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Research Paper

Assessment of Soil Erosion Under Different Land Uses in Nalanda Reservoir Catchment and Kuruwita, Kaluganga Sub Catchment Using Nuclear Techniques

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Abstract

Soil conservation act No. 25 was enacted in the year 1951 by Sri Lankan government to mitigate the consequences of soil erosion in the Central highlands. However, lack of catchment scale soil erosion data in different land uses is a serious limitation in successful implementation of the soil conservation act. Therefore, experiments in two contrasting agro-climatological regions of Low country Wet Zone (Kuruwita in Rathnapura district) and Mid Country Intermediate Zone (Nalanda in Matale district) were conducted to find out the rate of soil erosion/deposition in different land uses using two fallout radio-nuclides (^{137}Cs and ^{210}Pb). Relationships among soil chemical properties and the rate of soil erosion/deposition were computed. According to the results, land uses of shifting cultivation in Nalanda and tea cultivation in Kuruwita recorded the highest rate of soil erosion. Net soil deposition was observed under paddy cultivation in both sites. The highest soil nutrient availability was observed in paddy fields in Nalanda, but, tea fields in Kuruwita. Correlation analysis revealed a significant positive correlation between two radio-nuclides employed in determining soil erosion/deposition rate and between soil available phosphorus and exchangeable potassium in both sites. Based on results, it was concluded that both ^{137}Cs and ^{210}Pb can be utilized in assessing soil erosion and sedimentation. Among the land uses tested, shifting cultivation is highly contributing to soil erosion and paddy fields are acting as a sink to eroded soils from other land uses.

Keywords: **Land uses, Nuclear technique, Organic matter and nutrient concentration, Soil erosion/deposition**

Introduction

Recent focus on sustainability issues has resulted in increased attention on soil degradation problems, in particular soil erosion and sedimentation. In view of increasing water scarcity and limited land resources to feed ever-growing world population, there is an urgent need to obtain reliable quantitative data on the extent and the rates of soil erosion worldwide to provide a more comprehensive assessment of the problem and to underpin the selection of effective soil conservation technologies and sedimentation remediation strategies, including assessment of their economic and environmental impacts (Walling, 2002). Due to the expansion of agriculture and human settlements in hilly areas, ecological imbalances also appeared in central highlands of Sri Lanka. As a result of sloping nature of lands and loss of natural forest cover, soil erosion became the major cause of land degradation in Sri Lanka. In order to mitigate the adverse impacts of land degradation especially soil erosion and decline of soil fertility, Government of Sri Lanka, enacted soil conservation act No. 25 in year 1951. However, one of the major challenges for successful implementation of soil conservation act is the unavailability of sufficient soil erosion / sedimentation data under different land uses in catchment scale in different agro-ecological conditions. On this background, there is an urgent need for comprehensive assessment of soil erosion and downstream sedimentation under different land uses in catchment scale for mitigation of land degradation, allocation of lands for development programs and successful implementation of soil conservation act. Conventional methods used for assessment of soil erosion, such as runoff plots are time consuming and do not represent the whole watershed intended. On the other hand, use of Universal Soil Loss Equation (USLE) for predicting soil erosion is less accurate in tropical countries like Sri Lanka due to spatial and temporal complexity of factors used in predicting soil erosion. Borselli *et al.* (2008) also showed that USLE predictions can produce over estimates of sediment loss due to non-consideration of the quantity of eroded soil actually reaching the catchment outlet. Therefore, to fulfil the long felt need of assessment of catchment scale soil erosion and sedimentation, International Atomic Energy Agency (IAEA), has introduced fallout naturally occurring (^{210}Pb and ^{7}Be) and man-made (^{137}Cs) radio-isotopes (FRN) as tracers (Fallout Radionuclide Technique) for catchment scale soil erosion and sedimentation assessment. For the purpose of expediting the soil erosion assessment process, fallout radionuclide technique was used in Nalanda reservoir catchment (Mid Country Intermediate Zone) and in Kuruwita, Kalu Ganga sub catchment in Rathnapura district (Low Country Wet Zone) to determine the rate of soil erosion/ deposition in different land uses, and to find out the relationship among the rate of soil erosion/deposition assessed using two fallout radionuclides (^{137}Cs and ^{210}Pb) and different soil chemical properties.

Materials and Methods

Principle – fallout radionuclide technique

Fallout radionuclides are radio-isotopes, which emits ionizing radiation due to radioactive decay. Therefore, the presence of trace quantity of radio-isotopes can be detected using the property of emitting of ionizing radiation. International Atomic Energy Agency has introduced two naturally occurring (^{210}Pb and ^{7}Be) and one man made (^{137}Cs, which was emitted in nuclear weapon testing) radionuclides as tracers for determining soil erosion/deposition (soil redistribution). The chemistry of ^{137}Cs and ^{210}Pb is well understood (Wallbrink and Murray, 1993). When ^{137}Cs and ^{210}Pb reach the soil surface, they are quickly and strongly adsorbed by exchange sites and are essentially non-exchangeable in most environments (Cremers *et al*., 1988). Therefore, these radio-isotopes can be effectively utilized as tracers in soil erosion assessment. As the half-life of 210Pb is 22 years it is possible to estimate soil erosion and deposition in past 100 years using ^{210}Pb radio-isotope, whereas, as the half-life of ^{137}Cs is 30 years, it is possible to estimate soil erosion using ^{137}Cs from year 1954 which is the year of its first occurrence. In determining soil erosion/deposition, soil samples need to be collected from the "reference site" located in flat terrain in hill top. The assumption in the reference site is that the fallout radionuclides receiving from atmosphere deposited as it is, in the reference site, without removing or receiving radionuclides from other land uses. The amount of radionuclides presence in the soil sample in anywhere in the catchment can be compared with the reference site. If the radionuclides present in the other land uses are higher than the reference site (+ value), denotes the sediment deposition and if the number of radionuclides in land uses are less than the reference site (– value), denotes the soil erosion. The absolute value of soil erosion or deposition (t ha^{-1} yr^{-1}) can be computed by subtracting the amount of radioactivity (measured in Becquerel) in the soil samples of reference site from the other places in the catchment, where, intended to measure soil erosion/deposition and converting it using "mass balance model II".

Study site I. Nalanda reservoir catchment, Matale

Nalanda reservoir catchment (7° 40' 33" N and 80° 37' 1" E) in Matale district belongs to Mid Country Intermediate Zone (IM$_{3b}$) of Sri Lanka having the great soil group of Reddish Brown Latasolic (Figure 1).

Figure 1. Study area of the Nalanda reservoir catchment

Mean annual rainfall of the area is 1200 mm. (Panabokke, 1996). Reconnaissance survey was conducted to identify suitable sampling site that represent the agro-ecological region and land use changes of the area. Major land uses of the study area of the catchment were, (1) shifting vegetable cultivation, (2) low-land paddy, (3) pepper spice gardens, (4) coconut plantations, and (5) natural forest. In addition to these land uses, Nalanda reservoir sediment samples were also collected to determine the rate of siltation of the reservoir. Slope of the catchment ranged from 20 to 30% and the approximate land area of the study sub catchment was 543 ha.

Study site II. Kuruwita, sub catchment of Kaluganga river catchment, Rathnapura

Kuruwita, a sub catchment of Kaluganga in Rathnapura district belongs to the Low Country Wet Zone (WL1a) agro-ecological regions of Sri Lanka, having the great soil group of Red Yellow Podzolic (Panabokke, 1996). Mean annual rainfall of the area is 3809 mm (Imbulana and Neupane, 2003). According to the reconnaissance survey of the area, major land uses of the sub catchment were, (1) vegetative propagated tea, (2) rubber, (3) natural forest, and (4) lowland paddy. Slope of the catchment ranged from 40 to 50% and the approximate area of the study area was 386 ha (Figure 2).

Figure 2. Study area of the Kuruvita, Kaluganga river sub catchment

Selection of reference site

For the comparison of fallout radionuclide inventory, reference area has been chosen from the uncultivated flat grassland (abandoned cemetery site) located in a hill top which had not been subjected to erosion and deposition (assumption). According to the residents of the area the site was not used for any purpose from more than 75 years.

Sampling strategy for determining fallout radionuclide (FRN) inventory

Measurement of ^{137}Cs concentration vs. depth is required for cores representative of each landscape unit within the study site. It is essential to determine the inventory of ^{137}Cs and ^{210}Pb at a reference site near to the study area (Mabit *et al*., 2008). Therefore, samples were taken as 8 cm diameter sectional cores in 5 cm depth increments of soil, up to 40 cm to determine the appropriate depth of penetration of ^{137}Cs and ^{210}Pb in reference site. In order to define the spatial variability of soil ^{137}Cs and ^{210}Pb inventory, bulk soil cores were collected from four parallel transects. Twelve cores were collected to a constant depth of 40 cm. Each transect consisted of three sampling points with the spacing of 10 m. At each sampling point three cores were collected within an area of 1m^2 and mixed to make a composite sample. Radio activity values of 5 cm depth increment samples were used as an input to the *Mass Balance II* software model, which was used to determine the absolute soil erosion/deposition rates (t ha^{-1} yr^{-1}) in soil samples.

Sampling strategy in catchment area

Three core samples per m^2 were collected up to 40 cm soil depth from each sampling point in a grid pattern. Size of the one grid was 10 m × 10 m. Twenty four samples were collected in the grid pattern from one land use. Sediment samples from Nalanda reservoir was collected using sediment core sampler in shallow water near shoreline.

Sample preparation and analysis

Soil samples were air dried and passed through 2 mm mesh to separate the gravel from soil. A sub sample from the weighed fine fraction were filled into a specific container for the detector and kept for 21 days to allow complete ^{222}Rn decay in order to achieve secular equilibrium for the measurement of ^{210}Pb. Gamma spectrometry method using a Hyper Pure Germanium (HPGe) Gamma detector installed at Sri Lanka Atomic Energy Board was used for measuring ^{137}Cs and ^{210}Pb activities (Wallbrink and Murray, 1993).

The ISOCS/LabSOCS software calibration method (Geometry Composer Method) was used for efficiency calibration. The reference materials, IAEA Soil - 6 and MBSS 2 of known ^{137}Cs content were used for method validation. The net area under peak at 661.5 KeV was used to determine the ^{137}Cs concentration of soil and for total ^{210}Pb is 46.5 KeVin Bq kg^{-1}. The $^{210}Pb_{ex}$ activity was determined by subtracting ^{210}Pbsupp (average of ^{214}Pb and ^{214}Bi activities) from total ^{210}Pb for each depth interval and core samples. The spectra were analyzed using the software packages Genie 2000.

Fallout radionuclide data analysis

Soil redistribution rates induced by water erosion was calculated by Mass Balance Model II developed by Walling and He (2001).

Y=(10 B × d / P) × [1- (1-(X / 100) 1 / (t-1963)]………………eq. 1

Where,

Y = Mean annual soil redistribution (t ha^{-1} yr^{-1});

X = Percent loss of ^{137}Cs or ^{210}Pb at the sampling site compared to the reference site;

B = Bulk density of soil (kg m^{-3});

d = Depth of the plowed layer (m);

t = Year of sample collection; and

P = Correction factor for particle surface area.

Number of ^{137}Cs or ^{210}Pb radio-isotopes present in the soil samples were determined using Hyper Pure Germanium (HPGe) detector and the value was used as an input to mass balance II model with other soil parameters to convert radiation values to annual rate of soil erosion/deposition.

Soil nutrient analysis

The organic matter percentage of the soil was estimated by the rapid titration procedure given by Walkley and Black (1934). Available phosphorus of the soil samples was extracted with Olsen's extractant (0.5 M $NaHCO_3$). Phosphorus in the extractant was estimated colorimetrically by ascorbic acid method (Olsen *et al*., 1954). Exchangeable potassium of soil samples were extracted by neutral ammonium acetate solution and were determined by using flame photometer (Jackson, 1979).

Statistical Analysis

Statistical analysis of data was performed using the OPSTAT statistical package of Haryana Agricultural University, available online at www.opstat.com.

Results and Discussion

Significantly highest soil erosion (47.9 t ha^{-1} yr^{-1} under ^{137}Cs analytical method and 43.9 (t ha^{-1} yr^{-1}) under ^{210}Pb analytical method) was observed under the land use of shifting vegetable cultivation in both ^{137}Cs and ^{210}Pb analytical methods employed in Nalanda reservoir catchment, followed by land uses of coconut and pepper (Table 1). It was estimated that over 20% of the land area of the district is under some form of chena cultivation (CEA, 1991). Jayasekara *et al*. (2018) also reported that in Matale district 20.3% of area was under considerable susceptibility for soil erosion mainly due to the topography and the land use. Ahmad and Ikram (1990) also reported that most of vegetable cultivated lands in hilly watershed in Pakistan have annual erosion rates over 75 t ha^{-1}, thus significantly increasing the sediment yield in runoff and stream water. Schuller *et al*. (2007) assessed rate of soil erosion using ^{137}Cs isotope under undisturbed forest and conventional till vegetable cultivation in south central Chile and reported that conventional tillage in vegetable cultivation caused net soil erosion of 11 t ha^{-1} yr^{-1} whereas land use of forest recorded 1.4 t ha^{-1} yr^{-1} of net soil erosion, although, the gross erosion rate was 7.3 t ha^{-1} yr^{-1} indicating the ability of forest landscape to retain major part of eroded soil within the landscape. Although, low rate of soil erosion is expected under plantation crops like coconut and pepper, lack of undergrowth due to clearing and drying up of weeds during dry periods, expose the soil to high intensity rainfall in rainy season might be the reasons for comparatively high rates of soil erosion under pepper gardens and coconut plantations. It was observed that poorly maintained soil conservation measures (contour lock and spill drains) in coconut plantations and pepper gardens. Since de-silting of drains were not practiced for a long period of time, intended use of soil conservation from drains were not in the satisfactory level.

Table 1. Variation of soil chemical properties and rate of soil erosion in 137Cs and 210Pbex methods in Nalanda reservoir catchment

Land use	Erosion rates (t ha^{-1} yr^{-1}) From ^{137}Cs	Erosion rates (t ha^{-1} yr^{-1}) From ^{210}Pb	Olsen's P (mg L^{-1})	Exch. K (mg L^{-1})	OM%	Electrical conductivity (dS m^{-1})	pH
Vegetable (Shifting)	-47.90^{a*}	-43.97^{a*}	29.16^{c}	287.55^{b}	1.01^{e}	0.027^{b}	5.50^{b}
Pepper	-23.52^{b}	-21.43^{b}	12.44^{d}	199.11^{c}	1.39^{d}	0.043^{a}	5.56^{b}
Forest	-2.19^{d}	-1.64^{d}	19.52^{d}	224.44^{c}	2.22^{c}	0.025^{b}	6.08^{a}
Paddy	+1.15^{d}	+1.73^{d}	40.22^{b}	353.22^{a}	2.89^{b}	0.027^{b}	5.57^{b}
Coconut	-14.95^{c}	-13.36^{c}	16.32^{d}	210.00^{c}	1.00^{e}	0.049^{a}	5.81^{ab}
Reservoir Sediment	+53.59^{e}	+48.25^{e}	51.56^{a}	397.77^{a}	3.21^{a}	0.049^{a}	5.19
LSD (p = 0.05)	6.41	6.19	9.06	51.98	0.29	0.010	0.36
C.V.%	28	30	33	26	15	27	7

**Plus, sign denotes soil deposition and minus sign denotes soil erosion*
Means followed by the same letter are not significantly different at 5% probability level

Neergaard *et al*. (2008) also observed that the highest retention of original top soil in native forest plots and loss of 35% of top soil from pepper gardens. There was a sediment deposition in land use of paddy but on par with soil erosion rate of natural forest. Kaichen *et al*. (2012) also observed very low rate (0.77 t ha^{-1} yr^{-1}) of soil erosion under terraced paddy lands and suggested to formulate effective soil conservation measures and maintain sustainable rice planting in the terraced paddies. There was also a 48.25 t ha^{-1} yr^{-1} to 53.59 t ha^{-1} yr^{-1} sediment deposition in Nalanda reservoir, indicating the impact of soil erosion on reservoir sedimentation. Among the land uses tested, only the land uses of natural forest and lowland paddy, recorded the soil erosion less than the upper limit of maximum permissible rate of soil erosion (11 t ha^{-1} yr^{-1}) of agricultural lands (Bennett, 1939). However, Dias et al., (2019) also reported the soil erosion rate of 13 t ha^{-1} yr^{-1} to 648 t ha^{-1} yr^{-1} in Uma-Oya catchment, much higher than the present study.

In Kuruwita, Kalu Ganga sub catchment, significantly highest soil erosion was observed under the land use of tea (11.83 t ha^{-1} yr^{-1} in ^{137}Cs analytical method and 10.64 t ha^{-1} yr^{-1} ^{210} Pb analytical method) followed by land use of rubber (4.13 t ha^{-1} yr^{-1}) (Table 2). Direct exposure of soil and impact of rain drops due to vacant patches in tea fields may be the reason for higher rate of soil erosion under the land use of tea. Even though, upper canopy layer of rubber plantations mimics the canopy layer of natural forest, absence of middle and lower canopy layers might have enhanced the splash erosion due to through fall. Liu *et al*. (2016) also reported that splash erosion potential of rubber plantation was 3.12 times higher than the open environment. Although, under the land use of natural forest, slight rate of soil erosion (0.29 t ha^{-1} yr^{-1}) was observed under ^{137}Cs radio-isotope, slight rate of soil deposition (0.48 t ha^{-1} yr^{-1}) was observed when employed ^{210}Pb radio-isotope for analysis, which was comparable to the rate of soil deposition of the land use of lowland paddy.

Table 2. Variation of soil chemical properties and rate of soil erosion in 137Cs and 210Pbex methods in Kuruwita, Kalu Ganga river sub catchment

Land use	Erosion rates (t ha^{-1} yr^{-1}) From 137Cs	Erosion rates (t ha^{-1} yr^{-1}) From 210Pb	Olsen's P (mg L^{-1})	Exch. K (mg L^{-1})	OM%	EC (dS m^{-1})	pH
Tea	-11.83^{a*}	-10.64^{a*}	15.91^{a}	183.77^{a}	1.91^{c}	0.10^{a}	4.03^{b}
Rubber	-4.13^{b}	-3.54^{b}	3.60^{b}	53.11^{b}	2.47^{b}	0.05^{b}	3.91^{b}
Natural forest	-0.29^{c}	+0.48^{c}	6.83^{b}	34.55^{b}	3.13^{a}	0.03^{b}	4.33^{a}
Paddy	+5.52^{d}	+3.67^{c}	11.65^{a}	160.55^{a}	2.47^{b}	0.03^{b}	5.87^{a}
LSD (P = 0.05)	3.69	3.64	4.38	54.25	0.55	0.02	0.62
C.V.%	39	48	47	51	22	53	13

**Plus sign denotes soil deposition and minus sign denotes soil erosion*
Means followed by the same letter are not significantly different at 5% probability level

In light of the ever-growing demand for agricultural products and the environmental consequences of converting virgin land to agriculture, it is critically important that humanity minimize the erosion of agricultural soils and restore the productivity of soils that have already been degraded by erosion. Bennett (1939) indicated that tillage operations probably increase the rate of topsoil renewal to about 30 yr. cm^{-1}. This rate is nearly equivalent to 11 t ha^{-1} yr^{-1}. This value, therefore, has often been stated as an upper limit of permissible soil loss from agricultural lands. All the land uses studied in Kuruwita, Kaluganga sub catchment reordered lower rate of soil erosion than the upper limit of maximum tolerable soil erosion rate, except the soil erosion rate in tea lands measured using (^{137}Cs 11.83 t ha^{-1} yr^{-1}) which was slightly higher than the upper limit of maximum tolerable rate of soil erosion in agricultural lands. These erosion rates were well below the erosion rates of river basins of Kosi (555 ha^{-1} yr^{-1}), Red River (217 t ha^{-1} yr^{-1}), Irrawaddy (139 t ha^{-1} yr^{-1}), Caroni (105 t ha^{-1} yr^{-1}) and Mekong (t ha^{-1} yr^{-1}) in Asia, America and West Indies. Even the Amazon with its sparse population is estimated to have a mean field erosion rate of 13 t ha^{-1} y^{-1} (El-Swaify *et al*., 1982).

Although, the mean annual rainfall amount and the land slope in Kuruwita Kaluganga sub catchment was much higher than the Nalanda reservoir catchment, in general rate of soil erosion of Kuruwita Kaluganga sub catchment was much lower. The difference may be due to the differences of type of soil in two agro ecological regions or quick ground cover in low country wet zone by weeds or other vegetation after land clearing. Stockings (1984) also stated that the vegetation cover is acknowledged to be the principal determinant of specific erosion rates, and its lack, cause the incidence of very high rate of soil erosion. However, further investigations are needed using same land uses in these agro-ecological regions to confirm the findings.

Soil chemical properties in Nalanda reservoir catchment

Highest available phosphorus concentration (51.56 mg L^{-1}), exchangeable potassium concentration (397.77 mg L^{-1}) and organic matter percentage (3.21%) was recorded in reservoir sediment, indicating the impact of nutrient loss through erosion. Although the exchangeable potassium concentration in land use of paddy (353.22 mg L^{-1}) was on par with reservoir sediment, soil erosion/deposition data revealed that the land use of paddy also can be considered as a deposition site of eroded soil. Significantly lowest available phosphorus and exchangeable potassium concentrations were observed under the land uses of pepper, coconut and natural forest. Reconnaissance survey revealed that fertilizer application was practiced only once a year in pepper gardens and coconut plantations. Other than reservoir sediments, land use of paddy also exhibits considerable amount of soil organic matter possibly due to the anaerobic condition of paddy soils which might have slowed down the rate of decomposition of organic matter (Sahrawat, 2004). The high amount of available phosphorus under submerged condition of paddy soils may also be due to the greater reduction of ferric phosphate under the anaerobic environment (Khanan *et al*., 1997). The high available soil potassium concentration under submerged conditions in paddy fields, compared to other studied land uses, may be mainly due to the displacement of potassium from clay minerals by ammonium ions (Sriram Chandrasekaran and Manthan, 1988).

Soil chemical properties in Kuruwita, Kalu Ganga river sub catchment

Significantly highest available phosphorus and exchangeable potassium concentrations were recorded in the land uses of tea and paddy (Table 2). Among the land uses tested, chemical fertilizers and/or organic manures were applied only to these land uses. Land uses of natural forest and rubber recorded the lowest and on par soil available phosphorus and exchangeable potassium values. However, significantly highest soil organic matter content was observed under the land use of natural forest possibly due to the accumulation of thick litter layer under natural forest than other land uses.

There was a significant positive correlation between two radio-isotopic methods (^{137}Cs and ^{210}Pb) employed in Nalanda reservoir catchment and Kuruwita, Kaluganga river sub catchment in determination of soil erosion and deposition rates (correlation coefficient of 0.976 in Nalanda reservoir catchment and 0.860 in Kuruwita, Kaluganga river sub catchment). This can be considered as a conformity for using either radio isotope for the assessment of soil erosion and deposition rates (Table 3). Benmansour *et al*. (2012) reported almost comparable soil erosion rates assessed using ^{137}Cs (14.3t ha^{-1} yr^{-1}) and ^{210}Pb (12.1t ha^{-1} yr^{-1}) radio-isotopes, respectively in agriculture fields located in Morocco. There was also a highly significant correlation existed between soil available phosphorus and exchangeable potassium in both Nalanda reservoir catchment and Kuruwita Kalu Ganga river sub catchment (Table 3).

Table 3. Correlation matrix of soil erosion and soil chemical properties in Nalanda reservoir catchment (below the diagonal) and Kuruwita, Kalu ganga sub catchment (above the diagonal)

	Olsen's P	Exch. K	OM	EC	pH	Erosion rates from ^{137}Cs	Erosion rates from ^{210}Pb
Olsen's P		0.962**	-0.372^{NS}	0.360^{NS}	-0.156^{NS}	0.282^{NS}	0.114^{NS}
Exch. K	0.955**		-0.283^{NS}	0.512^{NS}	-0.158^{NS}	0.251^{NS}	0.144^{NS}
OM	-0.432^{NS}	-0.418^{NS}		0.280^{NS}	0.572^{NS}	0.253^{NS}	-0.363^{NS}
EC	0.379^{NS}	0.192^{NS}	-0.096^{NS}		0.150^{NS}	-0.493^{NS}	-0.394^{NS}
pH	0.056^{NS}	-0.108^{NS}	-0.120^{NS}	0.222^{NS}		-0.379^{NS}	-0.581^{NS}
Soil erosion ^{137}Cs	0.346^{NS}	0.339^{NS}	0.489^{NS}	0.249^{NS}	0.351^{NS}		0.860^{NS}
Soil erosion ^{210}Pb	0.488^{NS}	0.453^{NS}	0.403^{NS}	0.336^{NS}	0.337^{NS}	0.976**	

***Highly significant*
NS - Non significant

The reason may be the application of balanced fertilizer to the crops containing phosphorus and potassium to agricultural land uses in these two sites. Even in natural systems like natural forests, there may be a natural balance of nutrients as the system is self-sustaining without external inputs. Natural balance of nutrient status of soil in land uses, which were fertilized or not fertilized might have contributed to the highly significant correlation between available phosphorus and exchangeable potassium in both sites.

Conclusions

Among the land use studied in Nalanda reservoir catchment, shifting cultivation caused the highest rate of soil erosion. Land use of paddy cause soil deposition (1.15 t ha^{-1} yr^{-1} in ^{137}Cs isotope method and 1.73 t ha^{-1} yr^{-1} in ^{210}Pb isotope method) and hence can be considered as sink for eroded soil. There was a 47 to 52 t ha^{-1} yr^{-1} sediment deposition rate in Nalanda reservoir. Soils of land use of paddy can be considered as more fertile than the soils of other land uses.

Among the land uses studied in Kuruwita, Rathnapura district, tea plantation caused the highest rate of soil erosion. However, soils of land use of tea can be considered as more fertile than other land uses studied. Land use of paddy caused soil deposition (5.52 t ha^{-1} yr^{-1} in ^{137}Cs isotope method and 3.67 t ha^{-1} yr^{-1} in ^{210}Pb isotope method) and hence, can be considered as sink for eroded soils from other land uses. There was an accumulation of soil organic matter in land use of forest. There was a significant positive relationship between rate of soil erosion measured using ^{137}Cs and ^{210}Pb radio-isotopes in both Kuruwita, Kaluganga sub catchment and Nalanda reservoir catchment indicating the possibility of using either isotope for estimating soil erosion/deposition rates. There was also a significant positive relationship between available (Olsen's) phosphorus and exchangeable potassium concentration in both study sites of Kuruwita and Nalanda.

In the point of soil erosion, land use of shifting cultivation needs to be discouraged. Since, land use of paddy is acting as sink to the eroded soil, paddy cultivation needs to be promoted for arresting soil erosion and sedimentation of water ways and reservoirs. The study needs to be extended to other agro-ecological regions with different land uses for successful implementation of soil conservation act and allocation of lands for development activities.

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