Land and soil controls over the spatial distribution and productivity of rubber (*Hevea brasiliensis*) in Southern India

N. Usha Nair [A], K. M. Nair[B], S. Meti[A], D.V.K. Nageswara Rao[C], Binni Chandy [A] and L.G.K. Naidu[B]

[A]Rubber Research Institute of India, Kottayam, Kerala, India 686 009, Email usha@rubberboard.org.in
[B]National Bureau of Soil Survey and Land Use Planning, Hebbal, Bangalore, India 560 024, Email nairkmn@yahoo.com
[C]Indian Grassland and Fodder Research Institute, Near Pahuj Dam, Gwalior Road, Jhansi-284 003 (INDIA)

Abstract
The primary rubber-growing area in India is the west coast of Southern India. Land and soil qualities exert considerable influence on the spatial distribution and productivity of rubber in the area. Lowlands with imperfectly drained soils and lands with elevation more than 600 meters above mean sea level were found to be unsuitable for the crop. At higher elevations lower temperatures retarded the crop growth and yield. The effect of rainfall is more in its distribution rather than the quantity and the period of soil moisture deficit significantly influences rubber productivity. The highly weathered tropical soils with strong acidic reaction, gravelly clay texture, low bases and low cation exchange capacity presented no limitation for the crop. Psamments, Usterts and Ustalfs are generally not cultivated to rubber. Hydromorphic soils (Aquepts/Aquents) are also unsuitable for the crop. High available water capacity of soils, contributed by deep solum and non-gravelly clay texture, in combination with short climatic dry period resulted in better crop yield. Soil map with soil types defined according to Soil Taxonomy together with agro-climatic maps can help identify land and soils suitable for rubber cultivation.

Key Words
Rubber-growing soils of India, soil taxonomy, soil suitability for rubber

Introduction
Rubber was introduced to the west coast of Southern India, where soil and climatic conditions were similar to original habitat (Brazil), during third quarter of 19th century and commercial plantations were established by early 20th century. The area under rubber plantations witnessed a quantum leap since 1960's in the region, driven by the demand for natural rubber. The current area under the crop in west coast of Southern India is around 5,31,455 hectares. Land and soil qualities are the primary controls over the spatial extension of the crop and its productivity, when market economy is in favour of rubber. This paper gives an account of the land and soil related controls over the spatial distribution of rubber plantations in west coast of Southern India and attempts to relate the variability in crop productivity to land and soil qualities. The insight gained can be profitability employed for strengthening the soil-site suitability evaluation criteria for rubber, a perennial crop with long gestation period to production and long productive life.

Methods
A soil map of the study area (west coast of Southern India) at the scale of 1:250K was generated through land form analysis, field soil survey, laboratory analysis and GIS processing of data to derive maps (Krishnan *et al.* 1996). The map units were association of soil families (Soil Survey Staff 1990) which were described for land form and soil qualities. A soil map at 1:50K scale for rubber- growing areas was generated in similar fashion (NBSS Staff 1999) had map units of soil series association and more detailed description of land and soil qualities. An agro-climate zones map was generated following the methodology described by FAO (1976 and 1978) and the map units were described for over head climatic parameters and length of growing period (or length of dry period) in a year reflecting soil moisture availability for crop growth (Naidu *et al.* 2009). Rubber latex yield data gathered by Rubber Research Institute of India as part of their crop monitoring program (Chandy and Sreelakshmi 2008) was organised on regional basis and used for relating productivity to land and soil qualities.

Results
Land form, elevation, climate and soil qualities were the primary determinants of the spatial extension of rubber and the productivity of the crop in the study area. The findings are presented and discussed in brief in the following sections.

Land form
Major land forms of the west coast of southern India are high hills and coastal plains. The hilly terrain has steeply sloping lands with elevation ranging from 600 to 2000 meters. The coastal plains consist of land with rolling to undulating topography interspersed by nearly level narrow valleys and low lands. The rubber growing areas are confined mainly to the rolling and undulating lands. The rubber plantations established in hilly areas with elevation more than 600 meters failed to yield rubber latex in economically viable quantity. The spatial extent of rubber plantations also excluded valleys and coastal low lands which are subjected periodic inundation by water.

Climate
The west coast of Southern India experiencing humid tropical monsoon climate with high temperature and rainfall is climatically suitable for rubber. The mean annual rainfall range from 1500 mm to 5000 mm and mean annual temperature is 27.1 °C in rubber -growing areas. Mean annual temperatures lower than 20 °C experienced in hill ranges with elevation more than 600 meters above mean sea level was found to seriously impair the productivity of rubber. Again, the rubber latex production was found to be related to the period of soil moisture availability (or its deficit) in a year.

Soils
The highly weathered soils developed under humid, tropical climate are strongly acidic, low in exchange capacity and bases, but rich in organic matter. Major soils of the study area are Ustipsamments and Tropaquepts in coastal nearly level low lands and valleys, Kandiustults, Kandihumults, Palehumults and Humitropepts on rolling to undulating lands, Haplohumults and Argiustolls on high hills and Usterts and Ustalfs in small area of upland plains. The Psamments and Aquepts exhibiting hyromorphic features are seldom used for rubber cultivation. So also are the Usterts and Ustalfs. The soils extensively used for rubber cultivation are Kandiustults, Kandihumults, Palehumults and Humitropepts. The temperature regime and mineralogy class used for defining soil family are isohyperthermic and kaolinitic respectively for the entire region. The particle size class is either clayey or clayey-skeletal. Particle size class serves as good indicators of the effective soil volume and water retention capacity. The soil map of the rubber-growing areas indicted that soil variability is confined mainly to the content of gravel, organic matter and water holding capacity.

Rubber productivity in relation to land and soil qualities
The land and soil qualities, besides their influence on the spatial distribution of rubber, affect the yield performance also. The rubber yield in region A (Figure 1) was highest. This can be attributed primarily to the non-gravelly, deep soils with high water holding capacity. Though the total rainfall is quite low (compared to other regions), it is well distributed and the dry period is minimum. The decline in yield as one moves from zone B to zone E (south to north) corresponds with the increase in the length of dry period, in the absence of significant soil variability in the same direction.

Table 1. Regional variability of soil properties, climate and rubber latex yield.

	Region A	Region B	Region C	Region D	Region E
Annual rainfall (mm)	~1500	~2500	~3000	~3500	~3500
Length of dry period	12 weeks	12 weeks	12 weeks	16 weeks	20 weeks
Soil depth (cm)	100 – 150	100-150	100 – 150	100 – 150	100 – 150
Soil texture	Non-gravelly clay	Gravelly clay	Gravelly clay	Gravelly clay	Gravelly clay
Soil organic carbon (%)	1.2	2.3	1.6	1.3	1.4
Available water capacity of soil (mm)	116	87	76	60	70
Mean dry rubber yield (kg/ha)	1451	1375	1298	1281	1141

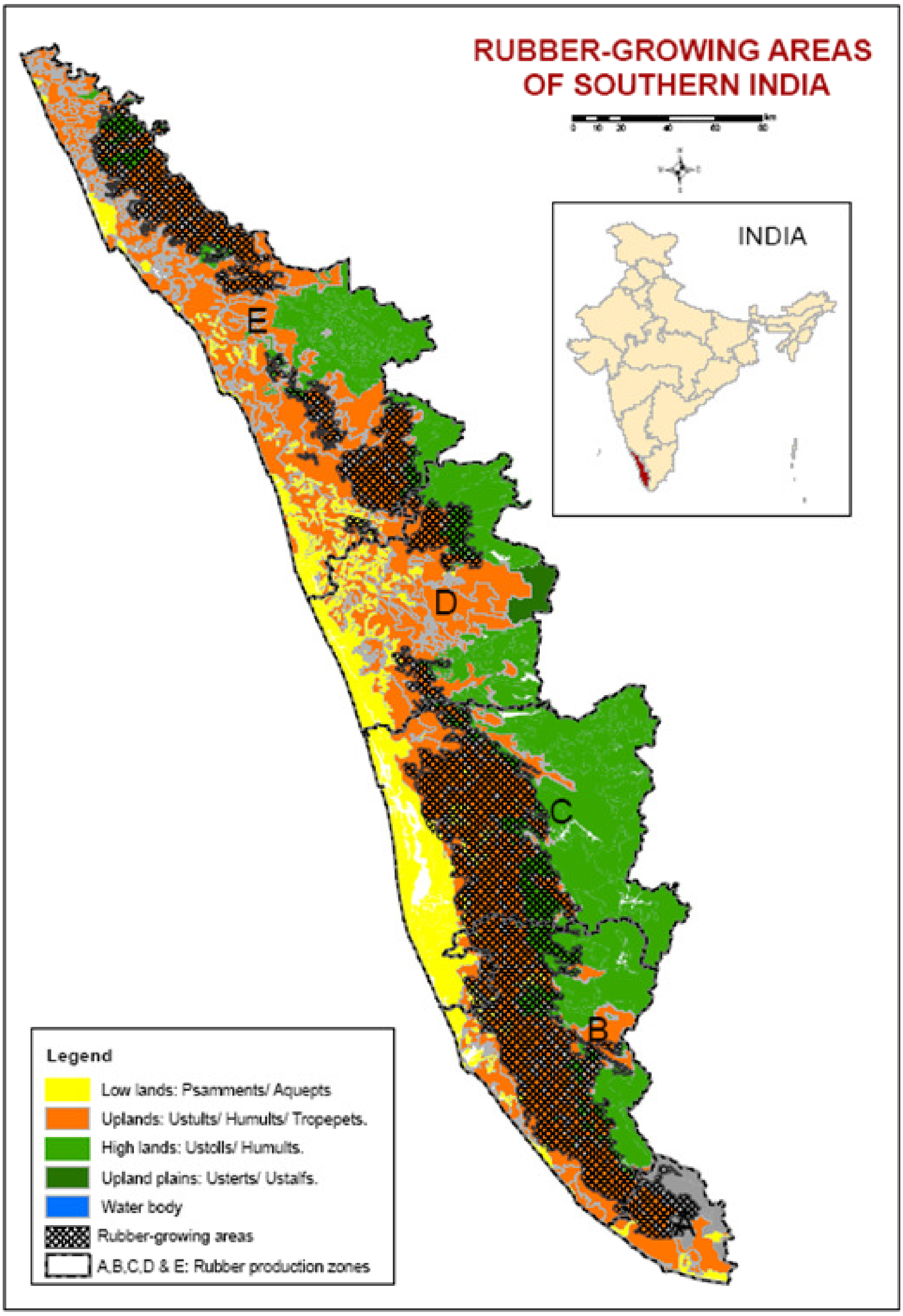

Figure 1. Spatial distribution of rubber-growing areas on a generalised landform-soil map of west coast of Southern India.

Conclusions

Tropical lands experiencing hot humid climate are eminently suitable for rubber production. The land related controls over rubber are elevation, climate and susceptibility of land to flooding. Elevation induced lower temperatures limit the suitability of land for rubber in high altitude regions of tropics. Well distributed rainfall, even when the total rainfall is only around 1500 mm, is adequate for the crop. Highly weathered, well drained tropical soils, though strongly acidic, low in bases and cation exchange capacity, were not found to limit rubber production. Soils with drainage limitations were unsuitable for rubber. Available water capacity of soils, as determined by the effective soil volume, coupled with amount and distribution of precipitation had a significant influence on productivity of the crop. Soil classification following USDA Soil

Taxonomy can be used as a primary guide for selecting areas for natural rubber production. Iso-hyperthermic temperature regime employed as a criterion for differentiating soil families according to Soil Taxonomy may be used with caution for assessing climatic suitability for rubber since the lower limit of the class (mean annual temperature of 22 °C) do not ensure year long temperature above 22 °C. Yield performance of rubber declines rapidly as the temperature goes below the value.

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