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Erodibility assessment of rubber-growing soils of Kerala, India

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Abstract : Rubber-growing soils developed on different landforms in Kerala were evaluated for erodibility *vis-a-vis* their inherent soil properties. Of the sixty-two soil series identified in Kerala, nineteen soil series cover nearly 70 per cent of the total area under rubber, were selected. The erodibility of the soils of seven series developed over charnockite, five over khondalite, four over laterite and three over granite-gneiss was assessed. The results indicated that soils of Vazhoor, Vijayapuram, Kaipuzha, Anayadi, Kadambanad and Pallippadi series are more susceptible to erosion than the others. The soils of lateritic origin showed relatively higher erodibility than the soils developed over other parent materials. The soil erodibility factor 'K' varied from 0.273 to 0.473, 0.353 to 0.481, 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 with higher content of intermediate particle-size 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, and hence needs suitable soil conservation measures to reduce soil loss and in turn their productivity.

Additional key words: *Rubber-growing soils, landforms, erodibility, soil properties*

Introduction

The cultivation of rubber (*Hevea brasiliensis*) in India is confined on slopy lands of western side of Western Ghats mainly in Kerala state accounting for 90 per cent of the area. The slopy lands under rubber are the most fragile and needs attention in view of accelerated soil erosion. The soils of this region are reported to be deep, acidic with poor nutrient reserve. The land degradation mainly due to soil erosion has significantly affected the productivity of rubber (Samarappuli 1992; Samarappuli and Tillekeratne 1995).

The prediction of soil erodibility (Elliot *et al.* 1989; 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 an important as erosion control. Prevention can be attained if one knows which soils are susceptible to erosion and what factors are determining their susceptibility. Although reliable soil and climatic databases are a pre-requisitic 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 using inherent soil properties.

Materials and Methods

The area under study lies between 75°10' E and 77° 30' E longitudes and 8° 15' and 12° 35' N latitudes with an area of 4.26 lakh hectares under rubber. The area represents a major part of the midlands encompassing numerous landscape from dissected hills to active lowlands starting from the sea coast to eastward to a elevations of above 20 to 30 m above MSL. The altitude ranges from 30 to 300 m above MSL and some of the isolated hillocks exceeding 300 m are also seen in the midlands.

The climate of the area is humid subtropical. Average annual rainfall in the area various from 2000 to 5000 mm. The rainfal is received from both southweat monsoon (June to September) and northeast monsoon (October to December) with about 60 per cent of the rainfall being received during the southwest monsoon. The mean maximum air temperature ranges from 28.1°C (July) to 37.4 °C (March) and the mean minimum temperature ranges from 19.0°C (December) to 26.0°C (April). The Kottayam district has the highest area under rubber in the state followed by Ernakulam, Pathanamthitta, Idukki and Kollam districts, the five districts together contributing 65 per cent of the total area under rubber. The geological formations in the area include crystalline rocks of Archean age, sedimentary rocks of tertiary age, laterites capping over crystalline and sedimentary rocks and recent and sub-recent sediments.

The soils under study area are developed over khondalite, charnockite, granite-gneiss and laterite landforms. Of the sixty two soil series identified in Kerala, a total of nineteen soil series 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) is 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 run-off 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 t ha^{-1} $year^{-1}$, 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. More over, 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 on-site deposition, (iv) it does not accurately estimate sediment yield from fields using delivery ratios, (v) it does not estimate sediment concentration in the run-off, 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 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 permeability class.

Results and Discussion

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

The erodibility indices/factor for different soils developed on 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 (K) is the combined effect of particle-size distribution, organic matter, structural strength and permeability. The estimated erodibility (K) of different soils showed variation ranging from 0.273 to 0.473, 0.353 to 0.481, 0.299 to 0.459 and 0.287 to 0.468 for soils developed on charnockite, laterite, khondalite and granite-gneiss landform respectively. It was observed that soils with high per cent of silt plus fine sand showed higher erodibility, however, Richter and Nagendank (1977) reported that very fine sand and silt are most susceptible textural ranges for detachment and transportation. 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 on granite-gneissic landform with high values of clay ratio and silt/clay ratio are relatively more susceptible to erosion than the other soils. The erodibility values of these soils ranged between 0.459 and 0.481. It indicates that soils with more content of intermediate

Table 1. Morphological and physical properties of rubber-growing soils developed on different landforms

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

Texture: sc-sandy clay, c-clayey, scl-sandy clay loam, g-gravelly; Structure: m-medium, c-coarse, 2-moderate, 3-strong, sbk-subangular blocky

Table 2. Physical and chemical properties of rubber growing soils developed on different landforms

Soil Series	pH	Organic matter (%)	CEC cmol(p+)/kg^{-1}	Base saturation (%)	Water holding capacity (mm/m)
Charnockite landform					
Kanjirapally (Kpl)	4.4	3.86	5.4	17	76.6
Thiruvanchoor(Tvr)	4.7	2.78	8.3	19	53.8
Vazhoor (Vzr)	4.5	4.55	6.9	7	31.4
Vijayapuram (Vpm)	4.6	1.74	3.6	14	58.8
Lahai (Lah)	4.9	6.26	9.3	14	119.4
Koruthode (Ktd)	4.9	6.12	12.8	13	68.5
Cheruvalli (Cvl)	4.7	4.38	6.1	13	77.6
Laterite landform					
Panachikkad (Pck)	4.5	3.72	10.0	13	48.8
Kaipuzha (Kpa)	4.7	2.41	4.1	24	47.1
Anayadi (Ayd)	4.8	1.53	5.3	28	103.7
Mannanam (Mnn)	4.3	3.69	5.5	22	57.9
Khondalite landform					
Kunnathur (Ktr)	4.9	2.97	6.3	42	31.5
Thrikkannamangal (Tmg)	4.7	3.43	9.0	31	93.6
Kadambanad (Kdb)	4.6	3.40	7.7	38	43.2
Chandanikunnu (Cdn)	4.5	3.40	6.1	6	59.5
Enathu (Ent)	4.9	2.28	7.6	14	17.0
Granite-gneiss landform					
Manjallor (Mnj)	4.5	3.14	8.0	13	83.0
Ezhallur (Ezl)	4.8	3.47	6.3	13	69.3
Pallippadi (Ppd)	4.8	1.71	4.0	78	93.9

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

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

Table 4. Soil erodibility ratings

Erodibility risk	'K†'	Soil series	Per cent of area
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 (1988)

particle-size fractions between sand and clay erode more than the soils with higher clay and higher sand content. It is 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 *ie* 0.273 and 0.299 respectively. This could be due to inherent resistance of the soil when the flow velocity to cause detachment of the soil must attain threshold value before erosion commences.

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 presence of higher content of intermediate size particles, which negate the effect of organic matter. Among the soils developed on different landforms, soils identified on lateritic 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 sloppy 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.

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