Journal of the Andaman Science Association Vol. 24(2):81-88 (2019)
ISSN 0970-4183, Printed in India

Effect of terracing on Soil and Nutrient Loss from Coconut based Intercropping Systems

Sirisha Adamala*, A. Velmurugan, T.P. Swarnam and K.R. Kiran
ICAR-Central Island Agricultural Research Institute, Port Blair-744105
Corresponding author: sirisha.cae@gmail.com

Abstract

The natural resources in Andaman and Nicobar Islands are profoundly affected by land degradation as a result of land use change, deforestation, overgrazing and subsistence agriculture. In order to assess the soil loss and evaluate the effect of soil conservation practices, a field experiment was conducted in different coconut based intercropping systems. The results showed higher N loss in the form of nitrate N than Ammoniacal N. The Silt, ammonia and nitrate losses from the experimental plots varied as 1.73-5.38 g/l, 3.11-3.71 mg/l and 3.5-5.17 mg/l, respectively. The measured soil loss from runoff plots was 1.1, 2.7, 2.9, and 3.4 t ha^{-1} for pineapple, fodder, sweet potato, and tapioca intercrops, respectively. Similarly, soil loss was predicted from USLE model using rainfall events and other soil, crop, slope and conservation practices data during 2013-14 year. Terracing of sloppy area had significant effect on soil loss ($p<0.05$) and soil loss was highest under fallow (8.5 t ha^{-1} y^{-1}) while pine apple intercropping recorded the lowest erosion rate (2.1 t ha^{-1} y^{-1}). It was observed that USLE predicted the soil loss for all intercrops were in good agreement (R^2 = 0.97) with measured soil loss data by runoff plots.

Keywords: soil and nutrient loss, coconut intercrops, USLE, terracing

Introduction

Sustainable management of soil and water resources are very critical for meeting food, fibre and shelter needs of growing population. At the same time, conservation of these resources should form part of production enhancement strategy. Andaman & Nicobar Islands (ANI) despite of having 300 cm annual rainfall, surprisingly experiences water crises both for drinking and irrigation especially during dry season from January to April. The island receives about 75% of its annual rainfall during May-November, of which nearly 50% is lost through runoff carrying 12-15 tonnes soil per ha annually (Singli and Gajja, 1982). Studies have established that runoff is associated with soil loss which increases with slope lengths and steepness. Thus higher intensity runoff from sloppy areas often causes landslides (Rai and Sharma, 1998). According to Sahoo *et al.* (2013), about 90% of ANI area is affected by various types of erosion with 20-80 t/ha/year erosion rate, which is in excess of tolerance limit (11.2 t/ha/year). National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) reported that out of 0.825 Million ha geographical area, 23% of area is severely eroded due to water erosion (on scale of 1:25000). These figures exhibit variations probably due to adoption of different methods, scale and interpretation criterion.

accelerated erosion due to the removal of forest cover and disturbance to the surface soil in cultivated land.

Soil erosion causes not only loss to productive top soil but also leaches out bases and nutrients from the agricultural lands due to which the soils of these islands became poor in organic matter (Mongia *et al.* 1989). The studies on soil and nutrient loss from different agricultural land uses in A&N Islands are limited. Pramanik *et al.* (1998) studied soil loss, nutrient recycling, and water yield under coconut and arecanut based intercropping systems planted in Garacharma watersheds, South Andaman. The results from this study indicated that on an average soil loss under coconut plantation (main crop) and intercrops was 3.4 t/ha during 1992-94. Velmurugan *et al.* (2008) carried out soil erosion study in Dhanikhari watershed of the South Andaman district using revised Morgan Finney (MMF) model with an aid of remote sensing (RS) and geographical information system (GIS) which indicated accelerated erosion in plantation areas. Shankar and Dharanirajan (2018) studied the drainage morphometry of Kalpong river watershed, North Andaman using RS & GIS. This study suggests that the Kalpong watershed is susceptible to soil erosion and severe runoff. Due to this, high concentration of nutrient rich sediments was discharged at the mouth of Kalpong River and finally reaching sea.

It can be inferred from these studies showed that in spite of having 85% area under forest cover, AN islands is experiencing soil degradation in the form of water erosion. Majority of agricultural activities in A&N islands include coconut and arecanut based main cropping system along with some intercrops. Due to cultivation of sloppy areas without adequate conservation measures and exposure of agricultural soils during rainy season resulted in loss of large amounts of nutrients to sea through low lying streams. This loss is expected to increase further due to land use change, high pressure for intensive land use and climate change events. This phenomenon not only causes loss of soil fertility but also creates threat to aquatic life by sedimentation of coastal areas. This necessitated quantification of soil and nutrient losses from agricultural lands for creating suitable soil and water conservation mechanism to enhance crop productivity and augment water resources potential. Therefore, a study was conducted to evaluate the effect of terracing and different coconut based intercropping systems on soil erosion by modelling approach whereas nutrient losses were quantified through erosion plot methods.

Materials and Methods

Study Area

The present erosion study was conducted at coconut based integrated farming system Unit, Garacharma Farm, Central Islands Agricultural Research Institute (CIARI), South Andaman. The soil of the study site is classified as Entisols with sandy loam texture. The pH varied from 6.1 to 6.8 and EC ranged from 0.20 to 0.35 dS m^{-1}. The climate of the study area showed very little annual variation in temperature (25 °C to 30.5 °C), high humidity (79-90%) and wind speeds (4.7-14.8 km/h). On an average the study area receives 3079 mm rainfall with mean monthly variation of 300-500 mm/month during wet season (May-October), 50-230 mm/month during post-wet season (November to January) and <100 mm/month during dry season (February to April). As the Islands are situated close to equator evaporation rate is fairly high which cumulatively ranges from 97-191 cm per annum.

Erosion study

The terrain of the study area was hilly and undulated with 10-25% slope with coconut plantation therefore, inward slopping terraces were made to reduce runoff and conserve soil. In order to study the effect of terracing, runoff plots (2 m x 1m x 0.3 m) were established under different coconut based cropping system to assess soil and nutrient losses though runoff. The study included four intercropping systems established in the terrace under coconut main crop *viz.* pineapple, sweet potato, tapioca and fodder. One runoff plot each was installed under pineapple, sweet potato, tapioca and fodder. One each erosion plots was established at fallow land and natural vegetation as well for comparison. Dikes of runoff plots were made with galvanized metal sheets and the runoff samples were collected from tank installed at end of plot through channel. Runoff volume in each tank was measured for erosive rainfall events and five litres of runoff water was sampled for analysis after thorough stirring. One litre water sample was coagulated by alum, decanted off and dried on a water bath to estimate soil loss (grams). Other portion of sample was used for analysing

Soil Erosion Modelling

The Universal Soil Loss Equation (USLE) predicts soil loss for a given site as a product of six major erosion factors (Eq. 1). The values of these erosion factors vary considerably about their means from event to event, but the effects of these fluctuations average out in the long run. Thus, the USLE is suitable for predicting long-term averages, and the soil erosion is estimated as follows (:

$$A \quad R \quad K \quad LS \quad C \quad P \qquad \text{eq (1)}$$

Where, A = soil loss per unit area in unit time (t ha^{-1} yr^{-1}), R = rainfall erosivity factor(MJ mm h^{-1} ha^{-1} year-

^{1}),K = soil erodibility factor (tons ha^{-1} MJ^{-1} mm^{-1}), L = slope length factor(dimensionless), S = slope steepness factor(dimensionless), C = cover management factor (dimensionless, ranges from zero to one), and P = support practice factor or land management factor (dimensionless, and ranges from zero to one). Each factor is described below:

Rainfall erosivity factor (R): It refers to the rainfall erosion index, which expresses the ability of rainfall to erode the soil particles from an unprotected field. From the long field experiments it has been obtained that the extent of soil loss from a barren field is directly proportional to the product of two rainfall characteristics: kinetic energy of the storm and its 30-minute maximum intensity. The product of these two characteristics is termed as EI_{30} or rainfall erosivity. The erosivity factor, R is the number of rainfall erosion index units (EI_{30}) in a given period at the study location. The rainfall erosion index unit (EI_{30}) of a storm is estimated as:

$$EI_{30} = \frac{KE \times I_{30}}{100} \qquad \text{eq (2)}$$

Where KE = kinetic energy of storm in metric tonnes/ha-cm, expressed as:

$$KE = 210.3 + 89 \log I \qquad \text{eq (3)}$$

Where I = rainfall intensity in cm/h, and I_{30} = maximum 30 minutes rainfall intensity of the storm.

Soil erodibility factor (K): It is a number which reflects the susceptibility of a soil type to erosion, i.e., it is the reciprocal of soil resistance to erosion. It ranges from less than 0.1 for the least erodible soils to close to 1.0 in the worst possible case. The formula used for estimating K is (Foster *et al.*,).

$$K = 2.8 \times 10^{-7} \times M^{1.14} \times (12 - a) + 4.3 \times 10^{-3} \times (b - 2) + 3.3 \times (c - 3)$$

Where, M = particle size parameter, a =organic matter content (%), b = soil structure code and c = soil permeability class.

Topographic factor (LS): Slope length factor (L) is a ratio which compares the soil loss with that from a field of specified length. Steepness of land slope factor (S) is a ratio which compares the soil loss with that from a field of specified slope. The topographic factor is used to account for the length and steepness of the slope. The longer the slope, the greater is the volume of surface runoff and the steeper the slope, the greater is its velocity. The value of LS can be calculated by using the formula given by Wischmeier and Smith (1978):

$$LS = \left(\frac{\lambda}{22.13}\right)^{m} \left[65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065\right] \qquad \text{eq (5)}$$

Where λ = field slope length in meters, m = exponent varying from 0.2 to 0.5, θ = angle of slope.

Crop management factor (C): The C factor is a ratio of the soil loss from a land under a specific crop and management system to the corresponding loss from a continuously fallow and tilled land. The C factor can be determined by selecting the crop type and tillage method. The cover and management factor to account for the effects of vegetative cover and management techniques for reduction of the soil loss would be equal to 1.0 in the worst case. In an ideal case when there is no sediment loss, C would be zero.

Conservation practice factor (P): The P factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. The most commonly used supporting cropland practices are cross slope cultivation, contour farming and strip-cropping. Ideally in an area with full support practice condition, P would be zero meaning there is no sediment loss; whereas in an area without any support practice P = 1.0 indicating maximum possible sediment loss in absence of any soil conservation practice.

The runoff water samples from the constructed plots were collected for various rainfall events during September to October months in 2013. The collected runoff water samples were analysed for soil/silt loss and nutrient losses at laboratory, CIARI following standard procedures (Jackson 1973). The input parameters considered for running USLE soil erosion model from the collected and analysed data are shown in Table 1.

Table 1: Input parameters for predicting soil loss using USLE erosion model

Sl. No.	Factor	Value	Parameters
1	Rainfall erosivity index (R)	505.9	Maximum 30 minutes rainfall intensity; Event wise rainfall (mm)
2	Soil erodibility index (K)	0.34	Texture class = Sandy loam; Organic Matter = 0.6%
3	Slope length factor (LS)	0.35	Length of field = 2 m, Slope = 10%
4	Conservation practice factor (P)	0.14	Terracing
5	Crop management factor (C)	0.25	Pineapple
		0.33	Fodder
		0.36	Sweet potato
		0.50	Tapioca

Evaluation of Models' Performance

The performance evaluation of USLE model was carried in order to examine the effectiveness in estimating soil loss. The performance indices used for evaluation are; root mean squared error (RMSE), mean absolute error (MAE), and coefficient of determination (R^2). A description of the aforementioned indices is provided below.

i) Root Mean Squared Error (RMSE) is a measure of the residual variance and it indicates the overall discrepancy between the target and the output values. A low RMSE indicates good model performance, and vice-versa. A perfect match between the target and the output values would yield RMSE = 0.0. It is expressed as:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(T_i - O_i)^2} \quad \text{eq (6)}$$

Where T_i and O_i = measured and predicted soil losses, respectively; n = number of data points.

ii) Mean Absolute Error (MAE) is a measure of average magnitude errors in a set of predictions, without considering their direction.

$$\text{Mean Absolute Error (MAE)} = \frac{1}{n}\sum_{i=1}^{n}|T_i - O_i| \quad \text{eq (7)}$$

iii) Coefficient of Determination (R^2) measures the degree to which two variables are linearly related. It is the square of the Pearson's correlation coefficient (r) and describes the proportion of the total variance in the observed data that can be explained by the model. The value of R^2 ranges from 0 to 1, with higher value indicating better agreement between the target and the output values.

$$R^2 = \frac{\left[\sum_{i=1}^{n}(O_i - \bar{O})(T_i - \bar{T})\right]^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2 \sum_{i=1}^{n}(T_i - \bar{T})^2} \quad \text{eq (8)}$$

Where $\bar{T}$ and $\bar{O}$ = average of measured and predicted soil losses, respectively.

Statistical analysis

The primary data was analyzed using descriptive statistics such as average, percentage, coefficient of variation and standard deviation in Microsoft excel. Statistical significance of terracing and intercropping in coconut garden based on't' test were carried out using SAS package.

Results and Discussion

Soil erosion is directly related to rainfall and the resultant runoff over the agricultural field. In the island ecosystem, rainfall occurs almost in a continuous patch (rainy days) during the wet season with break in the event. A rainfall event cannot be considered erosive if the corresponding rainfall event depth is lower than 12.7 mm (Wischmeier and Smith, 1978). Accordingly, erosive rainfall events were processed for predicting soil loss using USLE equation and are shown in Fig. 1. We have identified a total of 4 rainfall event which are erosive for which runoff, soil and nutrient data was determined.

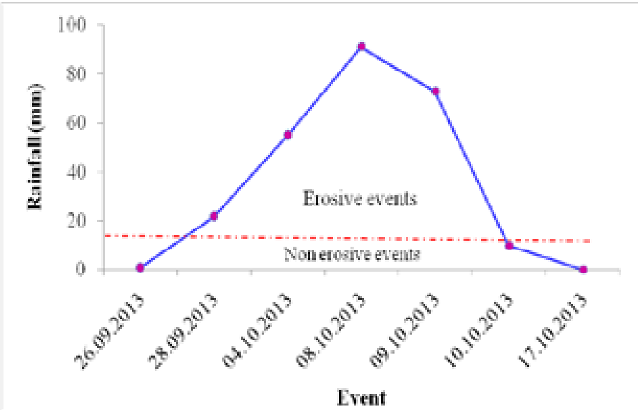

Fig. 1: Erosive and non-erosive events distribution in the study period

Table 2 shows the results of soil nutrient loss in the water samples collected from runoff plots under different intercrops. Nitrogen loss in the form of ammonia and nitrate from the runoff plots varied. 2.95-3.71 mg/l and 3.26-5.17 mg/l, respectively. The results showed that nitrate N loss was higher than Ammoniacal N loss that indicted the aeration status of the soil before the rainfall incidence. Among different cropping systems, N loss was significantly higher for grass followed by pineapple than other systems. There was no significant difference in soil pH and EC. The measured silt loss (g/l) was significantly higher for disturbed fallow land due to direct exposure soil surface to erosive rainfall. Among the intercropping system, tapioca recorded the highest silt loss (5.38 g/l) followed by sweet potato, fodder and pineapple. The measured soil loss in 'g/l' is projected to 't/ha' using measured data of infiltration and soil moisture parameters. From the infiltration experiments conducted in the study area, it was found that around 30-40% of rainfall infiltrated into the soil and maintains saturated moisture conditions at 20-35%.

Table 2: Soil and nutrient losses under different agricultural land uses

Sl. No.	Intercropping system	pH	EC (dS m^{-1})	Ammonia (mg/l)	Nitrate (mg/l)	Silt loss (g/l)
1	Pineapple	5.76	0.02	3.19^{b}	4.32^{a}	1.73^{a}
2	Sweet potato	5.98	0.03	3.33^{ab}	5.17^{a}	4.56^{b}
3	Tapioca	5.96	0.05	3.11^{b}	3.50^{b}	5.38^{b}
4	Fodder	6.20	0.03	3.71^{a}	4.15^{a}	4.29^{b}
5	Fallow-disturbed	6.12	0.08	2.95^{b}	3.26^{b}	14.62^{a}

The results of soil loss estimated in the present study and the previous study under different agricultural land use practices are shown in Table 3. This was done for comparison and represent more inter cropping systems so to select more suitable system for island condition. The soil loss and nutrients recycling were studied for plantation crops by Pramanik *et al.* (1998) under arecanut and coconut plantations. This study revealed that on an average soil loss under plantation (main crop) with intercrops varied from 0.6 to 9.7 t/ha/year. At the same time the results indicated decrease in soil loss during second year in all the intercropping systems. In general, inclusion of grasses as intercrop under plantation crops significantly reduced the soil loss.

The measured soil loss from the runoff plots was 1.1, 2.7, 2.9, and 3.4 t/ha for Pineapple, Fodder, Sweet potato, and Tapioca, respectively in coconut based main crop system. Among the intercrops, the highest (34-35%) and lowest (11-17%) soil loss was occurred in Tapioca and Pineapple, respectively. Fallow land (without terrace) recorded the highest soil loss among all the system.

Table 3: Observed soil loss based on runoff plots under plantation based intercropping system

Sl. No	Agricultural land use		Measured soil loss (t/ha/year)		
	Main crop	Intercrops	1992-93*	1993-94*	2013-14
1	Arecanut	Banana-Cinnamon-Pineapple-Black pepper-Grasses	9.7	4.0	-
		Black pepper-Cinnamon-Grasses	3.5	1.2	-
2	Coconut	Cinnamon-Arecanut-Grasses-Black pepper	6.4	0.6	-
		Pineapple	-	-	1.1[c]
		Fodder	-	-	2.7[b]
		Sweep potato	-	-	2.9[b]
		Tapioca	-	-	3.4[b]
3	Fallow land	Fallow	-	-	12.5[a]

*Adapted from Pramanik *et al.* (1998)

Soil loss was predicted from USLE model using rainfall events and other soil, crop, slope and conservation practices data during 2013-14 (Table 4). This was carried out for inter comparison and upscaling of the results. The model predicted average annual soil loss indicted significant effect of terracing on soil loss reduction. Accordingly soil loss from intercrops varied between 2.1-4.3 t ha^{-1} with terracing as conservation measure for sloppy areas. The estimated soil loss from coconut based intercrops without conservation practice varied between 15.1-30.1 t ha^{-1}, which exceeded the tolerance limit of 11.2 t h^{-1}. The study revealed that highest soil loss either with or without conservation practice was recorded for fallow land. Thus based on the study results, it is recommended that conservation measure like terracing is highly effective for arresting soil loss in plantation based intercropping system.

Table 4: Effect of conservation practice on the predicted soil loss using USLE in different coconut based intercropping system

Agricultural practice	With conservation practice				Without conservation practice			
	Soil loss (t ha^{-1})	RMSE	MAE	R^2	Soil loss (t ha^{-1})	RMSE	MAE	R^2
Pineapple	2.1*				15.1			
Fodder	2.8*				19.9			
Sweet potato	3.1*	1.89	1.24	0.971	21.7	27.69	24.88	0.971
Tapioca	4.3*				30.1			
Fallow land-disturbed	8.5*				60.2			

(*Significance level $p<0.05$ between with and without conservation practice)

Comparison results of measured and predicted soil loss under terrace based cropping system resulted low RMSE and MAE of 1.89 and 1.24, respectively (Table 4). Good agreement with coefficient of determination (R^2 = 0.97) was found between the measured and predicted soil losses (Fig. 2). This study recommended that the intercropping of pineapple with coconut plantation in terraced slope significantly reduced the soil loss. Pandey and Chaudhary (2010) also recommended that coconut plantation with crop cover as good vegetative barrier for arresting soil erosion in the Islands.

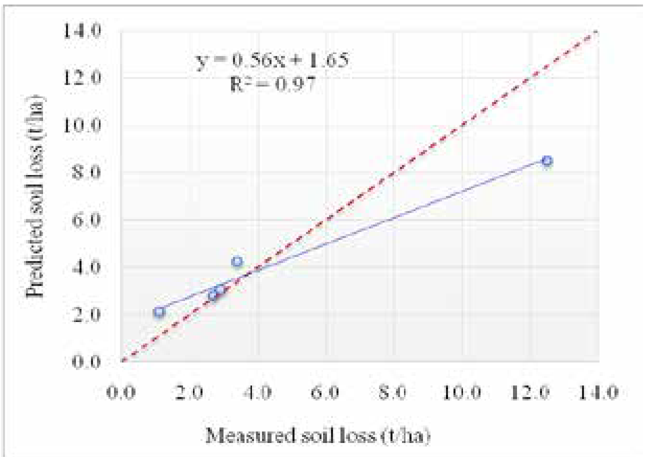

Fig. 2: Comparison of measured and predicted soil loss in coconut based intercropping system with conservation practice

Conclusions

This study concludes that plantation crops as main crop and pineapple as intercrop on the terraces can minimise the soil and nutrient losses significantly. This helps in building soil fertility and diversifying coconut plantation areas. Fallow land by virtue of more exposure to erosion factors recorded the highest soil loss. Thus in the island all the coconut garden having more than 10% slope should go for terracing followed by intercropping. Loss of soil not only affects the soil fertility, but negatively impacts the coastal areas by sedimentation. Further, in island ecosystem soils are most precious resource for agricultural production, once lost, cann't be restored back. Thus quantification of soil and nutrient losses under different agricultural land uses would help in monitoring and managing soil and water resources in sustainable manner.

Acknowledgements

The authors are grateful to ICAR-IIFSR, Modipuram and ICAR-CIARI, Port Blair for providing necessary

References

Foster, G.R., Mc Cool, D.K., Renard, K.G. & Moldenhauer, W.C. (1991). Conversion of the universal soil loss equation to SI metric units. Journal of Soil Water Conservation, 36:356-359.

Jackson, M.L. (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi, pp. 498.

Mongia, A.D., Ganeshamurthy, A.N. & Singh, N.T. (1989). Fertility status of cropping in: Multiple Journal of Andaman Science Association, 5(1): 31-34.

Pandey, C.B. & Chaudhari, S.K. (2010). Soil and nutrient losses from different land uses and vegetative methods for their control on hilly terrain of South Andaman. Indian Journal of Agricultural Sciences, 80(5): 399-

Pramanik, S.C., Sharma, T.V.R.S., Michael, S. & Bandyopadhyay, A.K.B. (1998). Studies on soil loss, nutrient recycling and economics of the plantation based intercropping systems in Bay Islands. Journal of Andaman Science Association, 14(1):1-6.

(1998). assessment of runoff characteristics under different land use patterns with in a Himalayan watershed. Hydrological processes, 12:2235-2248.

Sahoo, A.K., Das, K., Das, A.L., Obi Reddy, G.P., Singh, S.K., Sarkar, D. & Mishra, P.K. (2013). Soil erosion of Andaman & Nicobar Islands. NBSS Publ. No. 165, NBSS & LUP (ICAR), Nagpur, 30 p.

Shankar, S. & Dharanirajan (2018). A study on the drainage morphometry of the strategic Kalpong river watershed, North Andaman, India using geographic information system. Indian Journal of Geo Marine Sciences, 47(01):185-192.

Singh, N.T. & Gaija, B.L. (1982). Ecological considerations and agricultural developments of A & N Islands, Central Agricultural Research Institute. Port Blair. pp. 53.

Velmurugan, A., Swarnam, T.P., Praveen Kumar, & Ravisankar, N. (2008). Soil erosion assessment using revised Morgan, Morgan Finney model for prioritization of Dhanikhari watershed in South Andaman. Indian Journal of Soil Conservation, 36(3):179-18

Wischmeier, W.H. & Smith, D.D. (1978). Predicting rainfall erosion losses - A guide to conservation planning. Handbook No. 527, U.S. Department of Agriculture: Washington, DC, USA.

Received : 15th July 2019 Accepted : 20th October 2019