Greater Reduction of Soil Erosion Rates after the Introduction of Simple Conservation Measures to a Small Tank Cascade System in Palugaswewa, Sri Lanka

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Abstract - Agriculture in the dry zone of Sri Lanka has been sustained for over two millennia by harvesting rainwater using manmade village tanks, which are arranged in a cascade system. Induced soil erosion threats the Tank Cascade Systems (TCS) by causing a high level of sedimentation of tanks. There are no studies conducted in the country on spatial soil loss in TCS. Therefore, this study aims to study the spatial distribution of potential soil erosion rates in six selected sub-catchments in Palugaswewa TCS under various land uses. The revised Universal Soil Loss Equation (RUSLE) model was used with ArcGIS 10.8 to assess soil erosion. Erosion rates were estimated for the present conditions under each land use, assuming simple conservation practices to assess the effect of the introduction of conservation measures on soil erosion rates. The spatial distribution of soil erosion of the sub-catchments of Palugaswewa TCS was created by multiplying all factor layers of annual rainfall erosivity factor (R), soil erodibility factor (K), slope length and steepness factor (LS), vegetation cover and management factor (C) and support/conservation practice factor (P) with a raster calculator using map algebra in ArcGIS 10.8. Erosion values of the sub-catchments of Palugaswewa TCS vary between 19 t/ha/yr to 44 t/ ha/yr at the present conditions, and it is reduced between 8.9 t/ha/yr to 14.5 t/ha/yr after the conservation measures such as cover cropping and soil bunds were applied. The finding of this study suggests that adopting simple conservation measures such as soil bunds and cover crops can reduce soil erosion to a great extent.

Keywords: sedimentation, RUSLE, tank cascades, land use

I. INTRODUCTION

Tank chains or tank cascades are one of the traditional land and water management systems developed based on catchment ecosystems. Erosion rates rise with increased population, rapid development, human modifications and climate change [1]. Soil erosion and sediment accumulation in tanks are one of the serious issues of TCS [2]. Sediment accumulation gradually reduces the tank storage capacity, including the dead storage which is vital to meet the community and environmental needs during the dry periods Soil erosion in the catchments is the cause of tank sedimentation. Watersheds comprise many land uses. Land use is a major variable of soil erosion. Further, land slope, soil type, rainfall, and soil management influence soil erosion and these factors have a spatial distribution in the watersheds. Therefore, there is a spatial distribution of soil erosion in the TCS. Adopting supporting conservation practices such as terracing, contour farming, strip/ cover cropping and soil bunding will effectively reduce soil erosion by influencing drainage patterns, runoff concentration, runoff velocity and hydraulic forces exerted by the runoff on the soil surface [3]. A proper understanding of the spatial distribution of soil erosion in the watersheds is essential for the control of sedimentation of the tanks in the TCS. There are no studies conducted on the spatial soil loss in tank cascade systems in the country. Therefore, this study aims to study the spatial distribution of potential soil erosion rates in six selected sub-catchments in Palugaswewa TCS under various land uses in the present context and with some selected conservation methods.

II. METHODOLOGY

The study was conducted in the Palugaswewa TCS comprising of six tanks, namely a) Maha wewa, b) Alapath wewa, c) Yakandagas wewa, d) David wewa, e) Kundalugas wewa and f) Udakadawala wewa. The sub-catchments of the Palugaswewa TCS were delineated using ArcGIS 10.8. Extents of different land use in the catchment were assessed using the land use map of the year 2018 of the Palugaswewa DS division, prepared by the Land Use Policy Planning Department, Anuradhapura.

The mean annual rainfall was calculated using thirty years of daily rainfall data (1988 - 2018) for six rain-gauge stations around the study area, namely Anuradhapura, Diyabeduma, Giritale, Hingurakgoda, Mahagalkadawala and Mahaillupallama. R factor layer was calculated using the inverse distance weighted interpolation technique and a regression model proposed for the Sri Lankan conditions [4].

$$R = \frac{972.5+(9.95*P)}{100} \quad (1)$$

where R is the annual rainfall erosivity (MJ mm ha^{-1} $h^{-1}yr^{-1}$) and P is the mean annual rainfall (mm).

Palugaswewa TCS consists of Reddish-Brown Earths soils on upper land and Low Humic Glay soils in the valley bottoms. Their soil erodibility factors were used to create K factor layer. Slope length and steepness were calculated using 30 m × 30 m resolution Digital Elevation Model (DEM). The slope length factor was computed using equation (2), and "m" in this equation was taken as 0.2 as the slope of the sub-catchments of the study area is less than 1% [5]. According to equation (3), the slope steepness was determined [6].

$$L = (\lambda/22.1)^m \quad (2)$$

where L is the slope length factor, λ is the horizontal projected slope length (m), and m is the slope length exponent.

$$S = 10.8sin\theta + 0.03\ for\ slope\ percent < 9\% \quad (3)$$

where S is the slope steepness factor and θ is the slope angle in degree.

The C factor was estimated by using Wishmeirs graph, which explains the combined effect of mulch and canopy on soil erosion. The canopy cover was determined by looking at the Google image, and the surface cover was determined by ground observations and judgment. At present, conservation measures are used only in paddy lands which are terraced. The conservation techniques introduced in this study were cover cropping for the open forest and forest plantation and soil bunds for homesteads and *chena* lands. The spatial distribution of soil erosion of the sub-catchments of Palugaswewa TCS was created by multiplying all factor layers of R, K, LS, C, P (determined as explained above) with the raster calculator using map algebra in ArcGIS 10.8.

III. RESULTS AND DISCUSSION

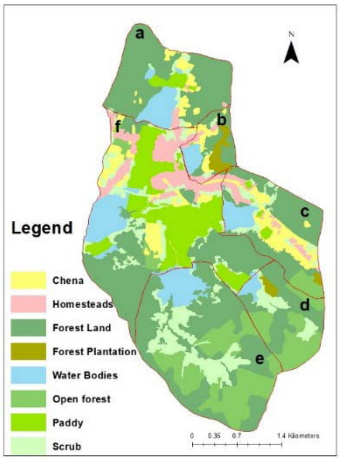

Figure 1. Land use map of sub catchments of Palugaswewa TCS in 2018

The drainage area of sub-catchments of Palugaswewa TCS vary only from 0.5 km^2 to 5 km^2, the R (168 MJ mm ha^{-1} $h^{-1}yr^{-1}$) and K (0.27 t h MJ^{-1} mm^{-1}) factors of the study area does not show any variation, LS factor only shows a very less variation of 3.7 to 4. The support or conservation practice represented by P factor adopted is only terracing of paddy at present. Therefore, the land use or vegetation (C) is the most important factor influencing soil erosion in this study. This is supported by reference [7] as when other factors are similar and if vegetation cover on a plot falls from 100% to 0%, erosion goes from 1 to over 1000 tons. The experimental cascade system, sub-catchments and land uses are given in Fig. 1. The land use distribution and soil erosion rates under the sub-catchments are given in Table 1. High erosive land use types are *chena*, homesteads, forest plantation and open forest and the least erosive land uses are scrub, forest and paddy. Some catchments, including Alapath wewa, David wewa, and Yakandagas wewa have a high percentage of high erosive land uses compared to other catchments. In present conditions, the Maha wewa sub-catchment has the lowest erosion as it has the lowest percentage of high erosive land uses and the highest percentage of dense forest cover. Alapath wewa sub-catchment has the highest erosion rate as it has the highest percentage of highly erosive land uses, namely forest plantation, homestead and *chena*. Yakandagas wewa sub watershed has the second highest erosion rate. It has the third highest percentage of highly erosive lands but has the highest percentage of *chena* lands which cause high erosion. When comparing the remaining watersheds, David wewa shows high erosion as it has a high percentage of open forest. In Udakadawala wewa sub-catchment, almost 75% of the land use includes forest, scrub and paddy, which are low erosive land uses. Kundalugas wewa sub-catchment shows the lowest erosion rate next to the Maha wewa sub-catchment and has the lowest percentage of highly erosive land uses. The data show very high potential for soil erosion under the present land management system in the cascade. The potential erosion rates varied between 18.8 to 44.3 t/ha/yr. Simple conservation measures such as cover cropping and soil bunds adopted in this study are respectively biological and mechanical techniques. Reference [8] reports that the effects of biological and mechanical practices in soil conservation are around 85% according to a global analysis. In this study, soil erosion reduced between 62 % to 68% in all the tanks other than Maha wewa after the introduction of these conservation practices. In Maha wewa, soil erosion was reduced by only about 43 %, as it already had the least erosion even before applying conservation measures.

IV. CONCLUSION

Potential soil erosion rates of the sub-catchments of Palugaswewa TCS vary with lamd use type and are reduced in the range of 43 % to 68% after the introduction of simple conservation methods such as soil bunds and cover crops to the present land use systems.

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Table 1. Comparison of soil erosion of sub-catchments in Palugaswewa TCS under present conditions and with the introduction of conservation practices

Name of the sub-watershed	Land uses in sub-catchments (%)							Soil erosion at present condition (t/ha/yr)	Soil erosion with the introduction of conservation practices (t/ha/yr)	Reduction of soil erosion after the introduction of conservation practice (%)
	Scrub	forest	paddy	Open forest	Forest plantat ion	homest eads	*Chena*			
Alapath wewa	5.10	44.30	-	-	22.60	11.50	16.50	44.3	14.5	67.3
David wewa	13.64	41.82	-	41.00	3.54	-	-	30.0	9.6	68.0
Yakandagas wewa	10.06	47.58	2.34	8.10	1.43	9.19	21.30	39.9	14.5	63.7
Kudalugas wewa	18.88	49.16	-	31.96	-	-	-	23.1	8.9	61.5
Udakadawala wewa	13.33	32.64	30.19	2.32	-	13.84	7.68	27.4	10.5	61.7
Maha wewa	4.97	78.35	5.66	-	-	2.46	8.56	18.8	10.7	43.1