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Comparative study of soils of different landforms under rubber with special reference to erodibility indices/factor

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Abstract

Soil erodibility factor 'K' is a quantitative description of the inherent erodibility of a particular soil and it represents the susceptibility of soil particles to detachment and transport by both rainfall and runoff. Soils of different landforms under rubber (*Hevea brasiliensis*) in Kerala were studied with special reference to erodibility factor. Soils of nineteen-soil series developed on different landforms representing 70 per cent of the total potential rubber growing area were selected and the susceptibility of these soils to erosion was assessed by soil ratios and erodibility factor 'K' using soil survey information. The soil erodibility factor 'K' varies from 0.273 to 0.473, 0.353 to 481, 0.299 to 0.459 and 0.287 to 0.468 for soils developed on charnockite, laterite, khondalite and granite-gneiss landform, respectively. The soils of Vazhoor and Vijayapuram series developed on charnockite, Kaipuzha and Anayadi series of laterite, Kadambanad series of khondalite and soils of Pallippadi series identified in the granite-gneiss landform contained relatively high values of clay ratio and silt/clay ratio indicating that these soils are more susceptible to erosion than the other soils. Among the landforms, soils developed on laterite were relatively more susceptible to erosion compared to soils of other landforms. The study also revealed that soils with higher content of intermediate particle size fractions between sand and clay showed more erodibility risk than the soils with higher clay and higher sand content. In general, all the soils have moderate to high risk of erosion, thus needs suitable soil conservation measures to reduce soil loss and protect existing productivity.

Keywords: Erodibility indices/factor, *Hevea*, Kerala, landforms, soil ratios

Introduction

Rubber (*Hevea brasiliensis*) cultivation in India is confined to slope lands in the western side of Western Ghats mainly in Kerala state accounting for 90 per cent of the area. Slope lands under rubber are the most fragile and need attention because unfavaourable natural conditions can cause rapid soil erosion. The soils of this region were reported to be deep, acidic and poor in nutrient reserves. Land degradation caused due to soil erosion has direct on-site effects on the productivity of rubber (Samarappuli, 1992 and Samarappuli and Tillekeratne, 1995).

The prediction of soil erodibility (Elliot *et al*., 1989 and Brubaker *et al*., 1992) has renewed the interest of many researchers in studying the intrinsic soil factors that control water-dispersibility of soil particles. From a practical standpoint, prevention of soil erosion is as important as erosion control. Prevention can be attained if one knows what soils are susceptible to erosion and what factors are determining their susceptibility. Although reliable soil and climatic databases are a prerequisitic for soil erosion assessment, under tropical conditions, soil erodibility is influenced by various soil and terrain conditions especially slope gradient and inherent physical and chemical properties of the soil. It is known that the conservation of top soil is an important management target for sustainable soil productivity. With this in view, an attempt has been made to estimate the status of erodibility of rubber growing soils of Kerala developed under different landforms using inherent soil properties.

Materials and Methods

The area under study lies between 75º10' E and 77º 30' E longitudes and 8º 15' and 12º 35' N latitudes

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*Corresponding author: e-mail: satishagc@gmail.com with an area of 4.26 lakh ha under rubber. The area represents a major part of the midlands encompassing numerous landscapes from dissected hills to active lowlands starting from the sea coast to extending eastwards to elevations of above 20-30 m above msl. The altitude ranges from 30 to 300 m above msl and some of the isolated hillocks exceeding 300 metres are also seen in the midlands.

The climate of the area is humid subtropical. Average annual rainfall in the area varies from 2000 to 5000 mm. Rainfall is received from both south-west monsoon (June to September) and north-east monsoon periods (October to December) with about 60 per cent of the rainfall being received during the former. The mean maximum air temperature ranges between 28.1ºC (July) and 37.4ºC (March) and the mean minimum temperature ranges between 19.0ºC (December) and 26.0ºC (April). The Kottayam district has the highest area under rubber in the state followed by Ernakulam, Pathanamthitta, Idukki and Kollam districts, together accounting for about 65 per cent of the total area under rubber with the slope of the terrain varying from flat low land to 22 per cent.

The major geological formations and their chronological succession are crystalline rocks of Archean age, sedimentary rocks of tertiary age, laterites capping the crystalline and sedimentary rocks and Recent and Sub-recent sediments. The crystalline rocks chiefly comprise charnockites, khondalites, granites and gneissic granites and basic dykes. Charnockites are the most extensive and prominent rocks among the crystalline rock types of Kerala. Charnockites are encountered in the districts of Pathanamthitta (northern part), Kottayam, Ernakulam, Thrissur, Palakkad, Malappuram, Kozhikode, Wynad, Kannur and Kasaragod and the area receives on an average 2640 mm rainfall distributed through 180-200 days and the intensities ranging from 9 to 16 cm hr^{-1}. Khondalites occur in the southern part of Kerala in the districts of Pathanamthitta, Kollam and Thiruvananthapuram and in Kanyakumari district of Tamil Nadu and the area receives on an average 3788 mm rainfall distributed though 200-230 days and the intensities ranges from 10 to 20 cm hr^{-1} for a five min. duration storm and 80 per cent probability. The major causes for erosion in these areas especially in the mid and up lands are rainfall, slope, soil characteristics and crop canopy.

Soils under the study area are developed on four landforms, viz., khondalite, charnockite, granite-gneiss and laterite landforms. Of the sixty-two soil series identified in Kerala (Anonymous, 1999), nineteen-soil series which cover nearly 70 per cent of the total area under rubber were selected. The erodibility of the soils of seven series from charnockite, five from khondalite, four from laterite and three from granite-gneiss landform were assessed by soil ratios and erodibility factor 'K' using soil survey information (Anonymous, 1999).

Erodibility estimation

The Universal Soil Loss Equation (USLE) an erosion prediction model is currently the most comprehensive procedure for estimating the long-time averages of soil losses from a specified land in a specified cropping and management system. The USLE is an empirical equation derived from field and rainfall-simulated data on runoff and soil losses (Foster, 1988). It computes the soil loss for a given site, as a product of six major factors, whose most likely values at a particular location can be expressed numerically (Wischmeier and Smith, 1960) as:

$$A = R \times K \times L \times S \times C \times P$$

where,

A = the computed soil loss per unit area, expressed in the units selected for K and for the period selected for R. In practice, these are usually so selected that they compute A in tonne per ha per year, but other units can be selected.

R = the rainfall erosivity factor, is the number of rainfall index units for a particular location.

K = the soil erodibility factor, is the soil loss rate per erosion index unit for a specified soil as measured on a unit plot.

L = the slope length

S = the slope steepness

C = the crop management factor, is the ratio of soil loss from an area with specified cover and management, to that from an identical area in tilled continuous fallow.

P = the soil conservation practice.

The USLE relates the expected soil loss A to land erodibility expressed by R, K, L, and S, and the type of actual land use expressed by C and P.

Limitations of the USLE

Basically, the USLE has no geographic boundaries but its use in the tropics is generally limited by lack of data to compute soil losses. Moreover, under tropical conditions, soil erodibility is influenced by soil properties different than those identified in temperate regions.

Major weakness of the USLE for short-term soil loss estimation is the failure of R factor to adequately express hydrology. Other limitations such as: (i) it does not accurately estimate erosion for a specfic storm event, season, or year, (ii) it does not estimate erosion by concentrated flow, (iii) it does not estimate onsite deposition, (iv) it does not accurately estimate sediment yield from fields using delivery ratios, (v) it does not estimate sediment concentration in the runoff, and (vi) it does not provide information on sizes, densities, surface area and other sediment characteristics required to estimate potential deposition, adsorption, and transport of chemicals by sediment (Foster, 1979; Wischmeier, 1976).

The USLE has been modified several times primarily to overcome lack of data to compute the parameters included in the above equation. To address some of these limitations, Manrique (1987) developed a land erodibility assessment methodology (LEAM) to assess potential erosion risk of agricultural lands from limited soil data based on slope hazard and soil erodibility factor 'K' (Manrique and Meyer, 1990).

The soil erodibility factor 'K' is defined as the rate of soil loss per erosion index unit from unit plot size (Wischmeier and Smith, 1978) and it actually is a measure of the susceptibility of a given soil to particle detachment and transport (Lal, 1988). This susceptibility depends on many soil properties such as particle size distribution, structural stability, organic matter content and clay mineralogy, and so on.

There are basically three approaches to determine K. The first one involves the measurement of K under field conditions (Mutchler and Greer, 1980). In reality, the direct measurement of K from experimental run-off plot is expensive, and time comsuming.

The second approach is based on measurement of K under simulated rainstorms (Meyer and McCune, 1958). This approach is less time consuming but still costly. The third approach is to predict K using regressing equations describing relationships between K and soil physical and chemical properties. In view of this, a simple nomograph developed by Wischmeier *et al.* (1971) expressing the relationships between K and soil properties was employed in the present study.

$$100\ K = 2.4 \times 10^{-4} \times (2 - OM) \times M^{1.14} + 3.25 \times (St-2) + 2.5 \times (Pt-3)$$

Where, OM is organic matter content, M is silt plus fine sand content, St is the soil structure code (granular, platy, massive, and so on), and Pt is the permeability class.

Results and Discussion

The physical and chemical properties of rubber growing soils developed on different landforms are furnished in Table 1 and 2, respectively. The soils in general are deep to very deep, gravelly, medium texture, medium subangular blocky structure and of moderate permeability. The soils are acidic in reaction with low CEC. The organic matter content of the soils varied widely, ranging from 1.53 to 6.26 per cent.

Erodibility indices/factor for different soils under different landforms are presented in Table 3. The results indicated that clay and silt/clay ratio were high due to dominance of coarser fractions in the particle size distribution in all the soils except soils of Thiruvanchoor series. The soil erodibility factor varied from 0.273 to 0.473, 0.353 to 481, 0.299 to 0.459 and 0.287 to 0.468 for soils developed on charnockite, laterite, khondalite and granite-gneiss landform, respectively (Table 3). The soils of Vazhoor and Vijayapuram series developed on charnockite, Kaipuzha and Anayadi series of laterite, Kadambanad series of khondalite and soils of Pallippadi series identified in the granite-gneiss landform contained relatively high values of clay ratio and silt/clay ratio indicating that these soils are more susceptible to erosion than the other soils. It was also observed that these soils contained high per cent of silt plus fine sand and thus suggesting higher erodibility. Further, it is apparent from the data in the Table 3, the erodibility values of these soils ranged between 0.459 and 0.481. It indicates that soils with more content of intermediate particle size fractions between sand and clay erode more (high risk of erodibility) than the soils with higher clay and higher sand content. Richter and Negendank (1977) came to similar conclusions and according to them; the most susceptible textural ranges for detachment and transportation were very fine sand and silt.

It is also evident from the results that in soils of Thiruvanchoor series with more clay (53.4%) and soils of Kunnathur with more sand (72.2 %), the erodibility is relatively low (0.273 and 0.299 respectively). This could be due to inherent resistance of the soil when the flow velocity (mainly controlled by slope and rainfall) to cause detachment of the soil must attain threshold value before erosion commences.The chemical weathering and laterite formation giving rise to planation surfaces are the dominant landform-forming processes in these areas, preferably silicate weathering in the absence of substantial carbonate rocks. Therefore, as such, kaolinite is the predominant clay mineral formed during the course of weathering.

Table 1. Physical properties of rubber growing soils developed on different landforms in Kerala

Soil Series	Soil sub-group	Soil separates (%)			Textural class	Structure	Permeability
		Sand	Silt	Clay			
Charnockite landform							
Kanjirapally (Kpl)	Ustic Kandihumults	58.4	8.6	33.0	gscl	m2sbk	Moderate
Thiruvanchoor(Tvr)	Ustic Kanhaplohumults	36.1	10.5	53.4	gc	f1sbk	Moderate
Vazhoor (Vzr)	Ustic Kanhaplohumults	59.0	14.0	27.0	gscl	f1sbk	Moderate
Vijayapuram (Vpm)	Ustic Kandihumults	65.8	9.5	24.7	gscl	f1sbk	Moderate
Lahai (Lah)	Ustic Kanhaplohumults	44.6	10.8	44.6	c	m2sbk	Moderate
Koruthode (Ktd)	Ustic Haplohumults	45.2	15.4	39.4	gsc	m2sbk	Moderate
Cheruvalli (Cvl)	Ustic Kanhaplohumults	59.4	6.1	34.5	gscl	m2sbk	Moderate
Laterite landform							
Panachikkad (Pck)	Ustic Kanhaplohumults	42.3	14.1	43.6	gc	f1sbk	Moderate
Kaipuzha (Kpa)	Ustic Kanhaplohumults	63.9	11.6	24.5	gscl	f1sbk	Moderate
Anayadi (Ayd)	Typic Kandiustults	63.7	8.5	27.8	scl	f1sbk	Moderate
Mannanam (Mnn)	Ustic Kanhaplohumults	58.0	9.8	32.2	gscl	f1sbk	Moderate
Khondalite landform							
Kunnathur (ktr)	Ustic Kanhaplohumults	72.2	2.9	24.9	gscl	c2sbk	Moderate
Thrikkannamangal (Tmg)	Ustic Kandihumults	39.0	14.9	46.1	gc	m2sbk	Moderate
Kadambanad (Kdb)	Ustic Kanhaplohumults	54.8	13.3	31.9	gc	f1sbk	Moderate
Chandanikunnu (Cdn)	Ustoxic Dystropept	55.5	11.0	33.5	gscl	f1sbk	Moderate
Enathu (Ent)	Lithic Dystropept	40.9	15.6	43.5	gc	f1sbk	Moderate
Granite-gneiss landform							
Manjallor (Mnj)	Typic Kandiustults	47.1	7.9	45.0	gsc	m2sbk	Moderate
Ezhallur (Ezl)	Ustic Kanhaplohumults	50.1	8.9	41.0	gsc	m2sbk	Moderate
Pallippadi (Ppd)	Ustic Kandihumults	64.0	9.0	27.0	gscl	m2sbk	Moderate

Table 2. Physico-chemical properties of rubber growing soils developed on different landforms in Kerala

Soil Series	Soil sub-group	pH	Organic matter (%)	CEC (cmol(p+)/kg)	Base saturation (%)	Water holding capacity (mm/m)
Charnockite landform						
Kanjirapally (Kpl)	Ustic Kandihumults	4.4	3.86	5.4	17	76.6
Thiruvanchoor (Tvr)	Ustic Kanhaplohumults	4.7	2.78	8.3	19	53.8
Vazhoor (Vzr)	Ustic Kanhaplohumults	4.5	4.55	6.9	12	31.4
Vijayapuram (Vpm)	Ustic Kandihumults	4.6	1.74	3.6	14	58.8
Lahai (Lah)	Ustic Kanhaplohumults	4.9	6.26	9.3	14	119.4
Koruthode (Ktd)	Ustic Haplohumults	4.9	6.12	12.8	13	68.5
Cheruvalli (Cvl)	Ustic Kanhaplohumults	4.7	4.38	6.1	13	77.6
Laterite landform						
Panachikkad (Pck)	Ustic Kanhaplohumults	4.5	3.72	10.0	13	48.8
Kaipuzha (Kpa)	Ustic Kanhaplohumults	4.7	2.41	4.1	24	47.1
Anayadi (Ayd)	Typic Kandiustults	4.8	1.53	5.3	28	103.7
Mannanam (Mnn)	Ustic Kanhaplohumults	4.3	3.69	5.5	22	57.9
Khondalite landform						
Kunnathur (ktr)	Ustic Kanhaplohumults	4.9	2.97	6.3	11	31.5
Thrikkannamangal (Tmg)	Ustic Kandihumults	4.7	3.43	9.0	15	93.6
Kadambanad (Kdb)	Ustic Kanhaplohumults	4.6	3.40	7.7	18	43.2
Chandanikunnu (Cdn)	Ustoxic Dystropept	4.5	3.40	6.1	17	59.5
Enathu (Ent)	Lithic Dystropept	4.9	2.28	7.6	14	17.0
Granite-gneiss landform						
Manjallor (Mnj)	Typic Kandiustults	4.5	3.14	8.0	13	83.0
Ezhallur (Ezl)	Ustic Kanhaplohumults	4.8	3.47	6.3	13	69.3
Pallippadi (Ppd)	Ustic Kandiustults	4.8	1.71	4.0	21	93.9

Table 3. Erodibility indices/factor for rubber growing soils developed on different landforms in Kerala

Soil Series	Soil sub-group	Clay ratio	Silt/Clay ratio	Intermediate soil particles	Soil Erodibility factor 'K'
Charnockite landform					
Kanjirapally (Kpl)	Ustic Kandihumults	2.03	0.261	22.9	0.314
Thiruvanchoor (Tvr)	Ustic Kanhaplohumults	0.87	0.197	16.6	0.273
Vazhoor (Vzr)	Ustic Kanhaplohumults	2.70	0.519	55.6	0.462
Vijayapuram (Vpm)	Ustic Kandihumults	3.05	0.385	42.4	0.473
Lahai (Lah)	Ustic Kanhaplohumults	1.24	0.242	20.4	0.272
Koruthode (Ktd)	Ustic Haplohumults	1.54	0.391	51.6	0.366
Cheruvalli (Cvl)	Ustic Kanhaplohumults	1.90	0.177	16.5	0.283
Laterite landform					
Panachikkad (Pck)	Ustic Kanhaplohumults	1.29	0.323	37.7	0.353
Kaipuzha (Kpa)	Ustic Kanhaplohumults	3.08	0.473	44.3	0.470
Anayadi (Ayd)	Typic Kandiustults	2.60	0.306	44.7	0.481
Mannanam (Mnn)	Ustic Kanhaplohumults	2.11	0.304	31.2	0.353
Khondalite landform					
Kunnathur (ktr)	Ustic Kanhaplohumults	3.02	0.116	15.7	0.299
Thrikkannamangal (Tmg)	Ustic Kandihumults	1.17	0.323	28.5	0.318
Kadambanad (Kdb)	Ustic Kanhaplohumults	2.13	0.417	51.9	0.459
Chandanikunnu (Cdn)	Ustoxic Dystropept	1.99	0.328	20.7	0.308
Enathu (Ent)	Lithic Dystropept	1.30	0.359	37.1	0.373
Granite-gneiss landform					
Manjallor (Mnj)	Typic Kandiustults	1.22	0.176	18.6	0.287
Ezhallur (Ezl)	Ustic Kanhaplohumults	1.44	0.217	18.6	0.290
Pallippadi (Ppd)	Ustic Kandiustults	2.70	0.333	42.8	0.468

It is known that the soils with high organic matter content are less erodible. However, the soils of Vazhoor and Kadambanad series with fairly high organic matter content are more erodible that the soils with comparably less content of organic matter. This anomaly could be due to the presence of higher content of intermediate size particles, which overcome the effect of organic matter. Among the soils developed on different landforms, soils identified in the laterite landform with higher content of intermediate size particles showed higher erodibility. In contrast, soils of Thiruvanchoor series developed on charnochite landform are relatively less erodible, likely due to higher content of clay.

Based on the erodibility indices the soils were rated and grouped into different classes in the line of Manrique (1987). The soils and their corresponding per cent area under each erodibility classes are given in Table 4. The results indicate that 28 per cent of rubber growing soils in Kerala qualify for highly erodibile class, 34 per cent for moderately high and 38 per cent for moderate erodible class. Characteristically, there is no soil with low erodibility rating and it may be difficult to reduce the erodibility to a safer limit within a reasonable time as it depends upon the inherent soil properties besides slope of the terrain. Thus, it is concluded that soils have moderate to high risk of erosion and soil conservation management with wide range of practices are urgently needed to protect these soils and their existing productivity.

Table 4. Soil erodibility ratings

Erodibility risk	'K†'	Soil series of area	Per cent
Very low	0.00-0.10	-	
Low	0.10-0.20	-	
Moderate	0.20-0.30	Tvr, Lah, Cvl, Ktr, Mnj, Ezl	38
Moderately high	0.30-0.40	Kpl, Ktd, Pck, Mnn, Tmg, Cdn, Ent	34
High	0.40-0.50	Vpm, Vzh, Kpa, Ayd, Kdb, Ppd	28
Very high	>0.50	-	

†Manrique (1987)

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