and studies conducted on the soil-site suitability for rubber plantation in different agro-ecological regions are limited and may warrant rubber expansion in areas which are agro-ecologically suitable for its cultivation. The present study was, therefore, undertaken to establish soil-site suitability criteria for rubber cultivation to provide guidelines for evaluating the suitability of other areas for rubber plantation.

MATERIAL AND METHODS

Six major rubber areas/research stations in Kerala and Tamil Nadu supporting excellent, moderate and marginal growth of rubber were selected (Fig. 1). Fifteen representative sites were identified and their soil and site conditions were studied. For selection of different sites, care was taken that the sites are with optimum crop density and under normal management practices followed for the widely grown variety of RRIM 600. The selection of plantations was also based on the similarity in age group. Representative soil profiles were studied and classified as per Soil Taxonomy (Soil Survey Staff 1975). The yield and climatic data of these stations for a period of 5 years were recorded. Soil samples were analysed for physical and chemical properties by following standard procedures (Jackson 1958; Black *et al.* 1965 and Page *et al.* 1965). The water balances for the study areas and the length of growing period (Fig. 2) including dry spells were computed as suggested by FAO (1976).

The climatic, soil and site parameters were compared with crop yield (dry rubber) for developing the criteria for the soil-site suitability of the crop (Sys 1985; Sys *et al.* 1991, & FAO 1983). An attempt

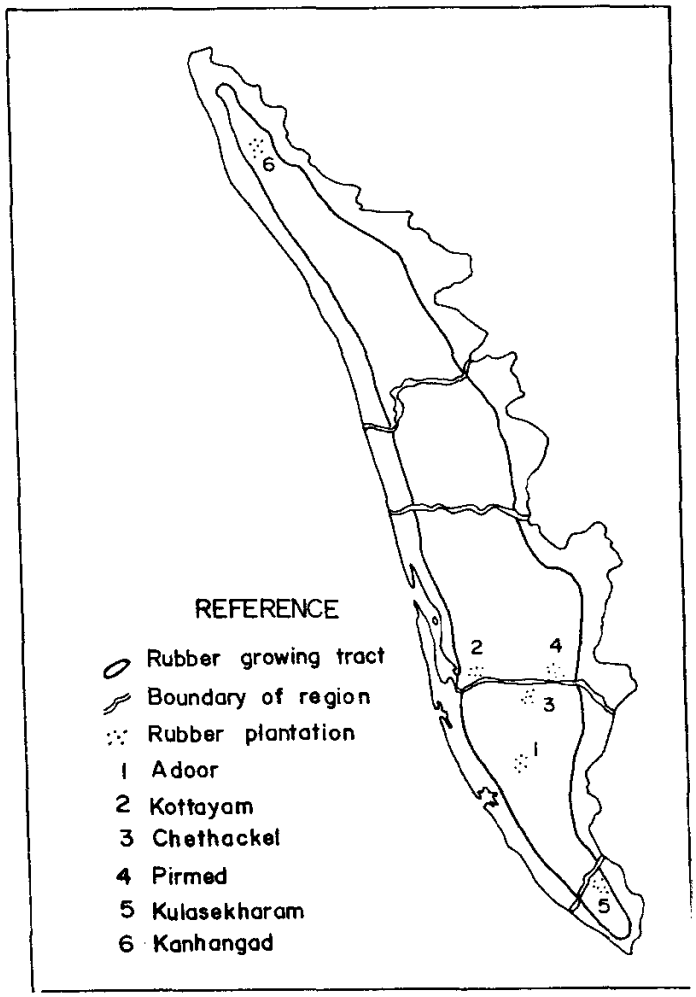

Figure 1. Location of study areas in the main rubber growing regions (Kerala and Tamil Nadu)

has also been made to arrive at the number of parameters influencing the yield of rubber through a statistical model. The suitability criteria are then compared with the climatic and soil-site parameters of each site to determine the suitability class of these soils. The potentials and problems of these soils for growing rubber successfully in the region have been discussed.

RESULTS AND DISCUSSION

Land Evaluation : The data (Table 1) show that the annual rainfall at the six research stations ranges from 1726 (Kulasekharam) to 3735 mm (Chethackel)while the length of growing period varies from 240 (Kanhangad) to 330 (Kulasekharam) days. The number of dry months vary from one (Kualasekharam) to four months (Kanhangad). Rainfall is considered to be an important parameter influencing the growth of rubber and its overall effect on yield. The yield at Kulasekharam having lowest total rainfall (1726 mm) is the highest as compared to other research stations. This indicated that, an evenly distributed rainfall to the tune of 100 mm each month may be a better criteria than the total rainfall alone (Landon 1984). This is further supported by the fact that the annual rainfall of 3600 mm, received at Kanhangad station, although the highest, yet the length of dry period extending to four months in a year, is critical to the growth of plants resulting in lowest yields at this site. Most of the rainfall (85 % of total) is received here within a period of 4 to 5 months (June to Sept.) and get lost due to run off or through deep percolation. At Kulasekharam station about 40 per cent of total rainfall is received during June to Sept. and 32 per cent during Oct. to Dec. (north-east monsoon period) whereas at Kanhangad station only 7 per cent is received during north-east monsoon period indicating the evenly and seasonal distribution of rainfall at these two sites respectively. It has also been reported (Vink 1975; Young 1975 and Landon 1984) that rubber has low drought tolerance. Since rubber can withstand only short dry spells (maximum about two months), the crop experiences physiological stress (under lengthy dry periods) resulting in reduction in yields.

The studied soils are under humid equable climate with mean annual maximum temperature ranging from 30.8 (Kulasekharam) to 32.5°C (Pirmed) and mean annual minimum temperatures of 20.4 (Kanhanad) to 24.3°C (Kulasekharam) (Table 1). The soil temperature regime is iso-megathermic (Sehgal & Mandal 1994) and the soil moisture regime is Udic and Ustic (Sehgal & Mandal 1993). The mean annual temperature ranges from 25.9°C (Kanhangad) to 27.5°C (Kulasekharam). Humid atmosphere with the mean relative humidity of 75 to 79 per cent in the study area throughout the year

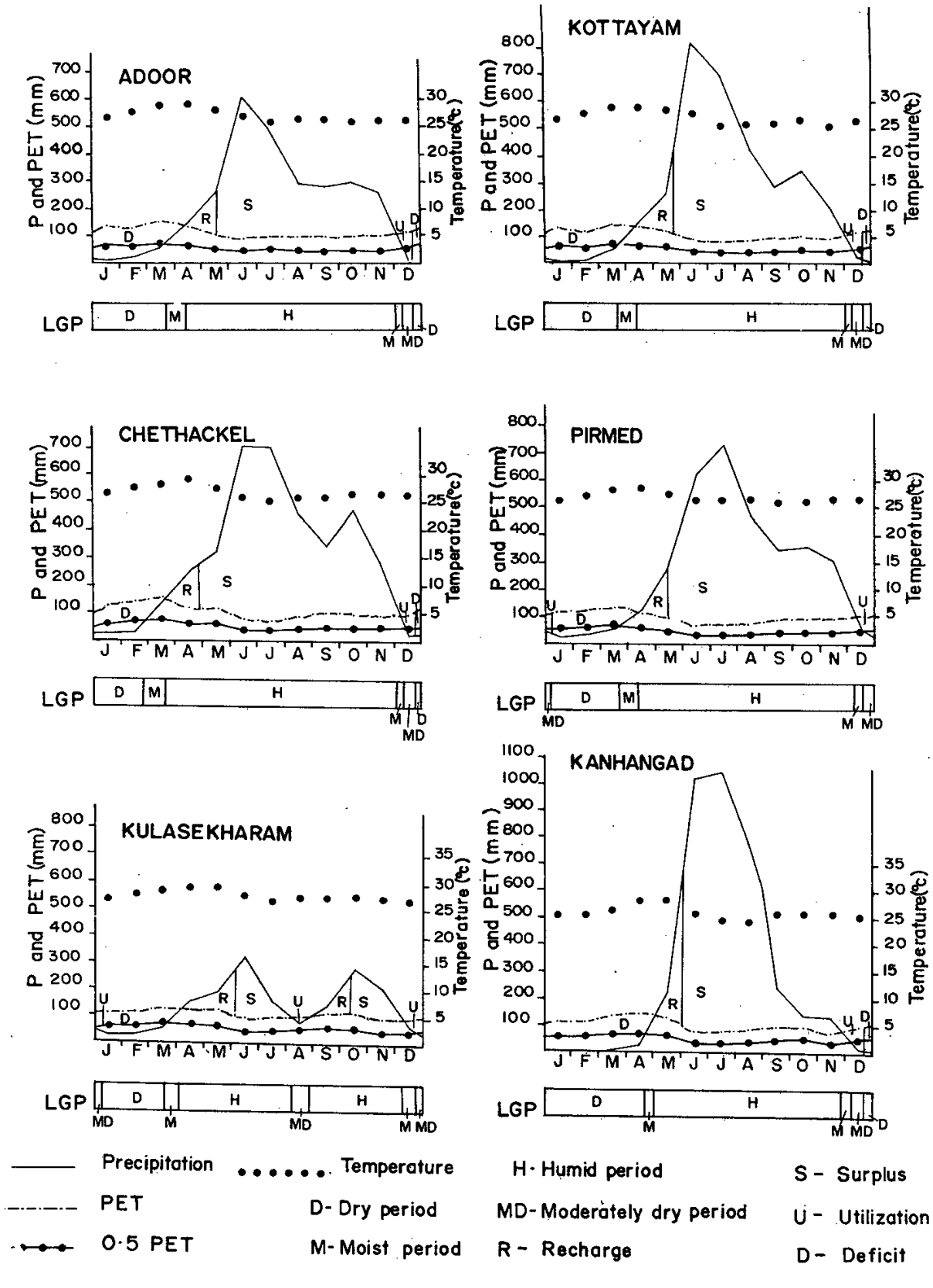

Figure 2. Water balance diagrams and length of growing period (LGP) for rubber growing areas

TABLE 1. Climatic characteristics of study area

Station	Location	Rainfall (mm)	Excessive rain* (months)	Dry season (months)	Growing period (days)	Temp °C			Relative humidity (%)	n/N** Mean annual
						Mean annual	Mean max.	Mean lowest		
Adoor	Rubber Estate near Agricultural Farm, Adoor, Pathnamthitta Distt. Kerala	2732	1.5	3	270	27.2	32.2	20.4	79.5	0.58
Kottayam	Rubber Estate on Puthupally, RRII Road Kottayam, Kerala	3328	3.0	3	270	27.2	31.5	21.3	76.0	0.54
Chethackel	Rubber Estate in Central Experimental Station of RRII Ranni, Pathnamthitta, Kerala	3735	4.0	2	300	26.8	31.7	19.5	77.7	0.50
Pirmed	Mannikal Estate of TR&T Co., Pirmed, Idukki, Kerala	3420	4.0	3	270	26.8	32.5	18.6	78.9	0.44
Kulasekharam	New Ambadi Estate, Kulusekharam, Tamil Nadu	1726	0.5	1	330	27.5	30.8	23.3	75.3	0.48
Kanhangad	Rubber Estate near Betul village, Kanhangad, Kerala	3618	3.0	4	240	25.9	31.4	17.4	77.4	0.51

* Total of months with >500 mm rainfall, plus half of the months with 300-500 mm rainfall

** n/N suggests the ratio of actual (n) to maximum possible (N) bright sundhine hours.

without much variation is congenial for the growth and yield of rubber (Pillay *et al.* 1980) The ratio of actual (n) and maximum possible (N), bright sunshine hours (n/N) ranges from 0.44 to 0.58 which is congenial for growth of rubber.

The soils of the study area are mainly derived form the rocks charnockite, khondalite, peninsular gneiss and laterites; the major physiographic units are the mid land lateritic mounds, low ridges and spurs radiating towards west from the Western Ghats and the undulating to rolling plains with moderately to steeply sloping topography. The elevation ranges from 50 to 305 m MSL.

Soils in the area are Ultisols and Inceptisols with depth ranging from shallow (46 cm) to deep (186 cm), with high amount of organic carbon in the surface ranging form 1.69 to 4.73 per cent. The CEC at 50 cm depth of soil ranges from 6.8 to 17.7 C mol (+) kg^{-1} of clay. These soils have low base saturation ranging from 11.5 to 42.1 percent indicating high leaching of the soils. They are acidic in reaction with pH ranging from 4.7 to 5.5 (Table 2).

Growth of rubber has been found to be satisfactory upto 450 m MSL (Pillay *et al.* 1980). At higher altitudes the low temperatures retard the growth since the rate of biochemical and physiological processes decreases. In the study area the mean

TABLE 2. Characteristics of the studied soils.

MSL (m)	Slope (%)	Drainage	Fragments (Vol.%)	Structure	Silt <----(%)--->	Clay	Texture	PAWC (mm)	Depth (cm)	O.C. % (0- 25 cm)	pH 1:2.5 (water)	CEC Cmol (+) kg^{-1} clay	Sum. Exc. cations	B.S. (%)	Yield $kgha^{-1}$
Adoor	Midland lateritic mounds														
150	8	Well	48.1	m 2 sbk	8.1	49.1	C	75	143	2.98	4.9	9.0	0.71	12.7	1250
	Midland lateritic mounds														
150	15	Well	42.8	m 2 sbk	9.0	45.3	C	75	180	2.76	4.8	11.0	0.64	12.1	1560
Kottayam	Midland dissected undulating to rolling laterite plateau;														
73	35	Well	39.9	m 1 sbk	9.5	55.8	C	42	63	1.89	5.3	6.8	0.76	14.4	945
	Midland lateritic plateau undulating														
73	8	Well	48.7	m 2 sbk	13.8	42.7	C	102	186	1.69	4.9	10.2	0.75	15.4	1300
Chethackel :	Midland lateritic mounds;														
50	8	Well	43.6	m 2 sbk	11.9	43.3	C	123	155	4.58	4.8	14.3	1.29	16.7	1655
	Midland laterite plateau;														
50	6	Well	46.1	m 2 sbk	10.7	46.3	C	102	170	3.58	4.8	13.0	1.89	20.1	1259
	Midland laterite palteau														
50	25	Well	38.9	f 1 gr	10.9	39.4	Sc	42	46	4.38	5.0	17.7	1.52	17.6	1022
Pirmed :	Foothills; long ridges														
305	6	Well	31.9	m 1 sbk	18.2	35.1	Sc	85	160	4.73	4.7	12.5	0.83	14.9	1177
	Foothills long ridges														
305	8	Well	36.2	f-m 1sbk	12.2	50.5	C	104	180	3.57	5.0	7.5	0.90	16.0	1289
	Foothills long ridges and hills;														
305	30	Well	32.3	m 1 sbk	11.4	40.3	Sc	44	61	2.21	4.9	8.1	0.78	14.7	1004
Kulasekharam:	Undulating hills and ridges;														
300	8	Well	43.6	m 2 sbk	7.5	57.0	C	110	130	2.81	4.9	7.3	0.86	13.2	1856
	Undulating hills														
300	8	Well	27.6	m 2 sbk	9.2	59.2	C	158	150	2.99	4.7	7.1	0.73	11.5	2016
	Undulating hills and ridges														
300	15	Well	37.2	m 2 sbk	8.8	57.7	C	97	110	2.44	4.7	7.1	0.61	12.5	1968
Kanhangad :	Midland laterite mounds														
80	15	Well	62.3	f-m 1 sbk	19.3	56.3	C	109	125	2.11	5.5	9.0	2.87	39.5	1105
	Midland laterite mounds														
80	6	Well	44.4	m 2 sbk	19.2	58.2	C	132	185	2.11	5.4	7.7	2.86	42.1	870

TABLE 3. Soil-site requirements for rubber as per different authors

Climatic/ Soil-site Parameters	Landon (1984)	Sys (1985)	Pillay *et al.* (1980)	Chan *et al.* (1975)	Pushparajah (1977)	Rao & Vijayakumar (1992)	Potty & Mannothra (1993)
Rainfall (mm)	1500-4000	>2000-4000	2000-3000	>2000	>2000	>2000	2000-3000
LGP (days)	-	300-360	-	-		-	
Mean Temp. (^{0}C)	27-28	>25(27-28)	-	-	25-28	25-28	-
Max. Temp. (^{0}C)	-	27-29(>29)	-	-	29-34	29-34	-
Min. Temp. (^{0}C)	-	>20	-	-	>20	≥ 20	-
R.H. (%)	-	-	70-95	-		70-95	70-95
Sunshine (hrs/yr)	-	-	>2000	-	>2100	>2000	-
Elevation (m MSL)	200	200-450	-	-	-	-	<600
Slope (%)	17	-	11-33	4-20	-	-	<26
Soil depth (cm)	>100	-	100 min.	>100	>150	-	-
Texture	sandy clay loam and clay loam,	clay, sandy clay loam clay loam, sandy clay	medium texture	>35% clay (35-50%) & 30% sand (35-50%)	-	-	-
pH	4.4-5.2	5-6	-	4.5	-	-	4-6.5
CEC Cmol(+)kg^{-1}	15	Any	-	-	-	-	3.55-18.02
B.S.(%)	-	20-35(<20)	-	-	-	-	-
O.C. (%)	>1	>1.2	-	-	-	-	-

temperature of coldest month varies from 17.4 to 23.3°C. The mean annual temperature is 27.2°C which is above the lower limit (20°C) of thermal adaptation of rubber (Moraes 1977).

The data showed that low yield was generally observed on shallow soils (46 cm) on steep slopes of > 35 per cent. The soils with limited depth might restrict the feeding zone which is reflected in the yield (Abdul Salam & Abdul Wahid 1993). The soils are well drained with fine to medium subangular blocky structure having clay and sandy clay texture permitting better conditions for root development. The tap roots of the crop grow as deep as 2.5 m and the laterals have a spread as much as the canopy. Because of this extensive root system and high oxygen demand associated with high respiration rates (Moraes 1977), very deep (200 cm) well drained soils might be ideal for rubber plantation. The amount of gravel on the surface and within the soil is ranging from 27.6 to 62.3 per cent by volume; this might restrict the volume of fine earth fraction available for nutrient and water supply to the crop. However, in the study area, the high amount of gravel in the site associated with optimum yield might have influenced the drainage conditions.

The variations in the yield of rubber plantations were explained by computing correlations between yield and different soil-site parameters. The multivariate Regression Yield Model (R^2=0.7589) Y=3366.5 + 7.6 slope + 3.7 soil depth + 18.3 clay content - 1.3 PAWC + 12.0 LGP

where Y= yield of rubber plantations in kg^{-1}ha.

The LGP is observed to be significant at 1 per cent level indicating that the period of moisture availability is the most important parameter influencing rubber yield. The model also indicated that the 76 per cent variation in the yield of rubber is due to variations in the parameters considered in the model. However, the effect of other parameters might have been supressed by the predominant parameter like LGP.

TABLE 4. Soil-site suitability criteria for Rubber plantation (Proposed)

Soil-site characteristics	Degree of limitations					
	0 (None)	1 (Slight)	2 (Moderate)	3 (Severe)	4 (V.Severe)	
	S1		S2	S3	N1	N2
Climatic Characteristics						
Total annual rainfall(mm)	>2000	1700-2000	1450-1700	1250-1450	-	<1250
Months with excessive rain	<1	1-2	2-4	-	-	-
Lenght of dry season (months)	<1	1-2	2-3	3-4	-	>4
Length of growing period (days)	330-360	300-330	270-300	240-270	-	<240
Mean annual temp.(^{0}C)	>25	22-25	20-22	18-20	-	<18
Mean annual max. temp.(^{0}C)	>28	26-28	24-26	22-24	-	<22
Average min. temp. coldest month(^{0}C)	>20	18-20	16-18	14-16	-	<14
n/N mean annual	>0.4	0.25-0.40	0.15-0.25	>0.15	-	<0.15
Mean R.H. in growing season (%)	70-80	80-90	90-95	>95	-	<70
Site Characteristics						
Elevation (m above MSL)	<450	450-500	500-550	550-650	-	>650
Slope (%)	0-3	3-8	8-15	15-35	>35	-
Flooding	F0	F0	F0	F_1	-	F_2
Drainage	Well	Well	Moderate	Imperfect	Poor	Very poor
Soil Characteristics						
Texture	SiC,CL,Sc	L,SCL C(<60)	SL, Lfs (C>60)	Ls,Lcs,Fs	-	S,cs
Coarse fragments (Vol.%)	<5	20-45	45-60	60-75	-	>75
Depth (cm)	>200	150-200	100-150	45-100	-	<45
PAWC (mm)	>150	100-150	50-100	40-50	-	<40
Soil Fertility						
CEC cmol(+)kg^{-1} clay	any	any	-	-	-	-
Base saturation (%)	20-35	<20	35-50	50-80	-	>80
Organic carbon (0-25cm) %	>1.2	<1.2	-	-	-	
pH (0-25 cm)	4.5-5.0	5.0-5.5	5.5-6.0	6.0-6.5	-	>6.5

The soil-site suitability criteria for rubber plantation is developed by referring the available literature (Table 3), actual yield and considering the local experience (Table 4). The existing climatic and soil-site characteristics at each site in the study areas (Table 1 & 2) are compared with the criteria (Table 4) and the soils have been evaluated for their suitability to rubber through limitation approach (FAO 1976; Sys *et al.* 1991) (Table 5).

The kind and degree of major constraints of the soils in the area for rubber production are presented in Table 6. The soils with no limitations or slight limitations are grouped under suitability class (S1);

the soils with moderate limitations under mod erate suitability (S2); the soil with more than three moderate limitations and one or more severe limitations under marginal (S3) class.

It is observed that in Kottayam-3, Chethackel-7 and Pirmed-10 soils, the slope, PAWC, depth are the major limitations (S3). The soils at Adoor (Pedon 1 & 2), Kottayam (Pedon 2), Chethackel (Pedon 5 & 6), Pirmed (Pedon 8 & 9), Kulasekharam (Pedon 11 & 13) have a few moderate limitations such as dry period, excess rain, depth, PAWC, coarse fragments and/or slope. These are evaluated and grouped under S2 class while Pedon-12 has slight

TABLE 5. Limitations of soil-site parameters in studied soils for suitability to rubber

Characteristics	Adoor (1) (1)	Adoor (2) (2)	Kott-aya-m (3)	Kott-aya-m (4)	Chet-hack-el (5)	Chet-hack-el (6)	Chet-hack-el (7)	Pirm-med (8)	Pirm-med (9)	Pirm-med (10)	Kula-sekh-ram (11)	Kula-sekh-ram (12)	Kula-sekh-ram (13)	Kan-han-gad (14)	Kan-han-gad (15)
Climatic Characteristics															
Total annual rainfall(mm)	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0
Months with excessive rain	1	1	2	2	2	2	2	2	2	2	0	0	0	2	2
Lenght of dry season (months)	2	2	2	2	1	1	1	2	2	2	0	0	0	3	3
Length of growing period (days)	2	2	2	2	1	1	1	2	2	2	0	0	0	3	3
Mean annual temp.(^{0}C)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean annual max.temp.(^{0}C)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Average min.temp.coldest month (^{0}C)	0	0	0	0	1	1	1	1	1	1	0	0	0	2	2
n/N mean annual	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean R.H. in growing season (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site Characteristics															
Elevation (m above MSL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slope (%)	1	2	3	1	1	1	3	1	1	3	1	1	2	2	1
Drainage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soil Characteristics															
Texture	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1
Coarse fragments (Vol %)	2	1	1	2	1	2	1	1	1	1	1	1	1	3	1
Depth (cm)	2	1	3	1	1	1	3	1	1	3	2	1	2	2	1
PAWC (mm)	2	2	3	1	1	1	3	2	1	3	1	0	2	1	1
Soil Fertility															
Apparent CEC cmol(+) kg^{-1} clay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BS (%)	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
OC (%)(Surface soil)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pH (1:2.5)(soil: water)	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1
Suitability class	S2	S2	S3	S2	S2	S2	S3	S2	S2	S3	S2	S1	S2	S3	S3

s1- Very suitable : +80% of optimum yield; S2 - Moderately suitable : 50-80% of optimum yield; S3 - Marginally suitable : 30-50% of optimum yield

TABLE 6. Kind and degree of major constraints, suitability class and yield of rubber

Soils	Kind and degree of constraints										Yield kgha^{-1}	Suitability class
	Dry Period	Excess rain	Min. temp.	Slope	PAWC	Texture	Fragment	Depth	B.S.	pH		
Adoor-1	**	*		*	**	*	**	**	*		1250	S2
Adoor-2	**	*		**	**	*	*	*	*	*	1560	S2
Kottayam-3	**	**		***	***	*	*	***	*	*	945	S3
Kottayam-4	**	**		*	*	*	**	*	*		1300	S2
Chethackel-5	*	**	*	*	*	*	*	*	*	*	1655	S2
Chethackel-6	*	**	*	*	*	*	**	*			1259	S2
Chethackel-7	*	**	*	***	***		*	***	*	*	1022	S3
Pirmed-8	**	**	*	*	**		*	*	*		1077	S2
Pirmed-9	**	**	*	*	*	*	*	*	*		1289	S2
Pirmed-10	**	**	*	***	***			***	*		1004	S3
Kuiusekharam-11				*		*	*	**	*		1856	S2
Kulusekharam-12				*		*	*	*	*		2016	S1
Kulusekharam-13				**	**	*	*	**	*		1968	S2
Kanhangad-14	***	**		**	*	*	***	**	*	*	1105	S3
Kanhangad-15	***	**		*	*	*	*	*	*		870	S3

* slight limitation; ** moderate limitation; *** severe limitation.

limitations of depth, coarse fragments and total rainfall and grouped under S1 class. The soils at Kanhangad have thesevere limitation of the dry spell and the moderate to severe limitations of slope, PAWC, coarse fragments and depth and grouped under S3 class.

This study indicated that for rubber cultivation the soils grouped as (S1) are very suitable, and the soils grouped as (S2) are moderately suitable, and the soils grouped as (S3) are marginally suitable. These grouping are based on the limitations/constraints either in the climatic and/or soil-site parameters governing the rubber yields. The soils under (S1) class yielded highest while soils under (S3) class yielded lowest. However, the yield in Indian situation from these soils is less as compared to Malaysia and other countries. This might be due to congeniality of the climatic conditions.

It can thus be concluded that the most striking factor governing the yield of rubber in India is the LGP followed by soil depth, PAWC, slope, winter temperature and excess rains.

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