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Research Article

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Soil Erosion from Farming Lands in Tropical Islands of India

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Abstract

Soil erosion from crop lands of tropical South Andaman district in Bay Islands of India was estimated using the Universal Soil Loss Equation. Using 38 years of rainfall, monthly and annual values of rainfall erosivity (R) were determined. Average monthly value of R was ranged from 1.48 to 132.67 metric ton.m.ha^{-1} hr^{-1}. It was observed that 103.77 thousand tonnes of soil were lost annually from the cultivable area of the district at the rate of 59.40 t ha^{-1}yr^{-1}. Under the single cropped land, green gram cultivated in *kharif* season contributes highest rate of soil loss (83.64 t ha^{-1}yr^{-1}) and ginger yields lowest rate of soil loss (22.17 t ha^{-1}yr^{-1}), whereas, for double cropped land, sweet potato-vegetable-fallow contributes lowest rate of soil loss (24.91 t ha^{-1}yr^{-1}) and green gram-vegetable-fallow yield highest rate of soil loss (79.09 t ha^{-1}yr^{-1}). Mono-cropped land contributed more soil loss due to upland farming situation, thin canopy, weak soil binding by crop roots, more erodibility and erosivity in the peak soil-eroding season and fallow state of crop lands. The average annual rate of soil loss in mono-crop land was estimated as 59.40 t ha^{-1}yr^{-1} and that of double cropped land was estimated as 42.63 t ha^{-1}yr^{-1}. It is assessed that there would be a reduction of 28.23% soil loss if the mono cropped land is converted to double cropped land in the district.

1. Introduction

Poor management and continuous degradation of land and water are the major constraints towards augmentation of agricultural production of a country. According to the National Bureau of Soil Survey and Land Use Planning, 146.8 Mha of land of India is degraded (NBSS&LUP, 2014). Nearly 29% of total eroded soil is permanently lost to the sea, while 61% is simply transferred from one place to another and the remaining 10% is deposited in reservoirs (Bhattacharyya *et al.,* 2015). India is losing a huge amount of money from degraded lands. Reddy (2003) valued the loss of production in India in the year 2003 as Rs. 68 billion using the National Remote Sensing Agency (NRSA) dataset. Additional losses resulting from salinization, alkalinization and water-logging are estimated as Rs. 8 billion. Water erosion is the most serious degradation problem resulting in loss of topsoil and terrain deformation. Sharda *et al.* (2010) made a comprehensive study on the impact of water erosion on crop productivity and observed that soil erosion due to water resulted in an annual crop production loss of 13.4 MT in cereal, oil seeds and pulse crops equivalent to US$ 162 billion. With changing climate, land degradation is expected to increase due to high intensity storms, extensive dry spells and denudation of forest cover. Major portion (98.0%) of total soil loss from a watershed is from the cultivated croplands. As a result of which, the total annual loss of productivity of major crops in India is 7.2 million tonnes (Brandon *et al.,* 1995; Suresh *et al.,* 2002; Naik *et al.,* 2015). The tune of soil loss from the cropped lands in tropical islands is generally higher in comparison to that of plain area due to undulating topography characterized with hills, hillocks and flat bottomed valleys and high intensity storms (Pandey *et al.,* 2007).

The Union Territory of Andaman and Nicobar in India consist of a group of tropical islands which experience torrential and high rainfall during wet season from South-West monsoon (Pandey *et al.,* 2007). Agricultural activities, particularly vegetable cultivation exposes surface soils to the rainfall which carry away a huge amount of top fine soil particles to the Andaman Sea in Bay of Bengal through low-lying streams and makes soil deficient in nutrients (Pandey and Singh, 2009). The land mass of these islands is precious not only from the soil fertility point of view, but also for the existence of the islands as well. Land

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use wise information on soil erosion estimated using run off plot, so far, is not available for these islands (Velmurugan *et al.,* 2008). In this study, an attempt has been made to assess the soil loss from the farming lands of South Andaman district applying the Universal Soil Loss Equation (Wischmeier and Smith, 1978).

2. Materials and Methods

The area selected for study is the South Andaman district, a group of ten inhabited islands spread over an area of 310.6 thousand ha as a part of Andaman and Nicobar group of islands of India in Bay of Bengal (Figure 1). The district lies between latitude of 6°45´ to 13°4´ North and longitude of 92°15´ to 94° East at an elevation of 13.0 m from mean sea level with 95.3 percent of the land area covered with dense tropical rain forest. The normal annual rainfall in the district is 3054.2 mm with 131.1 rainy days (Nanda *et al.,* 2018). The cultivable area, at present, is 10.41 thousand ha. Out of which 6.89 thousand ha area are under cultivation and the rest area are under fallow and uncultivated. Gross cropped area is 7,141.04 ha and cropping intensity is 104% (Nanda *et al.,* 2018). The agriculture and climate related data used in the study were collected from Directorate of Economics and Statistics, Andaman and Nicobar Administration, Port Blair and ICAR-Central Island Agricultural Research Institute, Port Blair.

Major field crops grown in the district are vegetables, paddy, maize, ginger, sweet potato and turmeric. Vegetables and paddy are grown in an area of 1317.0 ha and 216.0 ha which

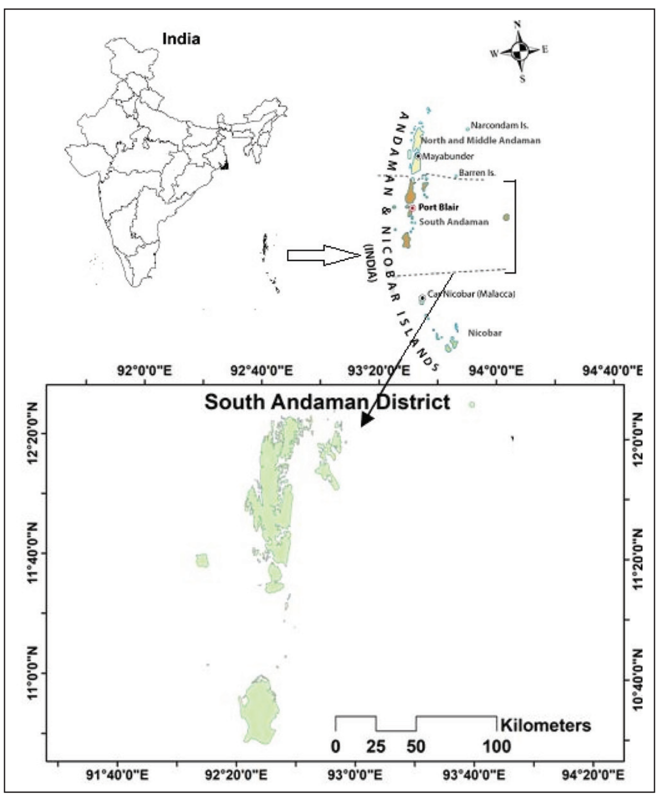

Figure 1: Location map of South Andaman district

accounts for 75% and 12% of the total cultivated area of 1747.8 ha respectively. Other crops cultivated in the area are maize (55.0 ha), ginger (51.5 ha), sweet potato (46.0 ha), tapioca (26.5 ha), turmeric (19.5 ha), green gram and black gram (13.7 ha). Among all the crops, paddy, maize, arhar, ginger, sweet potato, turmeric, tapioca and ground nut are grown in *kharif* season whereas, mustard, green gram, black gram and vegetables are grown in *rabi* season and only vegetables are grown in *summer* season.

Universal Soil Loss Equation, popularly known as USLE model (Wischmeier and Smith, 1978) is most widely used throughout the world for estimating annual soil loss from agricultural lands (Ahmad and Verma, 2013; Naik *et al.,* 2014) and was used to calculate the rate of soil erosion from crop lands of South Andaman district and was given in Equation 1.

$$A = R \times K \times L \times S \times C \times P \qquad \text{.................. (1)}$$

Where,

A = the average soil loss for the given period, t $ha^{-1}yr^{-1}$

R = Rainfall erosivity index

K = Soil erodibility factor

L = Length of slope factor

S = Steepness of slope factor

C = Cropping management factor

P = Conservation practice factor

Rainfall erosivity factor (R) was calculated by using the rainfall data for the period from 1978 to 2016. For this, kinetic energy of the rain storms was computed as per the equation proposed by Wischmeir (1959) as below:

$$KE = 210.3 + 89 \log_{10} I \qquad \text{.................. (2)}$$

Where,

KE = Kinetic energy of the storm, metric ton.m.$ha^{-1}cm^{-1}$.

I = Rainfall intensity, cm hr^{-1}.

Erosivity factor values for each erosive storm were computed for 30 minutes rainfall intensity using the following empirical equation (Raghunath and Erasmus, 1971) as stated in Equation 3.

$$R = (KE \times I_{30}) / 100 \qquad \text{.................. (3)}$$

Where,

R = Erosivity factor, in metric ton.m.$ha^{-1}hr^{-1}$.

KE = Kinetic energy of the storm, metric ton.m.$ha^{-1}cm^{-1}$.

I_{30} = Maximum 30 minutes rainfall intensity, cm/hr which is calculated from each storm event using recording raingauge chart.

Relationship between monthly R and rainfall (P) was to be established through regression analysis (Erasmus *et al.,* 1970). The highly significant empirical equation developed between R and P will be used to compute the monthly R values corresponding to normal monthly rainfall. The value of soil erodibility factor (K) was determined as 0.26 for South Andaman district referring the technical report published by Sahoo *et al.* (2013). The value of slope length and slope gradient factor (LS) was taken as 1.95 as area weighted average of lowest two nos. of data series for LS as published in Sahoo *et al.* (2013) and crop management factor (C) of crops were determined from the technical report published by Sahoo *et al.* (2013). Referring published journals and reports, the value of crop management factor (C) of common crops were used in this study (Table 1). The value of C factor was considered as "1" during the period when the field was left fallow (Ghosh and Babu, 1977; Shri Niwas *et al.,* 1980). The value of supporting conservation practice factor (P) was determined considering the crop wise conservation practice followed in the farmers' field of these islands (Table 2).

Table 1: Values of crop management factor 'C'

Sl. No.	Crop	Value of 'C' factor
1	Rice	0.28
2	Maize	0.45
3	Green gram	0.41
4	Black gram	0.49
5	Arhar	0.38
6	Ground nut	0.36
7	Mustard	0.30
8	Ginger	0.30
9	Turmeric	0.35
10	Sweet potato	0.33
11	Tapioca	0.50
12	Vegetable	0.33
13	Perennial grass	0.03
14	Fallow field	1.00

[Source: Roose (1976); Panigrahi (2007)]

Table 2: Values of Conservation practice factor 'P'

Sl. No.	Conservation practice	P-factor values
1	Contour bunding	0.20
2	Field bunding	0.30
3	Cultivated fallow	1.00

[Source: Kurothe, 1991]

3. Results and Discussion

A linear regression model was developed between the computed values of R and rainfall, P with coefficient of determination of 0.87 and the same was expressed as:

$$R = - 23.15 + 0.208 P \qquad \text{.................. (4)}$$

Using the above Equation 4, the value of R of each strom event of rest of the years of study was estimated using the values of P of each storm event. These monthly R values were added to get the R values for the yearly normal rainfall. The monthly and annual rainfall, and values of rainfall erosivity or erosion index unit (R) from 1978 to 2016 were given in Figure 2 and Figure 3.

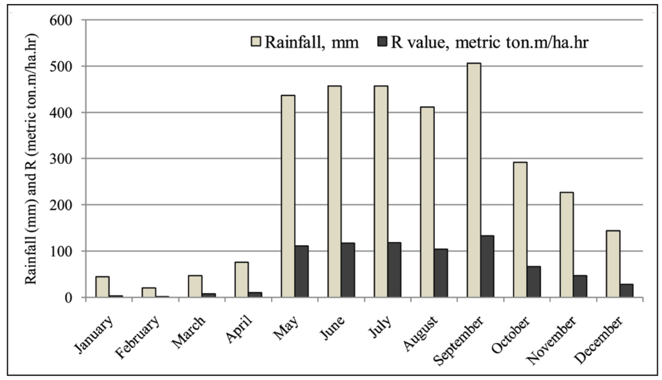

Figure 2: Month-wise rainfall and erosivity (1978-2016) [(a) Primary Y axis title : Rainfall (mm) and R (metric ton.m.ha^{-1}hr^{-1}); (b) Primary Y axis values: 0, 100, 200, 300, 400, 500, 600; (c) Primary X axis values: January, February, March, April, May, June, July, August, September, October, November, December; (d) Legends: Rainfall, mm, R value, metric ton.m.ha^{-1}hr^{-1}]

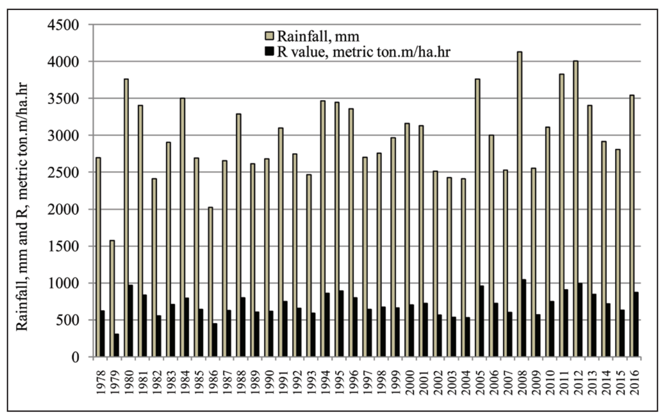

Figure 3: Year-wise rainfall and Erosivity (1978-2016) [(a) Primary Y axis title: Rainfall (mm) and R (metric ton.m.ha^{-1}hr^{-1}); (b) Primary Y axis values: 0, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500; (c) Primary X axis values: 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016; (d) Legends: Rainfall, mm, R value, metric ton.m.ha^{-1}hr^{-1}]

The values of erosivity factor corresponding to average monthly rainfall varied from 1.48 metric ton.m.ha^{-1}hr^{-1} (in February) to 132.67 metric ton.m.ha^{-1}hr^{-1} (in September). This is due to the occurrence of more nos. of erosive storms in the month of September as compared to other months. The highest and the lowest R values of 1047.2 metric ton.m.ha^{-1} hr^{-1} and 304.6 metric ton.m.ha^{-1}hr^{-1} was observed in the year 2008 and 1979 respectively due to the rainfall variation (highest rainfall of 4130.4 mm in 2008 and the lowest rainfall of 1574.1 mm in 1979). Higher rainfall amount was observed during the months from May to October as compared to other months. The months from May to September showed R values of more than 100 metric ton.m.ha^{-1}hr^{-1} (ranging from 103.68 to 132.67 metric ton.m.ha^{-1}hr^{-1}) with an average of 116.6 metric ton.m.ha^{-1}hr^{-1} per month.

As per the prevailing cropping practice, total crop growing seasons (*Kharif+Rabi+Summer*) was taken as 9 months (June to February) and R values were computed accordingly. R value for individual crop was determined considering its cropping period. When the land was fallow, R value for that particular fallow period was taken for soil loss calculation. Crop-wise annual soil loss was calculated and found that an annual soil loss of 1,03,773.58 tons at the rate of 59.40 t ha^{-1}yr^{-1} was yielded from the agricultural fields of the South Andaman district. Most of the crops are cultivated as mono crops and among them, green gram cultivated in *kharif* season contributes the highest rate of soil loss (83.64 t ha^{-1}yr^{-1}) and ginger yields the lowest rate of soil loss (22.17 t ha^{-1}yr^{-1}) (Figure 4). The land cultivated by green gram in *kharif* season contributed more soil loss due to longer fallow period and during which the soil is exposed to most of the erosive storms during the period than other crop fields. Rice crop is mostly cultivated in bunded low lying lands and water-logging occurs rarely in these islands due to quick drainage of excess rainfall to the sea. Most of the cases standing crop during *kharif* suffers when there is a dry spell of more than a week.

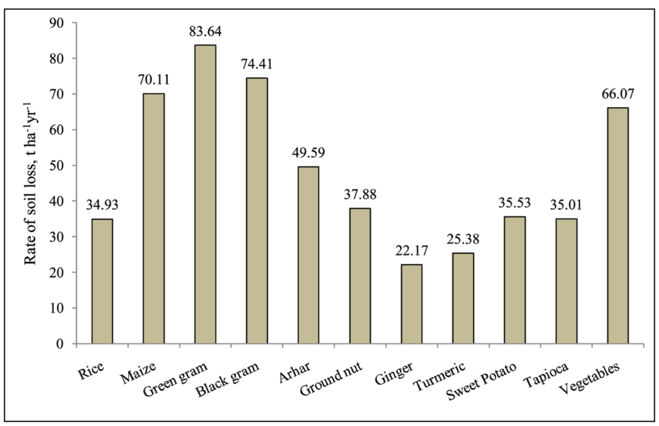

Figure 4: Soil loss from mono cropped land [(a) Primary Y axis title: Rate of soil loss, t ha^{-1}yr^{-1}; (b) Primary Y axis values: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90; (c) Primary X axis values: Rice, Maize, Green gram, Black gram, Arhar, Ground nut, Ginger, Turmeric, Sweet Potato, Tapioca, Vegetables; (d) Vertical Bar values: Rice (34.93), Maize (70.11), Green gram (83.64), Black gram (74.41), Arhar (49.59), Ground nut (37.88), Ginger (22.17), Turmeric (25.38), Sweet Potato (35.53), Tapioca (35.01), Vegetables (66.07)]

Among the double cropped lands (Figure 5), the sequence of sweet potato-vegetable-fallow contributes lowest rate of soil loss (24.91 t ha^{-1}yr^{-1}), where as the cropping sequence of green gram-vegetable-fallow yield highest rate of soil loss (79.09 t ha^{-1}yr^{-1}). The average rate of soil loss from double cropped

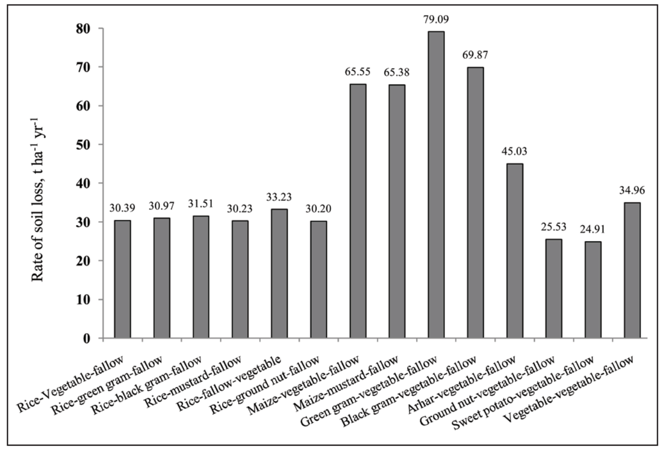

Figure 5: Soil loss from double cropped lands [(a) Primary Y axis title : Rate of soil loss, t ha^{-1}yr^{-1}; (b) Primary Y axis values: 0, 10, 20, 30, 40, 50, 60, 70, 80; (c) Primary X axis values: Rice-Vegetable-fallow, Rice-green gram-fallow, Rice-black gram-fallow, Rice-mustard-fallow, Rice-fallow-vegetable, Rice-ground nut-fallow, Maize-vegetable-fallow, Maize-mustard-fallow, Green gram-vegetable-fallow, Black gram-vegetable-fallow, Arhar-vegetable-fallow, Ground nut-vegetable-fallow, Sweet potato-vegetable-fallow, Vegetable-vegetable-fallow; (d) Vertical Bar values: Rice-Vegetable-fallow (30.39), Rice-green gram-fallow (30.97), Rice-black gram-fallow (31.51), Rice-mustard-fallow (30.23), Rice-fallow-vegetable (33.23), Rice-ground nut-fallow (30.20), Maize-vegetable-fallow (65.55), Maize-mustard-fallow (65.38), Green gram-vegetable-fallow (79.09), Black gram-vegetable-fallow (69.87), Arhar-vegetable-fallow (45.03), Ground nut-vegetable-fallow (25.53), Sweet potato-vegetable-fallow (24.91), Vegetable-vegetable-fallow (34.96)]

land was 42.63 t ha^{-1}yr^{-1}. It is assessed that there would be a reduction of 28.23% soil loss if the mono crop land is changed to double cropped land.

The rate of soil loss from the cropped land showed extremely severe soil erosion as it exceeds considerably the soil loss tolerance limit of 11.2 t ha^{-1}yr^{-1} (Mannering, 1981). Soil loss tolerance is a limit which denotes the maximum level of soil erosion that will permit crop productivity to be sustained economically. Mannering (1981) reported that the tolerance limits are ranging from 4.5 to 11.2 t ha^{-1}yr^{-1} and soil loss in excess of 11.2 t ha^{-1}yr^{-1} affected the effectiveness of water conservation structures. At this stage, the gully formation starts which in turn obstructs the intercultural operation (Singh *et al.,* 1981). It is a matter of serious concern that due to huge loss of surface soil on account of soil erosion, associated with macro, major and micronutrients are also lost recurrently each year leading to nutrient depletion and poor soil fertility. Therefore, good conservation planning in the Union Territory of Andamans' is of utmost importance towards optimizing agricultural production. Deforestation and forest degradation are the predominant causes of water erosion in undulating and steeply sloping hills of these groups of islands. Dense forests are being converted into poor stock and thin degraded fallow lands. The situation has now been aggravated due to pressure of population rise, deforestation etc. Besides these, due to the land surrounded by sea and other various limitation factors like intrusion of saline water into cultivable land causing soil salinity, stagnation and water logging in the low lying paddy areas, deposition of gravels carried from different gullies and nallahs and its deposition on the flat agriculture land in the foot hills are the major causes for land degradation in cultivable land.

Comprehensive soil conservation work for sustainable management of natural resources is to be undertaken in the study area. These includes treatment of all existing nallahs in upper, middle and lower reaches including construction of check dams, sunken ponds, staggered contour trenches, contour bunds, contour ditching, so that more water is allowed to percolate into the soil resulting in reduction in runoff volume, and increase in water table. Provision for safe disposal of overland flow and runoff will prove highly beneficial to control erosion. On sloppy crop lands where erosion is more, land terracing should be adopted. The cultivable land affected by soil salinity, water logging problems, deposition of gravels in flat agriculture land in the foot hills should be reclaimed through various measures like saline reclamation bunds, construction of sluice gates, improvement of drainage system, control of stream bank erosion and gravel deposition, construction of check dams are also equally useful. There is a need to develop site-specific strategies and resource conservation techniques to preserve soil's production potential, sustain productivity, conserve in-situ rain water, minimise soil erosion, mitigate soil salinity, moderate flood downstream, harvest and recycle inevitable runoff and ensure environmental security.

4. Conclusion

Quantitative assessment of soil loss indicated that annual soil loss of 103.77 × 10^3 tons was observed from the cultivable land of South Andaman district at the rate of 59.40 t $ha^{-1}yr^{-1}$. Among the mono-cropped area, the highest and the lowest rate of soil loss were obtained from the cultivation of green gram cultivated in *kharif* and ginger, respectively. Hence to minimise the annual soil loss, the mono crop ginger, turmeric or sweet potato should be covered more area in the upland and sloppy areas. Among the double cropped land, the sequence of sweet potato-vegetable-fallow contributes the lowest rate of soil loss whereas the cropping sequence of green gram-vegetable-fallow yielded the highest rate of soil loss. Hence cultivation of more area with sweet potato-vegetable-fallow will reduce the annual soil loss considerably. The study also reveals that converting more mono crop area into double cropped land will reduce the average soil loss annually by 28.23%. Keeping in view the severity of erosion, it is strongly recommended for adoption of appropriate soil and water conservation measures besides keeping croplands without fallow for erosion control and sustainable agricultural production.

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