Effect of Soil Erosion on Water Quality of Streams in Badulu Oya Watershed in Sri Lanka

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Abstract
Badulu Oya catchment is an intensively cultivated landscape in Sri Lanka. Soil erosion due to agricultural practices can reduce soil fertility and deteriorates of surface water quality. However, empirical evidence on soil erosion rates of the catchment and their association with surface water quality is less documented in Sri Lanka. The soil erosion rates of the 10 selected micro catchments within Badulu Oya catchment were evaluated using, Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Sediment Retention Model. Physical, chemical water quality parameters and benthic macro invertebrate indices EPT percentage taxa and Chironomidae percentage were calculated to evaluate the overall ecological health of the streams associated with micro- catchments. Pearson's correlation test was conducted to estimate the association between water quality and sediment delivery data of the micro catchments. A comprehensive household (HH) questionnaire survey was conducted to obtain the information from the farming community (n=71), on their land use, knowledge on soil and water conservation practices and the degree of interventions in catchment management. The average soil loss of ten micro catchments varied between 66.0t/ha/yr to 165.9t/ha/yr. Correlation analysis of average soil loss and average water quality parameters at micro-catchments indicated significant ($p<0.05$) positive relationships suggesting soil erosion in the catchment is affecting the stream water quality. Results of the questionnaire survey indicated that the soil erosion rates of the catchment are related to farmer's education level and their level of soil conservation adaptations ($p\leq=0.05$). The finding of the present study emphasized the need of human interventions in catchment management.

Keywords: InVEST Sediment Retention Model, Soil conservation, Soil erosion, Water quality
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Introduction
Sri Lanka is generously endowed with water resources, having a large number of rivers most of which originate from the Central Highlands. Upper Mahaweli Catchment (UMC) consists with several sub-catchments such as Uma Oya, Kotmale Oya, Badulu Oya and many of these are affected by soil erosion due to natural land modifications (Hewawasam, 2010). Badulu Oya which originates from Namunukula hills traverses approximately 40 km before it reaches the Mahaweli River. The total catchment area of Badulu Oya is 318 km^2 and annual average rainfall of the catchment area is 2000 mm (Atukorala, 2012). The natural landscape of the Badulu Oya watershed is highly modified due to agricultural activities and urban settlements. Soil erosion due to such anthropogenic activities may affect soil fertility in the agricultural fields and the surface water quality. However, the empirical evidence on quantitative assessment of soil erosion in catchments and their association with surface water quality is lacking in the context of river catchments in Sri Lanka. Therefore, the present study aimed to estimate the soil erosion in the Badulu Oya watershed and its relationship between water qualities. Further, it was also aimed at evaluating socio-economic factors of the farming community contributing to soil erosion control in the catchment.

Materials and Methods
The study consists of three major phases which include soil erosion assessment of the catchment, analysis of water quality of streams associated with selected micro catchments within Badulu Oya catchment, and analysis of socio economic aspects and land use practices of the farming community of the area. To assess annual soil erosion in the total catchment and in micro catchments InVEST sediment retention model was used (Figure 1). Input files of the model were prepared using ArcGIS™10.1 version. From STRM™ satellite image (30m×30m resolution) Digital Elevation Model (DEM) of Badulu Oya watershed was prepared. Watershed and sub-watershed shape files of polygons were demarcated using hydrology tool. Annual rainfall data of 21 gauge stations in 2014 were obtained from Meteorological Department of Sri Lanka and Roose (1996) equation was used for the preparation of erosivity (R factor) raster (Erik *et al.*, 2011). Soil erodibility (K factor) raster was prepared using the data obtained from the Irrigation Department of Sri Lanka. Land use practices were categorized in to five land use types (Tropical montane forests,

Tropical sub-montane forests, Tea, Paddy and Vegetable Crops) using supervised classification of Landsat™ satellite image of 30m×30m resolution. Crop factor (C factor), management practice factor (P factor) and sediment retention value for each land use type were obtained from previous studies (Senanayake *et al.*, 2013).

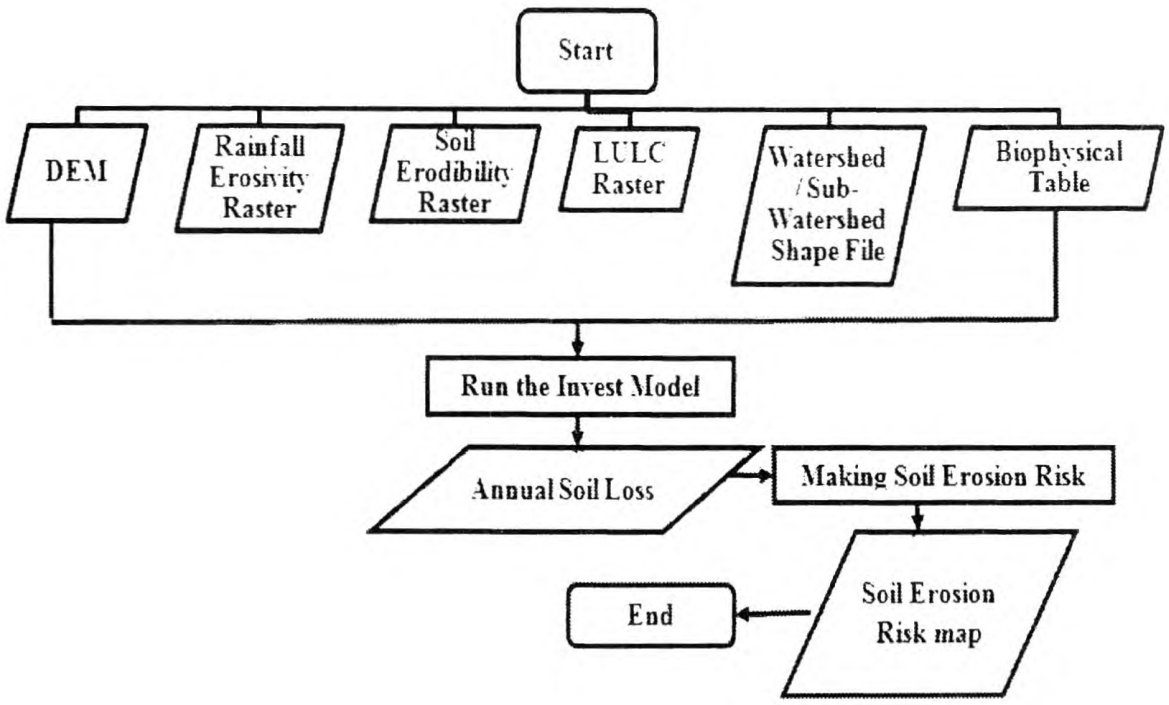

Figure 1: Steps of Invest model

Water samples were collected monthly from 10 sampling locations covering 10 micro catchments from December 2014 to May 2015. Electrical conductivity (EC), pH, temperature, Biochemical Oxygen Demand (BOD_5), Total Dissolved Solids (TDS), Total Solids (TS), Total Suspended Solids (TSS), NO_2-N, NO_3-N,NH_3-N, PO_4^{3-}-P, SO_4^{3-}, Mg^{+2}, and Na^{+} were measured following APHA(2005) procedures. Macro invertebrate samples were collected from study stream reaches using a suber sampler. The Macro invertebrate families were identified and biotic indices such as family richness, %EPT taxa (Ephemeroptera: Plecoptera: Tricoptera), % Chironomids were calculated since they are universally used metrics to track water-quality changes effectively. Pearson's correlation test was conducted for water quality data and sediment delivery data of all micro catchments to estimate their association.

A household questionnaire survey was conducted among the locals of the area to collect the information about land use practices, fertilizer and pesticides usage, knowledge on soil and water conservation practices and the interventions in catchment management (n=71). Multiple regression analysis was carried out to identify the significant socio-economic factors of farming community contributing to soil erosion in the catchment by using SPSS statistical software.

Results and Discussion

Badulu Oya watershed belongs to Uva province. The Province exhibits high agro-ecological diversity and consists of 18 agro-ecological regions. Thus, there is a high degree of variability in agricultural activities and cropping patterns practicing in the province (Senanayake *et al.*, 2013). The results of the soil erosion rates estimation indicated that average soil loss of selected micro catchments vary from 66.0t/ha/yr to 165.9t/ha/yr. The area under study is predominantly covered with areas of tea and paddy cultivation. Annual soil loss from scrub and forest areas was the lowest whereas degraded tea lands contributed to very high soil losses in the catchment

Hewawasam *et al.* (2003) have found that the natural rates of erosion ranged from 0.13 to 0.30 t/ha/yr in the Upper Mahaweli watershed in Sri Lanka. The current rate of human-induced soil erosion in the study catchment well exceeded the natural rate of soil erosion. This can be mainly due to human-induced forest fires, wanton destruction of forests and switching from cultivation of the existing paddy to soil erosion inducing cash crops such as tomato, cabbage and beans. From an environmental conservation point of view, these results can be taken as baseline information for formulating soil conservation programs and policies. Correlation analysis between average soil losses and average water quality parameters at sub-catchment level indicated significant ($p<0.05$)

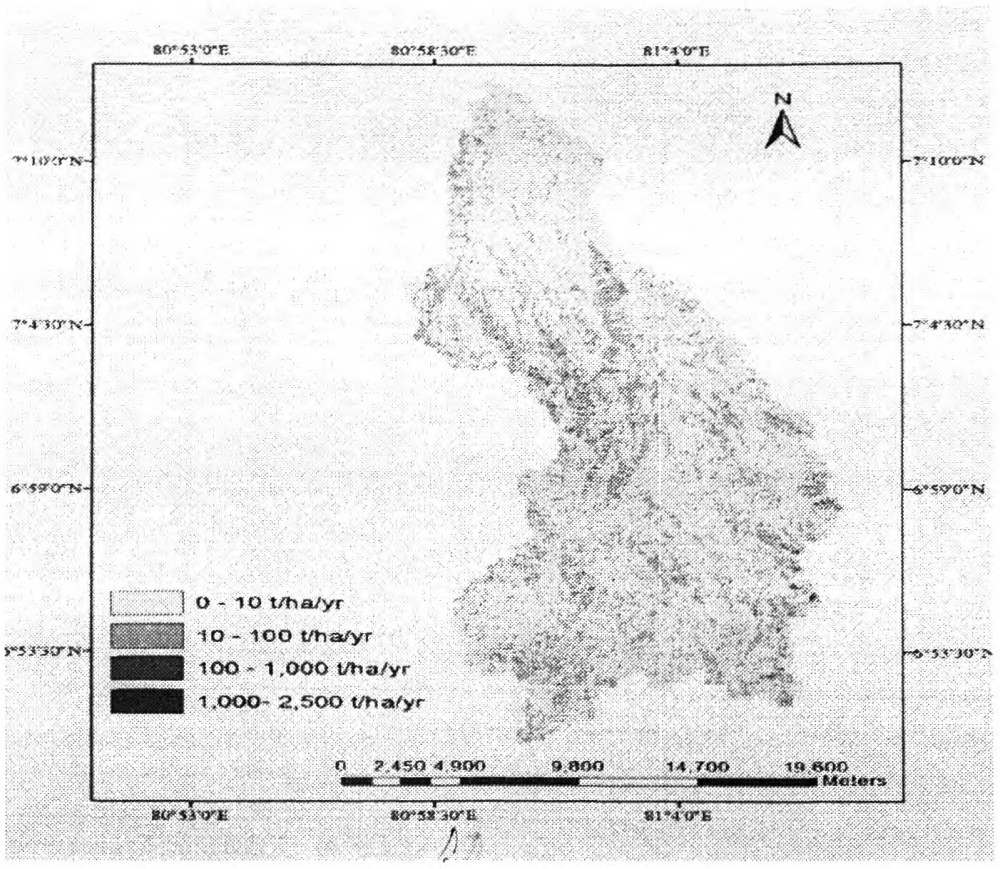

Figure 2: Pixel based soil erosion map of Badulu Oya watershed

strong positive relationships with hardness, Biochemical Oxygen Demand (BOD_5), Phosphate, Total Dissolved Solids (TDS) and conductivity. A significant ($p<0.05$) moderate positive correlations were detected between catchment soil loss and the nitrate, Mn, and Pb levels in the water. Macro invertebrates have long been used as indicators to assess water quality. However, no significant correlations were detected among soil loss in the catchment and macro invertebrate bio indicators. The association between water quality variables and soil erosion in the catchment in the present study suggest that the land degradation due to soil erosion in the catchment may have significant adverse impacts on stream water quality in the area. Specifically nutrients added into crops in the form of fertilizer and organic manure may have reached the stream water with runoff and may have contributed to the elevated levels of phosphate and BOD_5 levels in water. Significant changes in conductivity can be an indicator that a discharge has occurred or some other source of pollution has entered a stream. TDS and conductivity were positively related to the soil loss in the catchment. This may have attributed to the higher levels of ions added to water with eroded soils in the disturbed landscape. The results of the questionnaire survey indicated that more than 73% of the households in the catchment had fewer than or equal to 4 family members.

Majority of population studied were between 15-60 years of age group. The study showed 90% of interviewed farmers were educated up to Ordinary-Level. In general, agriculture is the predominant occupation of the study population. Paddy is the major crop cultivated in the upper catchment area of the Badulu Oya. In the lower catchment diverse crops are grown with tea and irrigated paddy as the major crops followed by some vegetables such as tomato and beans. About 43% of the study population engaged in agriculture, 16% in off-farm employment, 1.0% in wage labor, another 31% is students, and 9% are in other occupations such as running small-scale enterprises, trading, etc. Multiple regression analysis indicated that soil erosion rates of the catchment is related to the family size, farmer's education level and their level of soil conservation adaptations ($p\leq=0.05$). A majority (76.1%) of the farmers in the study area had poor knowledge on existing government policies related to the conservation of forests, water, land and agriculture practices and this has mainly contributed to their inappropriate land use practices. This suggests the need of extension services to increase the awareness of the community about the land conservation. The finding of the study shows that most of the farmers relevant to the study area had good perception on the causes, indicators and problems of soil erosion. The main causes of soil erosion perceived by farmers in the study area were over cultivation, cultivated of steep slopes, poor government policies, excessive rainfall and poor agricultural practices. The present study suggests that the stream health and soil erosion in the catchment are closely related suggesting possible impacts of land degradation. This study also highlights

the human factors contributing to soil erosion in the catchment and interventions needed for managing catchment.

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