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Journal Description

The **PUP JOURNAL OF SCIENCE AND TECHNOLOGY (PUPJST)** is a CHED-accredited, double-blind, peer reviewed journal that publishes original articles on theoretical and applied studies in the field of science and technology. It is an annual research publication that aims to provide significant involvement of researchers by presenting novel ideas as well as new knowledge for the advancement of the society in general.

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The PUP JOURNAL OF SCIENCE AND TECHNOLOGY (PUPJST) publishes original scientific papers and application-focused articles from recent accomplished researches on physical sciences, life sciences, food sciences, nutrition and dietetics, agricultural sciences, environmental sciences, computing and information sciences, mathematics, engineering and technology. The articles must pose valuable hypothesis to derive novel perspectives, verify scientific concepts and innovation in technological advances. The journal does not publish purely descriptive articles that descend from a well-documented exposition, short communication, survey or even a comprehensive review of currently active area of research.

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C O N T E N T S

GEOGRAPHIC INFORMATION SYSTEM-ASSISTED APPROACH IN SOIL EROSION HOTSPOT ASSESSMENT OF BANGA MICROCATCHMENT

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Abstract: The study aimed to characterize the biophysical environment of the microcatchment, predict soil loss (t/ha/yr.), quantify soil loss for six months, estimate carbon and primary nutrients nitrogen (N), phosphorous (P), potassium (K) loss of major land uses using Universal Soil Loss Equation (USLE) modified through Manifold System Version 8.0 and recommend doable mitigating measures. The Sibalew-Torralba Microcatchment (431.87 ha) is located in Banga, Aklan (122°19'845" and 122°19'449" East Longitude, 11°32"329" and 11°32'586" North Latitude). The two soil types were Sigcay and San Manuel clay loam with compacted surface value of 1.33-147g/cm, a pH of 4.7-6.1; with low N, P, K but medium in soil organic matter (SOM). The microcatchment belonged to Type III climate with mean annual rainfall of 2,183.47 mm. The topography is flat to undulating, rolling, and steep slopes. There are seven major land uses namely agricultural land, mixed vegetation, orchard/agroforestry, coconut-based, grassland, built-up, and water tributaries. Results revealed that the average soil loss at different land utilization types (LUT) was 159.51-1205.32 t/ha/yr. The average actual soil loss range from 19.98-1074.06 kg/ha for six months. Soil erosion hotspots (high-very high soil loss category) was predicted in four LUTs: agricultural land (upland rice, 206.29-618.73 t/ha/yr.; mix vegetation (natural vegetation, fruit trees associated with banana, and corn-vegetables, 75.15, 87.04 and 913.78 t/ha/yr., respectively); coconut-based (coconut-based perennial and mahogany, with underneath of upland rice, 96.37 and 154.77 t/ha/yr.), and built-up (institutional and roads going to provincial roads, 41.69 and 70.42-332.09 t/ha/yr.). Further, carbon loss range from 2.60 to 137.26 kg/ha/6 months; available N loss range from 3.65-172.27 kg/ha/6 months; available P loss range from 74.13-9297.25 kg/ha/mo. while exchangeable K loss range from 8.42-452.39 kg/ha/yr. Thus, application of best crop and soil conservation management practices (natural farming/organic farming and multi-story fruit based agroforestry) is recommended to mitigate soil erosion.

Keywords: *GIS, hotspot, microcatchment, erosion, watershed*

1. INTRODUCTION

The conservation and efficient management of soil and water resources serve as basis for food and health security. Soil, especially in the watershed, is the medium in which most plants grow, and is a vital resource for human survival. The watershed cleans and stores water, detoxifies pollutants, and plays a key role in regulating the global temperature. It is also habitat to a multitude of beneficial soil organisms necessary for the cycling of nutrients and maintenance of healthy environment for human beings. Unfortunately, approximately 33 million hectares or 45 percent of the country's arable lands are affected by soil degradation that make them unsustainable and less productive (Asio *et al*., 2009; Legarda, 2013).

In 2010, the Bureau of Soils and Water Management (BSWM) reported that around 13 million hectares of arable land in the country are either moderately or severely eroded because of massive deforestation and adoption of unsustainable land management practices in upland areas. This is seen as a serious environmental problem. Agricultural practices and economic pressures have severely degraded the agricultural resource base through accelerated soil erosion, siltation of irrigation systems, flooding, and water pollution (Briones, 2009). This situation really runs counter to the general objectives of sustainable water source from watershed. To resolve present threats, generating data and/or information on the extent and location of erosion hotspots is deemed very necessary.

Soil erosion indeed affect agricultural productivity and land use change; thus, quantitative estimates on relationship between soil erosion and crop productivity are vital. The use of conventional methods to assess soil erosion hotspot is expensive and time-consuming. Geographic information systems (GIS), coupled with the use of an empirical model to assess erosion hotspot, can identify and assess soil erosion potential and estimate value of soil loss (Breiby, 2006).

In this study, the researcher specifically aimed to characterize the biophysical environment of the catchment relative to its possible contribution to soil loss. This is followed by quantifying soil loss in major land uses in the microcatchment, identifying areas of erosion hotspot, estimating organic carbon and macronutrient losses such as nitrogen (N), phosphorous (P), potassium (K) from major land uses, and recommending doable mitigation measures to arrest further degradation.

This study is part of the collaborative Research and Extension project on Sloping Agricultural Land Technology (SALT) of the Aklan State University (ASU).

2. METHODOLOGY

2.1 Location and selection of study area

The study area is in Banga, Aklan (Figure 1), located in the central plain of the province. It is about nine kilometers from Kalibo, the provincial capital. The center of Poblacion Banga is approximately 11° 38’ 23.3” north longitude and 122° 19’ 58.9” east latitude. Banga is bounded by six (6) municipalities: Kalibo in the north, New Washington in the northeast, Lezo in the northwest, Madalag in the South, Balete in the southeast, and Malinao in the southwest.

This microcatchment was selected for the following reasons: (1) being agriculturally-active; (2) having a single drainage outlet; (3) being hydrologically well-bounded and delineated by well-defined topographic boundaries; (4) having a watershed area of at least 100 ha; and (5) having been previously studied, with more easily-accessible and available data. It is one of the microcatchments of Aklan River watershed located at Barangays Sibalew and Torralba, Banga, Aklan.

2.2 Delineation of the microcatchment

From the topographic map, the microcatchment was identified based on river tributaries that interconnect to the main outlet towards the Aklan river system, where water from the catchment finally drains out. The image was then scanned and converted to the digital image by digitization using the Manifold System Version 8 (Figure 2a). In the absence of a digital elevation model (DEM) map during the generation of maps as input, a DEM map was made from the digitized topographic map. From the DEM map, the micro-catchment boundaries were delineated by a digitizing point at the outlet to finally cover the microcatchment under study which is later validated using the DEM of GIS.

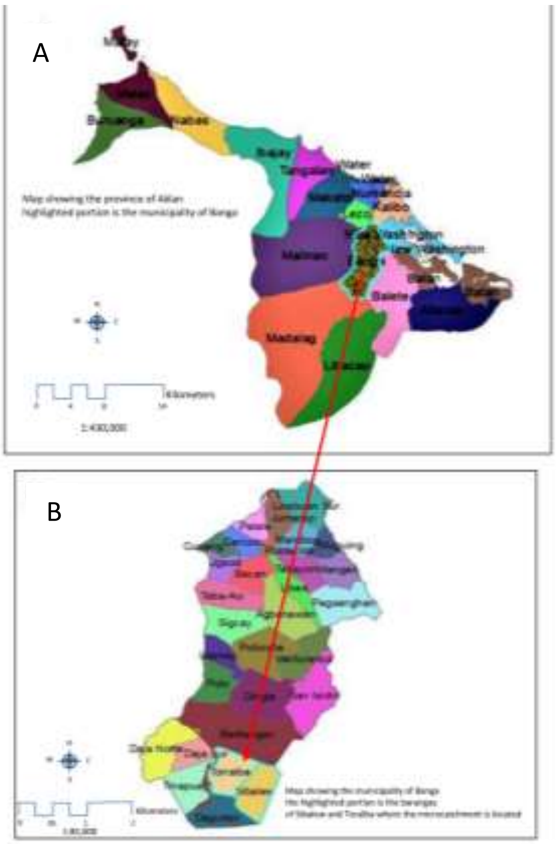

Figure 1. (A) Location of the study site in the Province of Aklan; and (B) municipal location map of the study site.

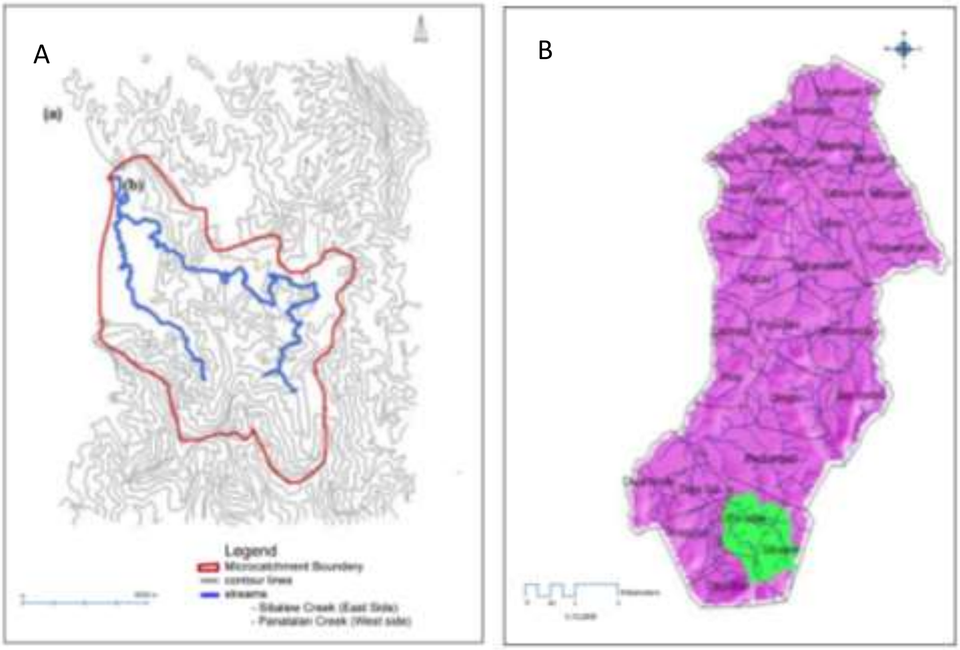

Figure 2. (A) Topographic map of Sibalew-Toralba microcatchment; and (B) the delineated microcatchment under study.

2.3. Microcatchment characterization

The microcatchment was described in terms of selected physical and chemical characteristics of the soil; the river and tributary systems; the climate, topography, slope, land use cropping pattern, and cropping system. Secondary data were sourced out from ASU-Agromet Weather station to include rainfall (automatic weather station installed in the university); soil type from the BSWM; topographic map from the National Mapping Resources Information Agency (NAMRIA); and land use or cover map using aerial photograph from ASU-Ateneo AUV Research Project, the SkyEye Services (Figure 3).

2.4 Soil sampling and analysis

Soil sampling and analysis were conducted to determine soil properties needed in the estimation of soil loss. Composite soil samples from each of the major land use category were collected and brought to the BSWM laboratory for analysis of their physico-chemical characteristics. The results were used to generate a soil database for the selected microcatchment as data input in predicting soil loss and in coming up with a doable recommendation to minimize or reduce soil loss in the microcatchment.

2.5 Parameterization of input data needed for the prediction of soil loss

Thematic maps such as contour (Figure 4), DEM, slope, soil, land use and soil loss factors were generated using secondary as well as primary data. All other maps were generated using the Manifold System version 8.0 software.

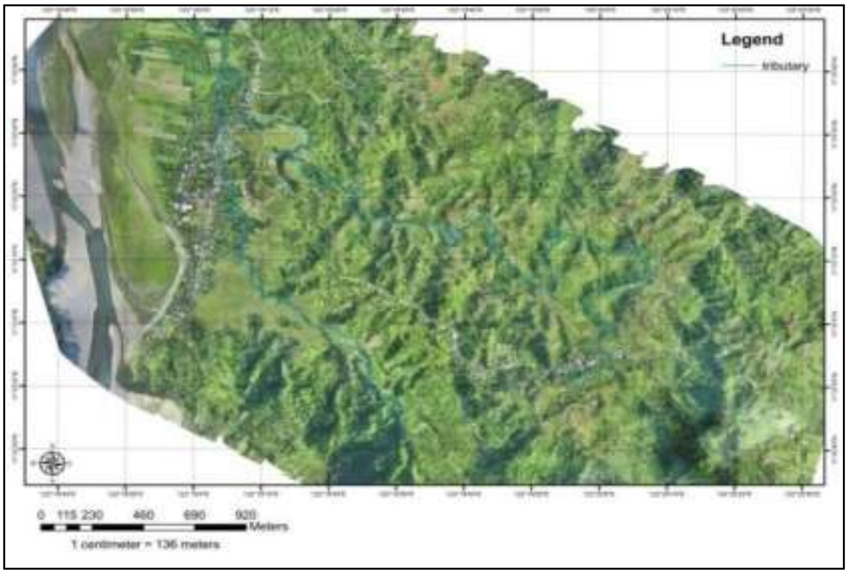

Figure 3. Aerial photograph of the microcatchment (from AUV research team).

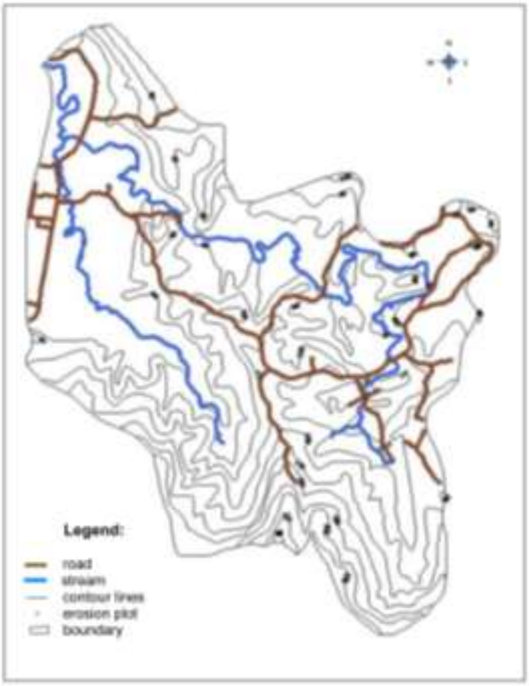

Figure 5. Contour map used in the creation of digital elevation map.

Data needed to predict soil loss were collected from the different major land utilization type characteristics in the microcatchment. This was done through ground truthing during microcatchment characterization. Input data in the prediction of soil loss was computed using the modified Universal Soil Loss Equation (USLE) (Lanuza, 2009) and expressed as:

$$A = R \times K \times LS \times C \times P$$

where: A = annual soil loss (ton ha-^{1});
R = rainfall erosivity index;
K = soil erodibility index which is a function of soil pH, organic matter and relative amount of sand, silt and clay;
LS = topographic factor (slope length and gradient); C is the land cover factor (David, 1998); and
P = is the erosion control practices factor.

2.6 Validation of predicted soil loss

The predicted soil loss values were validated using six (6) standard erosion plot for soil with a dimension of 22.1 m long x 2 m wide constructed at the representative component of the identified major land uses within the microcatchment. The actual soil loss from each location was calculated by measuring the concentration of sediments collected in the runoff water trapped at each erosion plot in each rainfall event for each month from July to December 2014. Actual soil loss (SL) was estimated using the formula:

$$SL = \text{sediment concentration (g/L)} \times \text{runoff volume (L)}$$

Sediment concentration was estimated by collecting one liter of the runoff water collected after mixing it homogeneously in the collecting drums. The collected runoff water was filtered using Whatman #42 filter paper; weighed, dried for at least 24 hours or until a stable weight was obtained (Figure 5).

2.7 Formulation of mitigation measures and policy recommendation

Based on generated soil erosion map, erosion hotspots were identified and mitigation measures were formulated. Areas considered as erosion hotspots are the parcels in the microcatchment with soil loss category of high to very high. To determine reduction on soil erosion within erosion hotspots as a function of recommended mitigating measures, different scenarios were made and integrated into a model to predict changes in soil loss. Recommendations with the highest reduction in soil loss were selected for possible adoption of the stakeholders within the microcatchment. Only C and the P factors were considered in making the scenarios for the formulation of mitigating measures.

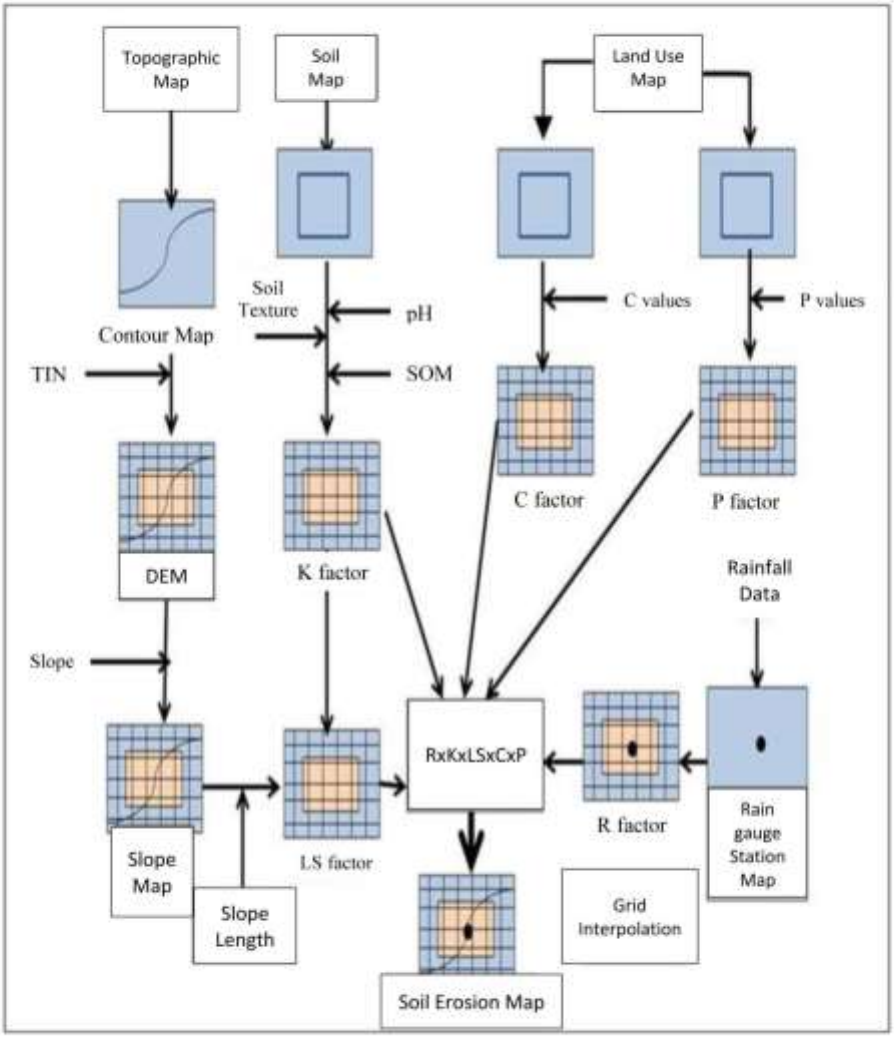

Figure 5. Process flow in the estimation of soil loss.

3. RESULTS AND DISCUSSION

3.1 Soil characteristics

Based on the existing soil map (Figure 6), there are two soil types found within the microcatchment. Sigcay clay, steep phase, dominated the microcatchment covering 86.23 percent or approximately 307.33 ha. San Manuel sandy clay loam occupied the middle part of the catchment up to the remaining part boundary of the connecting creek.

The soils in the catchment utilized for agricultural land, orchard/agroforestry, coconut-based, and built-up areas under Sigcay Clay consist of red soils and is found in rolling hilly and mountainous areas. This soil series is derived from basaltic rock materials and the solum is a deep layer of massive white soil materials, known locally as isu. The drainage is good to excessive. The native vegetation consists mostly of forest and grasses while the grassland and mix vegetation land use in the catchment have the San Manuel Clay loam which is found in areas adjacent along the Aklan river banks. The soil in 0-30 cm depth is clay loam; moderately granular in structure, slightly sticky, and contains a fair amount of organic matter. It is principally cultivated to rice with only a fair average production, which may be attributed to soil erosion and tillage practices.

The surface soils of the catchment are generally compact and degraded with an average bulk density of 1.42 g/cc, strongly acidic (pH 4.8), low to medium OM (3.8%), low N (0.19%), very low P (0.87 ppm), low to medium K (0.17 me/100g), and high CEC (20.07 me/100g) as shown in Table 1.

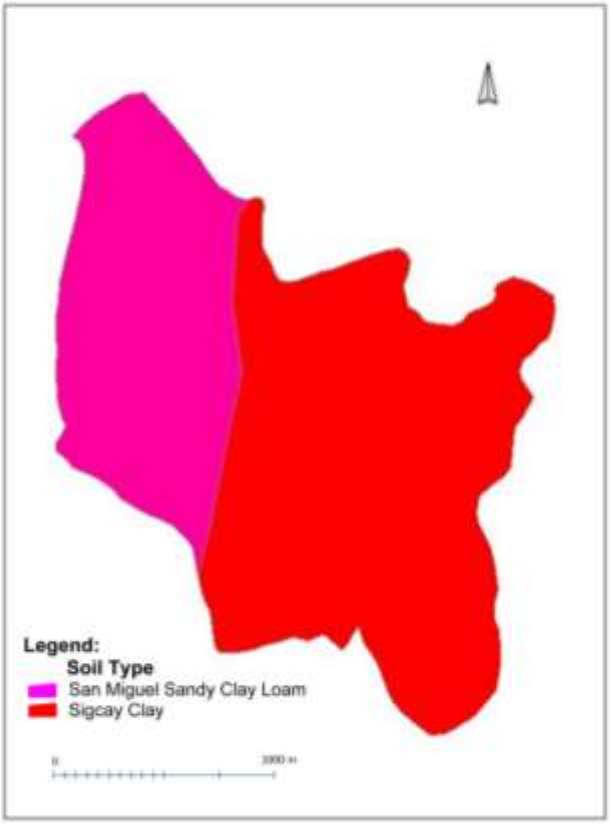

Figure 6. Soil Map of the microcatchment.

Table 1. Some physical and chemical characteristics of the surface soil from different representative component of the major land uses in the microcatchment.

LAND USE	**SOIL TYPE**	**BULK DENSITY** (g/cc)	pH	**TN** (%)	**OM** (%)	**AP** (ppm)	**EK** (me/100g)	**CEC** (me/100g)
Agricultural Land • Upland Rice- root crops	Sigcay Clay	1.38	5.0	0.12	3.66	0.63	0.15	19.3
• Corn-Legumes	Sigcay Clay	1.38	5.0	0.23	4.18	0.43	0.16	16.3
Orchard/ Agroforestry	Sigcay Clay	1.53	4.9	0.15	2.87	1.32	0.23	19.4
Coconut-Based	Sigcay Clay	1.47	4.8	0.26	4.49	0.34	0.13	33.5
Built –up	Sigcay Clay	1.40	4.9	0.20	4.18	2.23	0.19	14.3
Grassland	San Manuel	1.38	4.7	0.17	3.73	0.27	0.15	17.6
Mixed Vegetation	Clay Loam	1.33	6.1	0.11	2.10	60.7	1.46	40.8
Average		**1.42**	**4.88**	**0.19**	**3.8**	**0.87**	**0.17**	**20.07**

Legend: TN = total nitrogen; AP = available phosphorous; EK = exchange potassium; CEC = cat-ion exchange capacity; ppm = parts per million; me = milliequivalent; cc = cubic centimeters; OM = organic matter

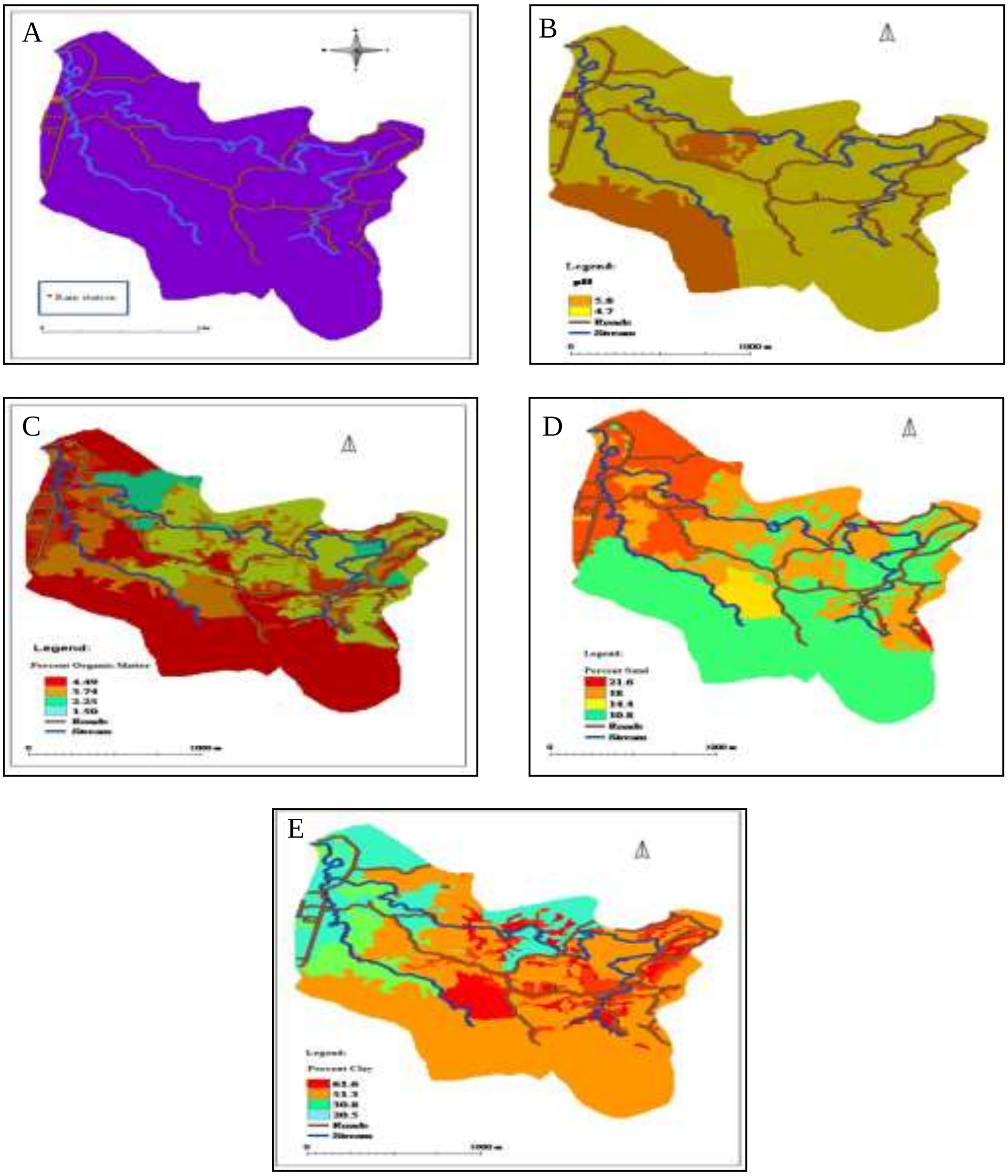

Figure 7. GIS-assisted environment for the soil loss in the microcatchment as product of (A) Rrainfall erosivity (B) soil pH map (C) soil OM Map (D) percent sand map (E) Percent clay map (F) percent silt map.

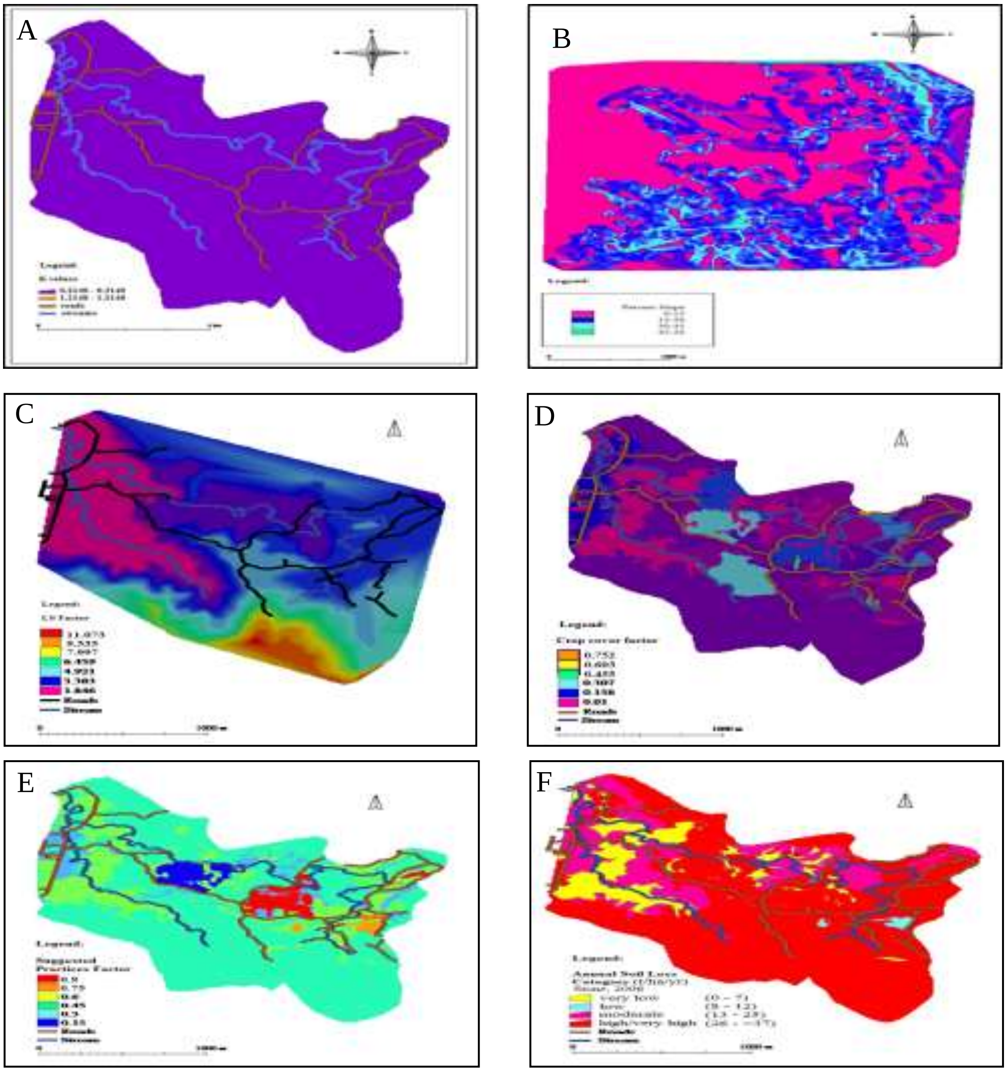

Figure 8. GIS-assisted environment for the soil loss in the microcatchment as product of (A) Soil erodability K map; (B) Slope map; (C) Slope gradient LS map; (D) Ground cover C map; (E) Soil conservation P map; (F) Predicted soil loss map.

Table 2. Description of current land utilization type.

MAJOR LAND USE	LAND USE SUB-COMPONENT	PREDICTED SOIL LOSS			
		AREA (ha)	Minimum (t/ha/yr)	Max (t/ha/yr)	Total Soil Loss (t/ha/yr)
Agricultural Land	Upland Rice ecosystem	36.37	0.47	5.21	207.72
	Lowland Irrigated Rice	25.40	0.18	8.18	189.42
	Upland rice with root crops/annual crops	0.67	206.29	618.73	411.63
	SUB TOTAL	62.44	2.55	5.09	808.77
Mixed Vegetation	Natural Vegetation, fruit, grass,	0.67	8.56	75.15	50.33
	Coco, banana, fruit trees	1.99	2.61	87.04	173.38
	Banana/fruit trees/Corn-Vegetables	0.93	46.23	913.78	849.89
	SUB TOTAL	3.59	15.01	19.91	1073.59
Orchard/ Agroforestry	Orchard	21.07	2.65	17.93	377.79
	Orchard/ Calamansi/ rambutan mixed	31.61	2.99	17.55	554.66
	Orchard, fruit trees,	8.22	0.73	3.41	28.05
	Perennial crops mixed	41.55	0.57	2.13	88.71
	SUB TOTAL	102.45	15.01	19.91	1049.20
Coconut-based	Mahogany, riceland	0.32	49.37	147.03	154.77
	Coconut	82.23	0.21	2.58	212.22
	Coconut Based/perennial	7.29	4.27	96.37	702.26
	Mixed plantation	51.00	0.44	1.91	97.54
	Coconut, mahogany, banana, Maganhop	47.87	0.79	1.97	94.52
	Rambutan, mahogany, coconut	4.77	1.32	10.36	49.42
	SUB TOTAL	193.47	0.836	6.23	1205.32
Grassland	Grassland, interspersed with shrubs	13.62	4.68	11.71	159.51
Built- up	Community living upland	28.51	1.21	7.33	208.98
	Institutional	1.40	4.81	41.69	58.26
	Community living low lying areas	16.77	0.98	4.13	69.23
	roads going upland	2.75	4.83	22.35	61.41
	roads going lowland areas	1.62	13.87	26.46	42.98
	provincial road	1.33	70.42	332.09	440.87
	SUB TOTAL	52.38	3.57	4.72	881.73
	GRAND TOTAL	**427.96**	**28.40**	**54.70**	**5178.13**

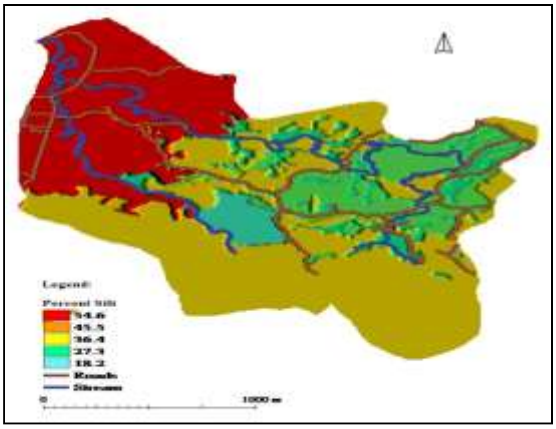

Figure 10. Predicted soil loss map in the microcatchment
as affected by major land utilization types.

3.2 Predicted soil loss per land utilization type

The soil loss predicted in the microcatchment was generated using the USLE equation as modified by Lanuza (2009) in a GIS-assisted environment by the product of each individual component map such as rainfall erosivity index (R), soil erodability (K), slope length factor (L), slope gradient factor (S), cover factor (C), and erosion control factor (P) in a grid or raster format (Figures 7 and 8). The model was built by instructing the GIS to multiply the USLE components to create new maps of erosion potential under certain conditions. The product, A, is the estimated soil loss in tons/ha/yr.

The output map generated from the model was presented as soil loss map (Figure 9). Soil loss in each individual representative component of the major land utilization types in the microcatchment is shown in Table 2. The predicted soil loss, in general, range from very low to very high category.

3.2.1 Agricultural land

Among the components of the land utilization type, agricultural land, the highest minimum soil loss was obtained from upland rice with root crops with a percent slope of 27.21 having a soil loss of 207.72 t/ha/yr, followed by the upland rice ecosystem with a minimum soil loss of 0.47 t/ha/yr; however, the lowest minimum soil loss was obtained from lowland irrigated rice production system which is 0.18 t/ha/yr because it is situated on a 0-3 % slope. When it comes to total soil loss, the highest, with 411.63 t/ha/yr, was obtained from upland rice with root crops, and the lowest soil loss, with 189.42 t/ha/yr, was obtained from lowland irrigated rice production system which occupies 62.44 hectares or 14.5 % of the total land area of 431.87 hectares of the microcatchment.

3.2.1 Mixed vegetation

The mixed vegetation land use dominantly grow fruit trees with associated banana underneath of which are corn and vegetables, and is situated on a 22% slope. It obtained the highest minimum soil loss of 46.23 t/h/yr. This land utilization type has the highest total soil loss of 913.78 t/ha/yr, and the lowest obtained from natural vegetation with fruit trees and grasses with 50.33 t/ha/yr. The average soil loss estimated was 15.01 t/ha/yr minimum and 19.91 t/ha/yr, categorized to be moderate.

3.2.2 Orchard/Agroforestry

The orchard/agro forestry land use occupies 102.45 hectares or 23.70% of the total catchment area. This land utilization type is composed of the orchard, orchards with fruit tree mixed and perennial trees as the major vegetation. The highest minimum soil loss was obtained from orchard mixed with calamansi/rambutan, with 2.99 t/ha/yr, while the lowest minimum soil loss is 0.57 t/ha/yr from the perennial crops mixed.

3.2.3 Coconut-based system

The coconut-based system comprises the biggest area in the catchment occupying around 193.47 ha or 44.8% of the total catchment area. The highest minimum soil loss of 49.37 t/ha/yr was obtained from mahogany underneath of which is upland rice production ecosystem that has a 33% slope with an aggregate area of 82.23 ha or 19% of the total catchment area to as high as 154.77 t/ha/yr but occupying only 0.32 hectare or 0.10 percent of the catchment area.

3.2.4 Grassland

The grassland occupies a total area of 13.62 ha or 3.2% of the total catchment area. The predicted soil loss range from very low to low with values of 4.68 t/ha/yr minimum and 11.71 t/ha/yr maximum. In general, soil loss in the grasslands is minimal considering the effect of crop cover and soil organic matter accumulation.

3.2.5 Built-up

The built-up comprises around 12.1% or 52.38 ha. The soil loss is categorized as very low to very high. The total soil loss predicted was 42.98-440.87 t/ha/yr obtained from roads going to lowland areas to the provincial road.

Table 3. The computed actual soil loss per month in a period of six months in each representative component of the major land uses in the microcatchment.

LAND USE	MONTHLY SOIL LOSS (kg/ha)							
	July	August	September	October	November	December	TOTAL	AVE.
Agricultural (Upland Rice with root crops/annual crops	141.72	3023.76	2.92	3000.64	271.67	3.64	6444.34	1074.06
Mixed Vegetation (Vegetables	0.00	1.74	0.00	1211.51	416.09	29.39	1658.73	276.46
Orchard/Agroforestry (Orchard/ calamansi/rambutan mixed	3.36	20.05	0.00	80.61	9.36	8.45	121.83	20.31
Coconut Based (Coconut based/perennial)	17.42	1910.60	1.68	1288.97	55.28	39.02	3312.97	552.16
Built Up (Community living upland	141.44	807.62	124.67	219.51	71.60	44.39	1409.24	234.87
Grassland (Cogonal)	3.01	3.39	0.69	34.34	29.04	49.43	119.90	19.98
TOTAL	306.94	5767.17	129.95	5835.58	853.05	174.31	3067.00	2177.83

Table 4. Estimated loss of total carbon in the soil surface and its equivalent cost per land use in the microcatchment based on actual soil loss within the 6-month period.

LAND USE	ACTUAL SOIL LOSS (kg/ha /6 months)	SOIL ORGANIC CARBON (%)	ORGANIC CARBON LOST *(kg/ha/6 months)*	EQUIVALENT COST PhP/ha/6months
Agricultural	6,444.34	2.13	137.26	54,356.72
Mixed Vegetation	1,658.73	2.43	40.31	15,961.63
Orchard/Agrofo restry	121.83	1.67	2.03	805.69
Coconut Based	3,312.97	2.61	86.47	34,241.53
Built Up	1,409.24	2.43	34.24	13,560.83
Grassland	119.90	2.17	2.60	1,030.32
TOTAL	13,067.00		302.91	119,956.72

Assumptions:
Organic carbon lost = Actual soil loss x (% Soil organic carbon/100)
Cost of organic carbon is USD 9 per ton 1USD=PhP44.00

Table 5. Estimated loss of available nitrogen in the soil surface and its equivalent cost per land use in the microcatchment based on actual soil loss within the 6-month period.

LAND USE	ACTUAL SOIL LOSS (kg/ha/6 months)	SOIL TOTAL NITOGEN (%)	MINERALIZED N (kg/ha/6 months)	EQUIVALENT AMOUNT bag Urea/ha/6 months	EQUIVALENT COST PhP/ha/6months
Agricultural	6444.34	0.12	154.66	6.72	6590.04
Mixed Vegetation	1658.73	0.23	76.30	3.32	3251.11
Orchard/Agroforestry	121.83	0.15	3.65	0.16	155.73
Coconut Based	3312.97	0.26	172.27	7.49	7340.39
Built Up	1409.24	0.2	56.37	2.45	2401.84
Grassland	119.90	0.17	4.08	0.18	173.70
TOTAL	13,067.00		467.33	20.32	19912.81

Assumptions:
Mineralization rate of organic N = 4% per year; 2% was used then for 6 six months
Equivalent number of bags Urea = (Mineralized N/0.46)/50 kg per bag
Cost of 1 bag urea = PhP 980.00

Table 6. Estimated loss of available phosphorus in the soil surface and its equivalent cost per land use in the microcatchment based on actual soil loss within the 6-month period.

LAND USE	ACTUAL SOIL LOSS (kg/ha /6 months)	SOIL AVAL. P (ppm P)	SOIL AVAIL. P (kg P/ha/6 months)	SOIL AVAIL. P (kg P_2O_5/ha/6 months)	EQUIVALENT AMOUNT (bag 0-18-0/ha/6 months)	EQUIVALENT COST (PhP/ha/6 months)
Agricultural	6444.34	0.63	4059.93	9297.25	1033.03	1084679
Mixed Vegetation	1658.73	0.43	713.25	1633.35	181.48	190558
Orchard/Agroforestry	121.83	1.32	160.82	368.27	40.92	42964.6
Coconut Based	3312.97	0.34	1126.41	2579.48	286.61	300939
Built Up	1409.24	2.23	3142.61	7196.57	799.62	839599
Grassland	119.90	0.27	32.37	74.13	8.24	8648.99
TOTAL		**5.22**	**9235.39**	**21149.05**	**2349.90**	**2467388.59**

Assumptions:
Soil available P = Actual soil loss x (% P/100); where percent P = ppm P/10,000
Soil available P was converted to P_2O_5 by multiplying P with 2.29
Equivalent number of bags 0-18-0 = (kg P_2O_5 /0.18)/50 kg per bag
Cost of 1 bag 0-18-0 =PhP 1,050

Table 7**.** Estimated loss of exchangeable potassium in the soil surface and its equivalent cost per land use in the microcatchment based on actual soil loss within the 6-month period.

LAND USE	ACTUAL SOIL LOSS (kg/ha/6 months)	SOIL EXCH. POTASSIUM (m.e/100 g)	SOIL EXCH. POTASSIUM (kg K/ha/6 months)	SOIL EXCH. POTASSIUM (kg K2O/ha/6 months)	EQUIV. AMOUNT bag 0-0-60/ha/6 months	EQUIV. COST PhP/ha/ 6months
Agricultural	6444.34	0.15	376.99	452.39	15.08	18,095.71
Mixed Vegetation	1658.73	0.16	103.50	124.21	4.14	4,968.23
Orchard/Agroforestry	121.83	0.23	10.93	13.11	0.44	524.55
Coconut Based	3312.97	0.13	167.97	201.56	6.72	8,062.44
Built Up	1409.24	0.19	104.42	125.31	4.18	5,012.38
Grassland	119.90	0.15	7.01	8.42	0.28	336.68
TOTAL		**1.01**	**770.82**	**925**	**30.84**	**36,999.99**

Assumptions:
Soil available P = Actual soil loss x (% K/100); where percent K = ppm K/10,000
Percent K was computed as:
1 m.e K=780 kg K/ha; kg K/ha x 2 = ppm K; ppm K/10,000=percent K
Soil exchangeable K was converted to K_2O by multiplying K with 1.20
Equivalent number of bags 0-0-60 = (kg K_2O_5 /0.60)/50 kg per bag and Cost of 1 bag 0-0-60 = PhP 1,200.00

3.3 Actual soil loss

The actual soil loss measured in a period of six months from July to December 2014 from the erosion plot constructed in one of each representative component of the major land uses is shown in Table 3. The highest average monthly soil loss of 1,074.06 kg/ha was measured from the agricultural land and the lowest value of 19.98 kg/ha from the grassland utilization system. The high soil loss from the agricultural land system was measured from the upland rice with root crops/annual crops. In terms of monthly soil loss, the highest was measured in the month of October with a value of 5,835.58 kg/ha/6 months, followed by 5,767.17 kg/ha/6 months in the month of August. The months of August and October had the highest amount of rainfall which contributed to the high soil loss in these months. The major factor of soil erosion established using the USLE is rainfall amount.

3.4 Estimated total soil organic carbon, nitrogen, phosphorus and potassium loss

One of the major impacts of high to severe soil loss in the catchment is soil degradation brought about by losses of soil organic carbon and soil fertility level as a function of loss in major macronutrients, nitrogen, phosphorus, and potassium. Values computed herein are based on estimated actual soil loss in the six-month period, and concentration of carbon and nutrients are based on analyses of surface soil relative to individual major land use. Results are presented in Tables 4, 5, 6 and 7. Total carbon loss range from 2.03 kg/ha/6months from orchard/agroforestry land use system to 137.26 kg/ha/6 months from agricultural land use system. The coconut-based land use system had 86.47 kg/ha/6 months, 40.33 kg/ha/6 months in mixed vegetation, 34.24 kg/ha/6 months in built-up and 2.17 kg/ha/6 months in grassland. These losses are equivalent to PHP 805.69 to PHP 54,356.00. On the other hand, nitrogen loss range from 3.65 kg/ha/6 months to 172.27 kg/ha/6 months amounting to an equivalent cost of PhP155.73 and PHP 7,340.39, whereas soil available phosphorus loss as P_2O_5 range from 74.13 to 9297.25 kg/ha/6 months or PHP 8,648.99 and PHP 1,084,679.00. The range of equivalent potassium as K_2O loss is 8.42 kg/ha/6 months to 452.39 kg/ha/6 months with corresponding peso value of PHP 336.48 and 18,905.71.

Soil organic carbon plays a vital role in sustaining life in soil because it is the ultimate source of energy of the soil biota. These microorganisms are responsible for nutrient recycling which is very important in mineralization of organic compounds for the release of soil nutrients for plant absorption. During these microorganisms' activities, some organic compounds important in the process of soil particle aggregation are released. Soil particle aggregation is one of the important naturally-occurring physical processes toward the development of soil structure. The quality of soil structure formed is very necessary for sustaining soil productivity and ultimately crop production. On the other hand, nutrient loss through soil erosion is one of the major factors in the decline of chemical soil fertility in uplands. The continuous movement of surface soil in uplands enhances removal of these plant nutrients for normal growth and development of agricultural crops. This implies the necessity of supplementing required nutrition of plants through chemical fertilizer application. Considering the continuous increase of fertilizer cost, as well as the difficulty of bringing fertilizer to uplands, its sustained use to maximize crop production in uplands may be difficult to maintain. If its use is not sustained, soil degradation is most likely enhanced, threatening, therefore, food production sustainability for stakeholders.

3.5 Prediction of the location of erosion hotspots and recommended mitigating measures

The potential soil erosion and the location of areas with potential soil loss predicted from the major land uses in the microcatchment is shown in Figure 9. In general, areas of steeper slopes and with low vegetative cover have higher soil loss and therefore vulnerable to soil erosion. The result is in conformity to the findings of Mongkolsawat *et al.* (1994) and Ogawa *et al.* (1997), although variations in the magnitude were observed. Presumably, this variation is due to the disparity in the values of the factors. Nevertheless, GIS data integration and analysis using USLE is an efficient approach for obtaining spatial variability of soil erosion (Suri *et al.*, 2002). The roads going up the microcatchment, as well as the open ground within the public institutional structure, likewise risk erosion. It can also be noted that parcels devoted to agricultural production without conservation practices are subject to high-risk erosion. Expectedly, soil productivity in these areas is relatively low due to the removal of essential soil nutrients along with the eroded sediments. Therefore, application of soil and water conservation measures are deemed necessary to restore the fertility status and consequently sustain productivity. The recommended mitigating measures are results of the focus group discussion with the stakeholders and the critical assessment done relative to the existing land uses, soil erosion factors, and the financial capability of the majority of the stakeholders.

4. CONCLUSIONS

Using Geographic information system-assisted approach, the microcatchment has seven major land uses, and most of these are not exposed to proper soil conservation practices. Erosion hotspots occurred in areas with a steeper slope and lower crop cover without conservation practices, and were predicted using the modified USLE. High soil loss was predicted in agricultural land particularly if the cover factor is low, i.e. during the land preparation and at the early vegetative stage. The highest soil loss of soil C, N, P, K were estimated in the agricultural land use system.

5. RECOMMENDATIONS

It is recommended that appropriate and proper soil nutrient and conservation management, such as routine soil testing, be applied in the microcatchment, and that the soil test recommendations be followed. The community within the microcatchment should be aware of erosion hotspots and the amount of soil loss, and adopt natural farming/organic agriculture as implemented by concerned agencies to arrest further soil degradation. There is a need to reforest coconut based/mixed vegetation land uses with indigenous woody species and vegetation cover following the proper implementation of the National Greening Program towards restoring and sustaining the microcatchment resources of Banga. The use of USLE in predicting soil erosion in a landscape should be continuously improved under GIS environment. There is a need to generate default values for rain erosivity and soil erodibility indices to land use change.

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