International Journal of Chemical Studies 2019; 7(6): 2907-2914

International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(6): 2907-2914

Received: 15-09-2019
Accepted: 19-10-2019

SP Maske
ICAR-NBSS&LUP,
Regional Centre, Hebbal,
Bangalore, Karnataka, India

KS Anil Kumar
ICAR-NBSS&LUP,
Regional Centre, Hebbal,
Bangalore, Karnataka, India

KM Nair
ICAR-NBSS&LUP,
Regional Centre, Hebbal,
Bangalore, Karnataka, India

Rajendra Hegde
ICAR-NBSS&LUP,
Regional Centre, Hebbal,
Bangalore, Karnataka, India

S Srinivas
ICAR-NBSS&LUP,
Regional Centre, Hebbal,
Bangalore, Karnataka, India

K Sujata
ICAR-NBSS&LUP,
Regional Centre, Hebbal,
Bangalore, Karnataka, India

BP Bhaskar
ICAR-NBSS&LUP,
Regional Centre, Hebbal,
Bangalore, Karnataka, India

Corresponding Author:
SP Maske
ICAR-NBSS&LUP,
Regional Centre, Hebbal,
Bangalore, Karnataka, India

Estimation of soil loss in rubber (*Hevea brasiliensis*) growing areas of Kerala and Karnataka, India

SP Maske, KS Anil Kumar, KM Nair, Rajendra Hegde, S Srinivas, K Sujata and BP Bhaskar

Abstract

Soil erosion is viewed as a major process of land degradation in rubber-growing areas under hot moist sub-humid to humid agro-ecological region of Kerala and Karnataka in India. The bench mark survey with geo-reference at 121 locations was carried out with the objective of deriving soil-water conservation strategies in the extensive rubber-growing areas of Kerala and Karnataka (5.2 lakh hectares with productivity of 1514 kg/hectare). In the present study, Rainfall erosivity for 7 locations (considering monthly rainfall 1971 to 2007) and soil erodibility (Epipedons of 121 bench mark soils) were used. Monthly rainfall data, for the period 1971 to 2007 were used to compute the Modified Fournier index (MFI) The results showed that June, July and August receive maximum rainfall with very high Modified Fournier index (>160) from 433.4 (Trivandrum) to 2641.2 MJ mm ha^{-1} h^{-1} y^{-1} (Kannur) with an increasing from southward to northward. The soil erodibility (K) for five major soil subgroups of humults were 0.15 to 0.24 indicating that these soils are weakly susceptible to water erosion. Majority of the area (45.73% of TGA) is susceptible to extremely strong erosion followed by very strong erosion on 25.40 per cent of TGA and strong erosion in 22.28 per cent of TGA. The soil loss estimations can serve as effective inputs in prioritizing soil conservation strategies and management in rubber growing areas of Kerala and Karnataka.

Keywords: Agro-ecology, Modified Fournier Index, Rubber, Soil Loss, USLE

Introduction

Degradation of agricultural land by soil erosion is a worldwide phenomenon leading to topsoil loss, increased runoff and decreased water availability to plants under tropical and subtropical regions of the world. It was reported that the human induced degradation accounting 1100 Mha by water and 550-Mha by wind was reported globally (Saha, 2003) [29]. Erosion reduces soil productivity with altered physical, chemical, and biological properties and can pose a direct threat to food security (Lal, 2001[16]; Stocking, 2003) [37]. In India, almost 130 million hectares of land (45% of the total geographical area, TGA), is affected by serious soil erosion (Kothyari, 1996) [14]. India also confronts such critical landscape ecology because of its growing population (1.15 billion people, 17% of world population) and degraded land of 105.48 mha (32.07% of TGA). Ajai, *et al.* (2009) [1]; reported that area under each category of erosional processes accounts to 26.21 mha (10.21% of TGA) by water erosion, 17.77 mha by eolian (5.34%) and vegetal (17.63mha or 9.63%), frost (3.1%), salinity and alkalinity (1.6%), mass movement (1.35%), water logging (0.3%), rocky/barren (0.5%) and others (0.04%). The cultivation of rubber (Hevea *brasiliensis*) in India is confined on slopy lands of Western Ghats in Kerala state accounting for 90 per cent of the total area. The rainfall is of high intensity (60 mm h^{-1}) and the average annual rainfall ranges between 1500 and 3000 mm within a short span of 6 to 7 months. Heavy downpours occur in short spell during the monsoons. Aerial distribution of slope classes indicates that 87% of the land is characterized by slopes where unscientific and indiscriminate land use intensify the erosion. The major portion of the state is lateritic and as such these soils are porous in nature, coarse texture and medium to low in cohesiveness and more prone to soil erosion. On an average 15-18 t ha^{-1} of top fertile soil is eroded in Kerala, ultimately resulting in low fertility status besides having other implications like low crop productivity and ground water recharge (State of Environment Report Kerala, Regulator 2007) [36]. 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 [31]. Samarappuli and Tillekeratne, 1995) [30]. The soil resource inventory on 1:50000 scale was initiated during 1996 in rubber growing areas of Kerala and identified 62 soil series to derive 411 soil mapping units as series association. These soil series were classified in the subgroups of Ultisols, Inceptisols and Entisols (NBSS & LUP, 1999) [22]. It was further reported that the estimated erodibility (K) of different rubber soils in Kerala varied from 0.273 to 0.473 (charnokite), 0.353 to 0.481(laterite), 0.299 to 0.459 (khondalite) and 0.287 to 0.468 (granite-gneiss) landform respectively. Based on the erodibility indices, the soils were rated and grouped into different classes in the line of Manrique (1987) [17]. 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. Studies showed that the major portion of Kerala (51.98%) falls in 0-5 tones ha^{-1}/ year soil loss categories and less than 5% of the area is subjected to severe form of soil erosion (Jose *et al*., 2011) [12]. The type of developmental activities in rubber plantations has significantly affected the ecological, biological and hydrological functions of hill land ecosystem and created a serious erosional loss of top soil. The rubber planted hill lands suffered from two kinds of erosion such as sheet and rill due to high intensity of surface runoff initiated by heavy rainfall. The unsustainable land use patterns within and around the rubber growing areas further aggravate erosion and sedimentation with drastic reduction in productivity levels (Prasanna Kumar *et al.* (2012) [24]. Modeling can provide a quantitative and consistent approach to estimating soil erosion and under a wide range of rubber growing areas of Kerala. In the present study, potential soil loss has been estimated for the 121 bench mark sites spread over the entire state of Kerala by spatially and also area of the state into 10 km x 10 km square grids made in soil resource mapping of Kerala (Krishnan *et al.* (1996) [15] and applying the Universal Soil Loss Equation (USLE). With this background, the objectives of the present study are: (1) to estimate soil loss of rubber growing areas in Kerala using remote sensing data and GIS with Universal Soil Loss Equation (USLE) and (2) to identify the priority zones for soil water conservation programmes useful for enhancing rubber productivity.

Materials and Methods

Study Area, Agroclimate and soils

The study area includes 14 districts of Kerala state and 5 districts in Karnataka, where rubber is grown in 8 lakh hectares (1.18 per cent of the total geographical area of the country). Kerala is on the Malabar Coast of South India and Spread over 38,863 km^2. It is bordered by Karnataka to the north and northeast, Tamil Nadu to the east and south, and the Lakshadweep Sea to the west. Geographically, Kerala can be divided into three climatically distinct regions: the eastern highlands; rugged and cool mountainous terrain, the central mid-lands; rolling hills, and the western lowlands and coastal plains The eastern region of Kerala consists of high mountains, gorges and deep-cut valleys immediately west of the Western Ghats' rain shadow. A catastrophic flood in Kerala in 1341 BC drastically modified its terrain and consequently affected its history. It also created a natural harbour for spice transport (Chattopadyay *et al*., 2006) [4]. Pre-Cambrian and Pleistocene geological formations are composed of the bulk in Kerala's terrain (Sharma *et al*., 2006) [33].

The area comes under the agro-ecological sub-region of Western Ghats with hot humid-perhumid eco-region (E2BA5) with deep, loamy to clayey red and lateritic soils, low to medium AWC and LGP 210-270 days (Sehgal *et al*., 1995) [22]. in recent agro-climatic studies, considering weekly rainfall and probability of wet/dry cycles of minimum 10 years of data to bring out ninety-eight agroecological subunits (Nair *et al*., 2011) [21].

Soil sampling was carried out at selected sampling stations located around the rubber gardens of Kerala / parts of Karnataka. The monthly rainfall data was obtained from the IMD (Indian Meteorological Department, Pune). Physical conditions such as slope, land cover and conservation practices were considered at the time of survey and sampling. The GIS software was used in spatial data analysis to determine erosion potential and erosion risk map of the study area. The study area was digitized by Ilwis 3.3 and ArcView GIS 9.3 for the soil series, topography and land use. For the measurement of the soil erodibility factor, using USLE, a soil map was used as the basis for determining the LS factor, C factor and P factor values. Particle size distribution was determined by the international pipette method (Gee and Bauder, 1977) [8]. The texture of the soils was obtained by plotting the ratio of sand, silt and clay using the soil texture triangle. Organic matter content was determined by wet digestion method (Walkey and Black, 1934) [40]. Soil erosion were estimated using the Universal Soil Loss Equation (Renard *et al*., 1997) [27]. A flow chart showing the preparatory steps for estimation of soil erosion is presented in Fig. 1.

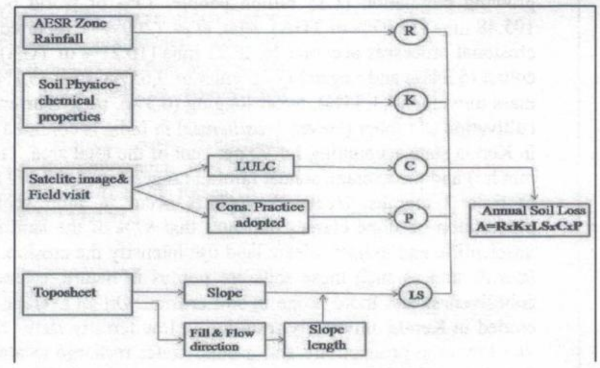

Fig 1: Methodology for deriving map showing soil loss

Universal Soil Loss Equation (USLE)
The most widely used model for soil loss estimation is the USLE because of its simplicity and empirical nature (Fistikoglu and Harmancioglu, 2002[6];). USLE estimates annual soil loss using empirical formula as given under

A=R K L S C P (1)

Where,
A is rate of soil loss, tonnes / ha / yr, R is rainfall erosivity, MJ mm/ha/h/yr, K is soil erodibility, LS is topographic factor, C is crop management factor and P is conservation practice factor.

Rainfall erosivity (R)
It represents contribution of impact of rainfall in the soil erosion process. This factor is most influential when compared to the other USLE factors (Jebari, 2009) [11]. It is calculated by multiplying the kinetic energy (E) and maximum intensity for the 30 minutes of the storm (I_{30}). The expression for computation of R factor (Wischmeier and Smith, 1978 [41]; Brown and Foster, 1987 [3]; Meusberger *et al*, 2012) [18] is:

$$R = \sum_{j=1}^{n} \sum_{k=1}^{m} (EI_{30})_k \quad (2)$$

Where,
R is average annual erosivity, MJ mm/ha/h/yr, n is number of years of records, m is number of erosive events of a year.

This stated procedure in original approximation by Wischmeier (FAO, 1996) [7] requires pluviograph and rain gauge chart of each storm. But in many meteorological stations in rubber growing areas of Kerala and Karnataka. The EI data was not available. Therefore we attempted to estimate R factor from readily available data using modified Fournier index proposed by Arnoldous (1980) [2] and expressed as

$$F = \frac{\sum_{i=1}^{12} P_i^2}{P} \quad (3)$$

Pi is the mean monthly rainfall for month I and P is mean annual rainfall
Renard and Freimund (1994) [28] obtained the relationship between rainfall erosivity (R in MJ mm/ha/h/yr) and easily obtainable modified fournier index (F) as described in the following equations:

$$R = \frac{0.7397F^{1.847}}{100} \quad (4)$$

$$R = \frac{95.77+6.081F+0.477F^2}{100} \quad (5)$$

Equation 4 is valid for F<=55 and equation 5 is valid for F>55. In this study these two equations are used for the calculation of rainfall erosivity using Fournier index from rainfall data.

Soil erodibility (K)
Soil erodibility is the susceptibility of the soil to the erosion by water. It depends on spatial soil properties. Soils with high clay content and coarse textured soils have low K values whereas soils having high silt content are most erodible of all soils. Medium textured soils are moderately erodible. Wischmeier and Smith (1978) [40] proposed the relationship for soil erodibility based on experiments with simulated and natural runoff plots given as:

$$K = 2.1\, M^{1.4} 10^{-4}(12 - a) + 3.25(b - 2) + 2.5(c - 3) \quad (6)$$

Where, M = % silt (100-% clay)
a is organic matter in per cent
b is soil structure code
c is soil permeability code

Laboratory analysis of horizon wise soil samples was done for particle size distribution and organic carbon collected during soil survey of the area. Soil structure code and permeability code was determined according to soil type.

Topographic factor (LS)
In hilly regions of rubber growing areas in Kerala and Karnataka, the slope length and steepness factor was calculated as per the equation proposed by Morgan and Davidson (1991) [19] and tested by Jebari (2009) [11] and Onyando *et al.* (2004) [23] and expressed as below:

$$LS = \sqrt{\frac{L}{22}}(0.065 + 0.45\, S + 0.0065\, S^2) \quad (7)$$

Where, L is the slope length and S is slope in per cent.
Crop management factor (C)

It is the ratio of soil loss from the land use to the soil loss from the bare land. Several authors have calculated the C factor for various types of land uses (Singh *et al*., 1981) [34]. The value of C factor ranges between 0 to 1. In theory, we adopt a value of 1 for completely unprotected, bare soil and for more erosion reducing plant cover the value decreases, giving a lower estimation of gross erosion. The C factor was calculated from the experimental data for the rubber garden by Kelvin *et al.* (2013) [13] and used in the present study.

Conservation practice factor (P)
P factor in USLE accounts for the impact of soil conservation practices on soil erosion and it is most uncertain factor (Haan *et al*., 1994 [9]; Morgan and Nearing, 2011) [20]. P factor for rubber growing areas were determined as per Kelvin *et al.*, (2013) [13] and presented in Table 1. Similar values were used in computation of soil loss.

Table 1: P factor for different conservation practices

Soil conservation practice	P factor
None	1.0
Contouring	0.60
Contour strip cropping	0.35
Terracing	0.15

Results and Discussion
Characteristics of rubber growing soils
Twenty-three agro-ecological units (AEU's) have been delineated (Nair *et. al*, 2011) [21]. for the rubber-growing areas of Kerala and Karnataka. The state profile shows that 4.76 lakh hectare (ha) of land is under rubber cultivation and concentrated mostly in five agroecological units *viz*., southern central laterites (AEU-9, 9.42% of total geographical area (TGA), southern and central foot hills (AEU-9, 8.13% of TGA), Northern foot hills (AEU-13, 3.71-% of TGA), southern hills (AEU-14, 17.3%of TGA) and Northern high

hills(AEU-15, 13.6of TGA). Broadly, the rubber growing soils are moderately shallow (50-75 cm) to deep (100-150 cm) / very deep (>150 cm), well drained, gravelly clay soils occurring on midland laterites to moderately steeply sloping (15-25%) laterite mounds. They are classified at sub-group level as Kandihumults, Kanhaplohumults, Kandiustults and Kanhaplustults. The rubber under low hills in midlands are associated partly with forest having moderately shallow (50-75 cm) to very deep (>150 cm), well drained, gravelly clayey soils with high AWC (150-200 mm/m) occurring on gently sloping (3 to 5%) to moderately steeply sloping (15-25%). These soils are classified as Palehumults / Haplohumults / Haplustolls / Argiustolls / Dystrustepts and Haplustepts (Krishnan, *et al.*, 1996) [15]. The soil resource data along with climatic and topographic, landuse / conservation practices recorded during field survey were used to estimate soil loss as per USLE as given under:

Erosivity factor (R)

R factor was calculated for the thirteen rain gauge stations located in rubber growing areas of Kerala and Karnataka during the period of 1991 to 2007 (Table 2). The annual mean rainfall of rubber growing area is 2779.3 ± 625.9 mm with coefficient of variation of 22.52% characterizing the mean modified Fournier index of 549.3 ± 195.6 mm and CV of 35.6% to class the region as having high aggressiveness in the region (Szilassi *et al.*, 2006) [38]. The erosivity density was calculated as the erosivity per rainfall unit (mm), and is expressed as MJ ha^{-1} h^{-1}.

Erosivity density (ED) = R / P where R = average annual rainfall erosivity (MJ mm ha^{-1} h^{-1} yr^{-1}) and P is the average annual rainfall (mm yr^{-1}) (Hijmans *et al.*, 2005) [10]. Erosivity density values higher than 1 in kollur and hosanagara locations indicate that a certain precipitation amount may cause relatively higher rainfall erosivity. This means that regions with high erosivity density are exposed to risk of flooding and even water scarcity as a result of their infrequent but very intense and erosive rainstorms (Dabney *et al.*, 2011) [5]. Erosivity density (ED) is lower than 1 ranging from 0.76 to 0.87 due to the predominance of low intensity rainfall events. High erosivity density months indicate that the precipitation is characterised by high intensity events of short duration (rainstorms). Earlier the average annual EI value had been used as a basis for developing the iso-erodent map of India (Rambabu *et al.*, 1978) [26] which was then subsequently improved and published by Raghunath *et al.* (1982) [25]. by inclusion of additional rainfall data from new stations. The R factor for each of the grid points in the state of Kerala was generated with the help of this iso-erodent map (Fig. 2(a)) by employing interpolation technique and reported that higher values of erosivity (>2000) are observed in more than 90% of Kasargod and Kannur districts; Kozhikode (78.95%) and Waynad (17.99%) districts which constitute the southern part of Kerala state (Krishnan *et al.*, 1996) [15].

Table 2: Erosivity of rubber growing areas (1991 to 2007)

Location	R (Erosivity) (MJ mm/ ha/h/yr)	Modified Fournier index (MFI)	Mean annual rainfall (1991-2007)	Erosivity density (ED) MJmmha $^{-1}$ hr $^{-1}$
Kollur	3772-High	886	3292.0	1.15
Hosanagara	2543-medium	729	2000.0	1.27
Payyanur	3187 -high	815	3553.0	0.90
Kannur	2641 medium	723	3160.7	0.84
Manthanavadi	1252-medium	542	2517.5	0.50
Ambalavayal	373 -very low	283	2011.7	0.19
Kozikode	2126-medium	646	3112.2	0.68
Palakkad	701-low	379	2037.3	0.34
Thrissur	1166 -medium	495	2983.5	0.39
Iddukki	1260- medium	490	3762.7	0.33
Kottayam	1088-medium	474	3059.9	0.36
Punalur	705-low	378	2679.5	0.26
Trivandrum	433-very low	301	1960.8	0.22
Mean	1634.38	549.31	2779.29	0.57
SD	1104.32	195.55	625.89	0.36
CV(%)	67.57	35.60	22.52	63.28

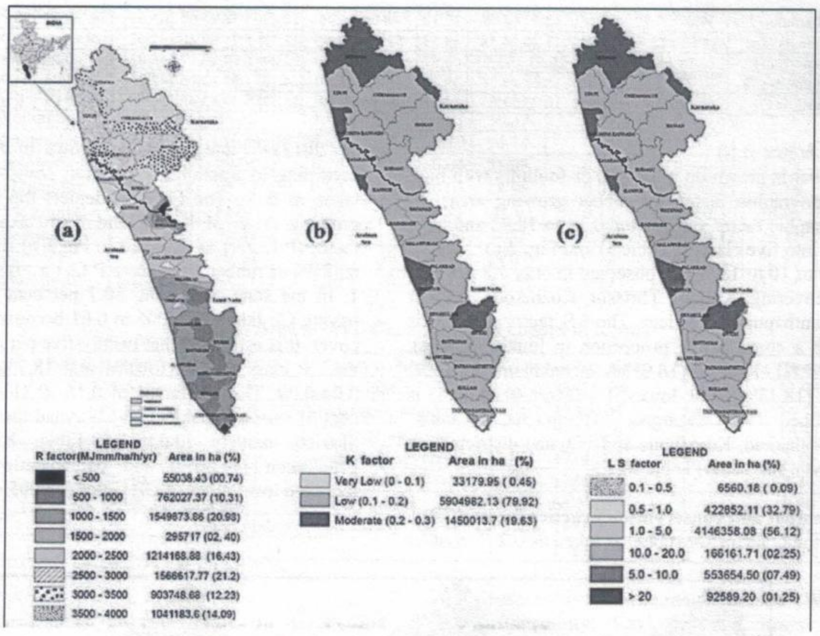

Fig 2: USLE factors: (a) R factor, (b) K factor (c) factor

Soil erodibility factor (K)

The soil erodibility map of Kerala and a part of rubber growing Karnataka is presented in Fig. 2(b). In soil erodibility estimations, only the particle size and organic matter data of top A-horizons were used. The K values of rubber growing soils are less than 0.2 (Manrique 1988) [17] indicating that these soils are not susceptible to water erosion due to good infiltration capacity and good permeability over very steep slopes (Table 3). The Pachic Paleustolls and Humic Dystrustepts have K value more than 0.2 indicating that these soils are weakly susceptible to water erosion due high humus content and good structure. This finding is in agreement with the results reported in soils of Czech Republic (Vopravil *et al.*, 2007) [39]. The lower values of erodibility (0.03-0.08) are observed in considerable area only of Alappuzha (21.45%) and Thiruvananthapuram (4.69%) districts while most of the area (>80%) in Kannur, Kasargod, Kottayam, Kozhikode, Mallapuram, Palakkad, Thrissur and Waynad of Kerala. The K factor varies from 0.15-0.20. The maximum acreage of second class of K-factor (0.09-0.14) is observed in Thiruvananthapuram (52.61%); Alappuzha (47.98%), Kollam (44.47%), Pathanamthitta (27.36%), Idukki (26.12%), Ernakulam (26%), Kannur (15.76%), Kasargod (13.6%), Kottayam (11.12%), Thrissur (10.46%) and other districts. The mean silt content is 20.51±1.37% (Pachic Paleustolls) with variation of 66.97% (Table 4).The mean sand is more than 40% in Ustic Plinthohumults (40.77±8.47%), Typic Kandihumults (44.32±7.95%) and Ustic Haplohumults (44.03±7.54%).These soils have clay content more than 40% with coefficient of variation of 15.77 to 26.9 per cent with low K values.

Table 3: Soil erodibility of rubber growing soils

Soil taxonomy	Particle size distribution (%)			OM (%)	Structure code	Permeability code	K value	Classification
	Sand	Silt	Clay					
Typic Plinthohumults 10	38.15	13.14	48.71	1.92	4	6	0.19	Low
Ustic Haplohumults 16	44.03	13.54	42.43	1.67	4	6	0.18	Low
Ustic Palehumults 16	36.29	14.37	49.34	1.79	4	6	0.17	Low
Ustic Kanhaplohumults 21	39.07	12.60	48.33	1.68	4	5.94	0.18	Low
Ustic Kandihumults 26	34.37	13.28	52.35	1.48	4	6	0.19	Low
Patchic Paleustolls 5	35.39	20.51	44.10	1.17	4	6	0.21	Moderate
Ustic Plinthohumults 6	36.64	11.47	51.89	1.84	4	6	0.17	Low
Humic Dytrustepts 3	49.01	17.93	33.06	3.21	4	5.5	0.20	Moderate
Typic Kandiustults 3	44.32	10.73	44.95	0.69	4	6	0.16	Low

Table 4: Soil erodibility of rubber growing soils of Kerala

Soil subgroups	Sand		silt		clay		Very fine sand		Organic matter		K value	Classification
	-------------------------------------(%)-------------------------------------											
	$\bar{x}$ ±SD	CV (%)	$\bar{x}$ ±SD	CV (%)	$\bar{x}$ ±SD	CV (%)	$\bar{x}$ ±SD	CV (%)	$\bar{x}$ ±SD	CV (%)		
Typic Plinthohumults (10)	38.15 ±6.41	16.81	13.14 ± 2.21	16.83	49.03± 5.17	10.54	5.29 ± 1.44	27.19	1.92 ± 0.58	30.42	0.194	Low
Ustic Haplohumults (16)	44.03 ±7.54	17.12	13.54±2.75	20.32	42.16±8.12	19.27	7.12± 3.03	42.56	1.67 ±0.47	28.21	0.178	Low
Ustic Palehumults (16)	36.29± 13.07	36.02	14.37± 3.97	27.62	49.54± 13.33	26.90	5.70± 2.69	47.25	1.79± 0.61	34.03	0.177	Low

Ustic Kanhaplohumults (21)	39.07 ±7.49	19.18	12.60 ±4.68	37.12	48.08 ±6.96	14.47	5.78 ±2.64	45.67	1.68 ±0.57	33.72	0.184	Low
Ustic Kandihumults (26)	34.37 ±12.73	37.04	13.28 ±6.58	49.53	51.67 ±11.46	22.18	5.71 ±2.40	42.02	1.48 ±0.46	31.00	0.189	Low
Patchic Paleustolls (5)	35.39 ±8.82	24.92	20.51 ±13.73	66.97	45.87 ±10.20	22.24	6.89 ±3.17	46.02	1.17 ±0.21	17.67	0.206	Moderate
Ustic Plinthohumults (6)	40.77 ±8.47	20.78	13.63 ±5.36	39.30	45.61 ±10.99	24.10	4.86 ±2.06	42.28	2.30 ±1.03	44.96	0.168	Low
Typic Kandiustults (3)	44.32 ±7.95	17.93	10.73 ±1.53	14.27	44.96 ±7.09	15.77	5.94 ±3.48	58.68	0.69 ±0.01	1.96	0.160	Low

Topographic factor (LS)

Generally rubber is grown on hillslopes or foothills with high values for topographic factor for rubber growing areas. In Kerala, topographic factor varies from 0.14 to 18.93 and have been grouped into five classes (Table 5) and Fig. 2(c).

The LS factor of 10 to 18.93 are observed in only 1.8 per cent of total area covering: Kollam, Thrissur, Kozhikode, Kannur and Thiruvananthapuram districts. The LS factor 3 to 10 is prevalent with a considerable proportion in Idukki (27.6%), Thrissur (24.72%), Kollam (18.92%), Ernakulam (18.13%) and Palakkad (18.13%). The lowest LS factor (0.14 -0.5) is mostly confined to Kasargod, Alappuzha, Kannur, Mallapuram, Palakkad, Kozhikode and Waynad districts with low level alluvial flat lands (Table 5).

Crop management and conservation practice factor (CP)

In this study, the C factor for rubber is taken as 0.2 (Kelvin *et al.*, 2013) [13] and for rubber grown in thick forest is taken according to fractional vegetation cover. For this area, it is taken as 0.03. The Fig 3(a) depicts the C factor for rubber growing areas of Kerala and Karnataka. The conservation factor (P factor) as depicted in Fig.3(b) shows that more than 62.85% of rubber areas have P factor >0.6 and 32.68% under 1. In the state of Kerala, 30.7 per cent to the total area is having CP factor of 0.005 to 0.01 because of thick vegetation cover. It is estimated that twenty-five per cent of area is under the CP class of 0.02 to 0.04 and 18.7% under CP class of 0.04-0.08. The CP factor of 0.16 -0.31 covers only 2.0 per cent of area in Palakkad and Waynad districts (Table 5). The districts namely Idukki (58.13%), Kottayam (55.95%), Ernakulam (44.86%) and pathanamthitta (44.19%) have recorded low values of CP factor (0.0005 – 0.01).

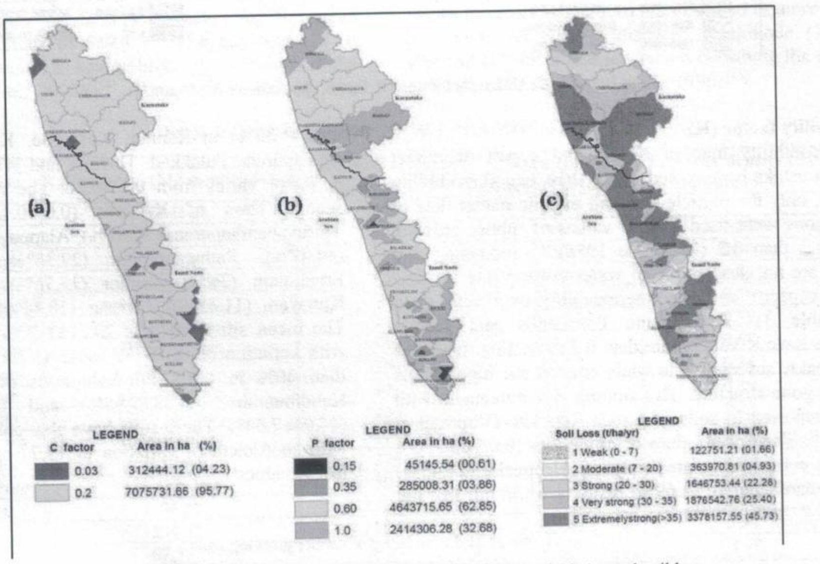

Fig 3: USLE factor and soil loss (a) C factor, (b) P factor and (c) Annual soil loss

Mapping and estimation of Soil loss

The soil erosion map of Kerala / part of Karnataka depicts five classes of soil loss (Fig. 3(d)). Majority of area (49.8%) in Kerala comes under 0 - 5 t ha^{-1} yr^{-1} soil loss category and spreads over the state. The reason for large area of the state falling in the category is due to dense cover rubber in association with forest.

Even in the higher slope ranges the presence of thick forest restricts soil loss. In coastal areas flatness of the terrain contributes to lower rates of soil loss. Moderately slight (5-10 t ha^{-1} yr^{-1}) erosion occur 31.8 per cent area. Major part of this class covers the districts of Kasargod, Kannur, Kozhikodu, Malappuram, Palakkad, Thrissur, pathanamthitta and Kollam. In 10.5 per cent area of Kerala, the potential soil loss is estimated at 10-15 t ha^{-1} yr^{-1}. Mostly this catogery of soil loss is concentrated in the districts of Wayanad, Palakkad, Thrissur and Kollam with small pockets in Ernakulam, Idukki, Alapuzha, Pathanamtitta and Thiruvanatapuram districts.

Moderately severe (15-20 t ha^{-1} yr^{-1}) and severe (20-40 t ha^{-1} yr^{-1}) categories of the soil loss occur in 2.59 and 2.4% of TGA respectively in the districts of Wayanad, Thrissur, Idukki, Ernakulam, Kottayam and patches in Palakkad, Alapuzha and Kollam. Some of the areas of Wayanad and Ernakulam have soil loss of 20-40 t ha^{-1} yr^{-1} due to high rainfall. In parts of strongly sloping areas of Kollam, Thrissur, Palakkad, Wayanad and Ernakulm, severe soil loss (>40 t ha^{-1} yr^{-1}) is reported (Table 6).

Table 5. Topographic, crop management and conservation practice factor for rubber soils of Kerala /part of Karnataka

Soil taxonomy	Topographic factor			Crop management factor			Conservation factor		
	$\bar{x}$ ±SD	CV (%)	C.I. at 95%	$\bar{x}$ ±SD	CV (%)	C.I. at 95%	$\bar{x}$ ±SD	CV (%)	C.I. at 95%
Typic Plinthohumults	1.99±2.04	102.67	1.26	0.20±0.00	0.00	0.00	0.41±0.15	36.55	0.09
Ustic Haplohumults	3.69±2.08	56.35	1.02	0.18±0.07	38.37	0.03	0.46±0.26	57.56	0.13
Ustic Palehumults	7.05±9.16	130.01	4.49	0.11±0.10	94.14	0.05	0.66±0.33	50.66	0.16
Ustic Kanhaplohumults	2.24±1.77	79.04	0.74	0.19±0.04	21.98	0.02	0.40±0.17	41.75	0.07
Ustic Kandihumults	2.59±2.48	95.54	0.95	0.18±0.05	28.96	0.02	0.48±0.23	47.19	0.09
Patchic Paleustolls	2.21±1.80	81.60	1.58	0.08±0.11	131.91	0.10	0.79±0.30	38.08	0.26
Ustic Plinthohumults	2.72±2.45	90.01	1.96	0.20±0.00	0.00	0.00	0.48±0.13	26.71	0.10
Humic Distrustepts	2.47±1.00	40.54	1.13	0.13±0.11	84.67	0.12	0.58±0.43	72.90	0.49
Typic Kandiustults	1.26±1.03	81.37	1.17	0.07±0.11	165.64	0.13	0.78±0.38	47.91	0.43

Table 6. Area under different soil loss classes in Kerala

S. No.	Soil loss (t ha^{-1} yr^{-1})	Erosion class	Area (sq. Km)	Area (% to TGA
1	<5	slight	38419.19	51.98
2	5-10	Moderately slight	22749.95	30.78
3	10-15	Moderate	7546.362	10.21
4	15-20	Moderately severe	1914.307	2.59
5	20-40	Severe	1744.311	2.36
6	>40	Very severe	66.52033	0.09
7	Water bodies		1411.709	1.91
	Total		73911.48	100.0

Conclusion

Soil loss for the rubber growing areas of Kerala and Karnataka is estimated using Universal Soil Loss Equation. The estimated erosivity factor (R) using the Modified Fournier Index showed that this region is categorized as high aggressive with risk of flooding and high intensive rains (MFI =549.3±195.6mm) and low erodability of ultisols and associated soils (K = 0.03 to 0.08). The topographic factor is varied from 0.14 to 18.93 with lowest values in low level alluvial flat lands. The crop and conservation factor (CP factor) is 0.01 to 0.05 indicating dense vegetation cover throughtout study area. As per USLE equation, The region is classified into six soil loss categories and estimated area under each category. The results showed that only 2.45% of area is classified as severe to very severe soil loss covering Wynad and Thrissur districts with high LS factor and erosivity. The study demonstrated the utility of soil resource information in estimation of soil loss in rubber growing areas and to prioritise the areas for improving soil-water conservation measures.

Acknowledgement

The authors wish to express their sincere gratitude to Dr L.G.K. Naidu and P. Krishnan, retired Principal scientist and Head, Regional Centre, ICAR-NBSS&LUP, Bangalore for their constant encouragement and support during this study. We express thanks to Dr. S.K. Singh, Director, ICAR-NBSS & LUP, Nagpur for his cooperation and useful discussions in improving the status of manuscript.

References

1. Ajai AS, Arya PS, Dhinwa S, Pathan K, Ganesh Raj K. Desertification / Land Degrdation Status Mapping of India. Current Science. 2009; 97:1478-1483.
2. Arnoldous HMJ. An approximation of the Rainfall Factor in the Universal Soil Loss Equation. In De BoodtM, Gabriels D. (eds.). Assessment of Soil Erosion.John Wiley and Sons, Chichester, Gran Bretaña, 1980, 127-132.
3. Brown LC, Foster GR. Storm erosivity using idealized intensity distribution. Trans. ASAE. 1987; 30:379-386.
4. Chattopadhyay Srikumar, Richard WF. Striving for Sustainability: Environmental Stress and Democratic Initiatives in Kerala Concept Publishing Company, 2006, 110
5. Dabney SM, Yoder DC, Vieira DAN, Bingner RL. Enhancing RUSLE to include runoff-driven phenomena. Hydrol. Process. 2011; 25(9):1373-1390.
6. Fistikoglu O, Harmancioglu Nilgun B. Integration of GIS with USLE in assessment of soil Erosion. Water Resources Management. 2002; 16:447-467.
7. FAO (Food and Agriculture Organization of the United Nations) Land husbandry – Components and strategy: FAO, 1996.
8. Gee GW, Bauder JW. Particle size analysis, In Klutem A. (Ed.). Methods of Soil Analysis: Physical and mineralogical methods, Part-1.2nd. Soil Science Society of America Inc., Madison, WI, 1986, 383-409.
9. Haan CT, Barfield BJ, Hayes JC. Design Hydrology and Sedimentology for Small Catchments Academic Press, San Diego, 1994.
10. Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A. Very high-resolution interpolated climate surfaces for global land areas. Int. J. Climatol. 2005; 25:1965-1978.
11. Jebari S. Water erosion modeling using fractal rainfall disaggregation – A study in semiarid Tunisia, Water resources engineering, Lund University, Sweden, 2009.
12. Jose PA, Pandurangan AG, Hussain A. Effect of auxins on clonal propagation of Gluta travancorica Bedd. - an endemic tree of Southern Western Ghats. Ind. J For. 2011; 34(1):85-88.
13. Kelvin KK, Kuok Darrien YS, Mah Chiu PC. Evaluation of C and P Factors in Universal Soil Loss Equation on Trapping Sediment: Case Study of Santubong River. Journal of Water Resource and Protection. 2013; 5:1149-1154.
14. Kothyari UC. Erosion and sediment problems in India Proc. of the Exeter Symposium on Erosion and Sediment Yield: Global and Regional Perspectives, 1996, 531-540.
15. Krishnan P, Venugopal KR, Sehgal JL. Soils of Kerala for optimizing land use. 1996; NBSS Publ. 48b. NBSS & LUP, Nagpur, 2001, 54.

16. Lal R. Soil degradation by erosion. Land Degradation and Development. 2001; 12(6):519-539.
17. Manrique LA. A methodology to assess land erodibility from information contained in Soil Taxonomy-based soil surveys. Agronomy Abstracts, American Society of Agronomy Annual Meeting, Atlanta, GA, 1987, 22.
18. Meusburger K, Steel A, Panagos P, Montanarella L, Alewell C. Spatial and temporal variability of rainfall erosivity factor for Switzerland. Hydrol. Earth Syst. Sci, 2012; 10.5194/hess-16-1-2012.
19. Morgan RP C, Davidson DA. Soil Erosion and Conservation, Longman Group, U.K, 1991.
20. Morgan RPC, Nearing M. Handbook of Erosion Modelling John Wiley & Sons, 2011.
21. Nair KM, Anil Kumar KS, Krishnan P, Naidu LGK, Dipak Sarkar. Variability of lateritic soil development in humid tropical environment. Clay Research. 2011; 30(2):12-20.
22. NBSS and LUP. Resource soil survey and mapping of rubber growing soils of Kerala and Tamil Nadu-Consultancy project for Rubber Research Institute of India, Rubber Board, Kottayam, National Bureau of Soil Survey and Land Use Planning, Nagpur, India, 1999, 295.
23. Onyando JO, Kisoyan P, Chemelil MC. Estimation of Potential Soil Erosion for River Perkerra Catchment in Kenya, Department of Agricultural Engineering, Egerton University, Njoro Kenya, 2004.
24. Prasannakumar V, Vijith H, Abinod S, Geetha N. Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using Revised Universal Soil Loss Equation (RUSLE) and geo-information technology. Geoscience Frontiers. 2012; 3(2):209-215.
25. Raghunath B, Khullar AK, Thomas PK. Rainfall energy maps of India. Indian J Soil Cons. 1982; 10(2):1-17.
26. Ram Babu, Tejwani KK, Agrawal MC, Bhusan LS. Rainfall Intensity Duration-Return Equation and Nomographs of India. CSWCRTI, ICAR, Dehradun, India, 1979.
27. Renard K, Foster G, Weesies G, McCool D, Yoder D. Predicting Soil Erosion by water: a guide to conservation planning with revised universal soil loss equation (RUSLE). US Government Printing Office, Washington, DC, 1997.
28. Renard KG, Freimund JR. Using monthly precipitation data to estimate the R-factor in the revised USLE. J Hydrol. 1994; 157:287-306.
29. Saha SK. Satellite Remote Sensing and GIS Applications in Agricultural Meteorology. Proceedings of a Training Workshop held 7-11 July 2003 in Dehra Dun, India, 2003; 315-330.
30. Samarappuli LN, Tillekeratne LMK. Impact of physical environment and agromanagement on land degradation and on the performance of Hevea brasiliensis; A commissioned paper on rubber. Rubber Research Institute of Sri Lanka, Dartonfield, Agalawatta, Sri Lanka, 1995.
31. Samarappuli, Lalani. Some agronomic aspects in overcoming moisture stress in Hevea brasiliensis. Indian Journal of Natural Rubber Research. 1992; 5:127-132.
32. Sehgal J, Mandal DK, Mandal C. AgroEcological Subregions of India (Map). NBSS and LUP, 1995.
33. Sharma S, Joachimski MM, Tobschall HJ, Singh IB, Sharma C. Chauhan MS *et al*. Correlative evidence of monsoon variability, vegetation change and human habitation in Senai lake deposit, Ganga plain. Current Science. 2006; 90:973-978.
34. Singh G, Ram Babu, Chandra S. Soil loss prediction research in India; Tech. Bull. T-12/D-9, Central Soil and Water Conservation Research and Training Institute, Dehradun, India, 1981.
35. Soil Survey Staff. Keys to Soil Taxonomy; 12th ed. USDA-NRCS, Washington, DC, 2014.
36. State of Environment Report-Kerala Land Environment, Wetlands of Kerala and Environmental Health. Kerala State Council for Science, Technology and Environment. Govt. of Kerala I, 2007.
37. Stocking MA. Tropical Soils and Food Security: The Next 50 years. Science. 2003; 302(5649):1356-9.
38. Szilassi P, Jordan G, van Rompaey A, Csillag G. Impacts of historical land use changes on erosion and agricultural soil properties in the Kali Basin at Lake Balaton, Hungary. Catena. 2006; 68:96-108.
39. Vopravil J, Janecek M, Tippl M. Revised soil erodibility K-factor for soils in the Czech Republic. Soil and Water Research. 2007; 2(1):1-9.
40. Walkley A, Black IA. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 1934; 37:29-37.
41. Wischmeier WH, Smith DD. Predicting Rainfall Erosion Losses: a Guide to Conservation Planning. Agriculture. USDA-ARS, USA, 1978, 282.