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Degree of Erosion of Small Water Impounding Projects' Watersheds in Cagayan Valley: An Assessment

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ABSTRACT

Small Water Impounding Projects (SWIPs) play a vital role not only in increasing agricultural production but also in flood control. However, soil erosion decreases storage capacity and lessens the economic life of these SWIPs. This research aimed to assess the degree of soil erosion of 19 SWIP watersheds in Cagayan Valley. The overall methodology was done by integrating Modified Universal Soil Loss Equation (MUSLE) and Geographical Information System (GIS) to calculate the annual erosion rate of these sites considering the parameters: rainfall, soil type, topography, land use, and conservation practice. GIS data layers including rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management (C), and conservation practice (P) factors were computed to determine their effects on average annual soil loss in the study sites. As a result, it was found out that 12 SWIP watersheds assessed – four from Cagayan, three from Isabela, four from Nueva Vizcaya, and one from Quirino – possess extreme high erosion (greater than 100 tons/ha/year). In addition, four SWIP watersheds possess very high erosion (25-100 tons/ha/year), while three SWIP watersheds possess moderate to high erosion (10-25 tons/ha/yr). Thus, to lessen the soil loss and the deposition of sediments on SWIP reservoirs with very high and extremely high erosion rate, human, financial, and physical support from the National Government Agencies, Non-Government Organizations, Local Government and SWISA is urgently needed to prolong SWIP economic life. Furthermore, the research output should serve as baseline information for watershed planning, development, management, and policy-making.

***Keywords**: MUSLE, GIS modelling, soil and water conservation, soil erosion, watershed development*

Introduction

Climate change is one of the significant environmental challenges the Philippines is currently facing. This phenomenon significantly affects the susceptibility to water resource scarcity (Victoriano and Aranas, 2013). The adverse effect of climate change on the agricultural sector differs from region to region. It is expected to abruptly change the temperature and precipitation, which is related to flood and drought occurrence (Arora, 2019; Trenberth, 2011). Flood and drought has decrease the production of goods due to unfavorable environmental condition. With an increasing population (population pressure) that varies directly with an increase in food demand and decreasing water availability, the utilization of water resources should be preserved and properly managed (Mekonnen and Hoekstra, 2016).

The alarming problem of water scarcity in agricultural production has triggered decision-makers to set attention to water availability and conservation of resources. One of the significant solutions outlined is the storage of rainwater for agricultural production (Biazin et al., 2012; Helmreich & Horn, 2009).Water storage is a vital factor in sustaining crop production during the dry season when demand varies inversely with the water supply. However, dams, one of the water harvesting technologies, have become increasingly expensive to construct, and in addition to their social, environmental, and political influences, which present complex problems regarding their operation (Boyé and Vivo, 2016). Due to the constraints above, a large-scale storage reservoir is rendered a less feasible option. Thus, small water harvesting technology has been the new interest of concerned agencies despite the limitation in storing rainwater above the ground.

In partnership with the Local Government Units (LGUs), there are Small Water Impounding Projects (SWIP) that have been developed and implemented by the Department of Agriculture (DA). SWIP, a water harvesting technology, is an earth-fill structure that collects and stores rainfall and runoff during the rainy season. It is intended for soil and water conservation and flood control by storing rainwater as much as possible. It has been a priority since it supports the governments' fishing programs and irrigation programs (Bureau of Soils and Water Management, 2011). The development of the irrigation projects aims to provide optimum utilization of the harvested water for agricultural production in upland and rainfed areas. Also, SWIP contributes to satiating water requirements of animal production and recreation. SWIP has proven its value in the northern Philippines, where wet and dry seasons are extremely pronounced. From 1974 to 2010, 2060 SWIPs were installed across the country by the Bureau of Soils and Water Management (BSWM), which cost around 3 billion pesos. These 2060 SWIPs can irrigate approximately 84,186 hectares and have benefited 64,266 farmers (Bureau of Soils and Water Management, 2011).

Meanwhile, soil erosion decreases the efficiency of the water storing capacity caused by the deposition of sediment to the catchment pond of the Small Water Impounding Project affects the usability (Naval, 2016; Rahmani et al., 2018). Soil is being lost from land areas 10 to 40 times quicker than the rate of soil renewal, imperiling future human food security and environmental quality (Zhao et al., 2013). Hence, it lessens the economic life of this water harvesting technology. Furthermore, soil erosion is significantly caused by land use management, specifically the agricultural or cultivated areas of each watershed. Also, a severe negative impact of sedimentation is the transport of pollutants such as nutrients, pesticides, and toxic metals that contaminates the water quality, aquatic habitat, and hydrologic system.

Because of the enormous contribution of SWIP to mitigate the impact of climate change in agricultural production, there is a need to assess the degree of soil erosion in the watershed areas of the SWIPs using Geographical Information System (GIS) considering the parameters: rainfall, soil type, topography, land use, and conservation practice. GIS standardized the assessment process by providing the resource specialist with a tool to quickly visualize the likely sheet and rill erosion potential (soil detachment potential but not transport and deposition) based on several major environmental parameters for small and large areas (Nasser Mohamed Eid, 2016).This study will help concerned agencies (e.g., Department of Agriculture and Department of Environment and Natural Resources) protect and preserve the Small Water Impounding Projects, including the soil resources of its watershed.

Methods

Study Sites

SWIP watersheds within Cagayan Valley were selected as study sites (Table 1 and Figure 1). Selection and validation were based on the following criteria: land use and accessibility of the site, peace and order in the community, and less than 400 hectares of the watershed area. The activity was carried out through GIS analysis (plotting existing SWIP on Google earth Pro; road network analysis and watershed delineation on ArcGIS) and through surveys and interviews.

Table 1. Geographical location of the study sites in Cagayan Valley

Location	SWIP Name	Watershed Area (Hectares)	Geographical Location Latitude	Geographical Location Longitude
Cagayan				
1.Afusing Daga, Alcala	Afusing Daga	158.342	17.875786°	121.62124°
2. Alaguia, Lallo	Alaguia	41.947	18.138958°	121.633056°
3. Bacring, Amulung	Bacring 1	80.12	17.813875°	121.593389°
4. Cabuluan, Amulung	Cabuluan 1	179.402	17.84143°	121.6036°
5. Cabuluan, Amulung	Cabuluan 2	79.445	17.866587°	121.614891°
Isabela				
1. Bubug, Sto. Tomas	Malakab	229.057	17.337835°	121.685045°
2. Bubug, Sto. Tomas	Matakayan	202.497	17.344929°	121.689768°
3.Kaligayan, Tumauini	Kaligayan Pritil	30.507	17.266914°	121.93203°
4. San Andres, City of Ilagan	San Andres	258.218	17.145109°	121.926031°
5. Caloocan, Delfin Albano	Kasabay	385.86	17.304781°	121.700849°
Nueva Vizcaya				
1. San Antonio South, Dupax Del Norte	San Antonio South	71.392	16.342654°	121.115137°
2. West Dullao, Bambang	West Dullao	184.345	16.349741°	121.124116°
3. Munguia, Dupax Del Norte	Munguia	316.175	16.321279°	121.154551°
4. Darapidap, Aritao	Darapidap	100.416	16.321279°	121.154551°
5. Poblacion, Diadi	Cabra	96.195	16.688°	121.3508°
Quirino				
1. San Salvador, Maddela	San Salvador	12.101	16.41964°	121.693148°
2. Pinaripad, Aglipay	Pinaripad	42.137	16.456472°	121.608056°
3. Divisoria, Maddela	Divisoria	286.335	16.408194°	121.725083°
4. Cajel, Diffun	Cajel	15.343	16.55356°	121.525612°

Figure 1: Study sites in Cagayan Valley

Soil Erosion Estimation

David & Collado (1987) adapted the universal soil loss equation (USLE) to suit locally available knowledge and prevailing environmental circumstances in the lack of any other approach for determining soil erosion rates in tropical Asia. The overall methodology of this study was by integrating the Modified Universal Soil Loss Equation (MUSLE) and GIS to estimate and map annual soil loss within the SWIPs watershed. First, rainfall, soil characteristics, topography or elevation, land use, and management practice on each specific SWIP were determined, and separate layers for each parameter were developed in the MUSLE model and combined by modeling procedures in ArcGIS software. Then, the average annual soil erosion rate was calculated by multiplying the respective MUSLE factor values through Field Calculator, which is a function in the shapefile attribute table.

MUSLE computes the annual average soil loss as:

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

Where: *E* soil loss rate in tons/ha/year, *R* is the rainfall erosivity index, *LS* is the length-slope factor which is estimated based on percent slope, *C* is the cover factor, *K* is the soil erodibility value, and *P* is the product of the management and conservation practices.

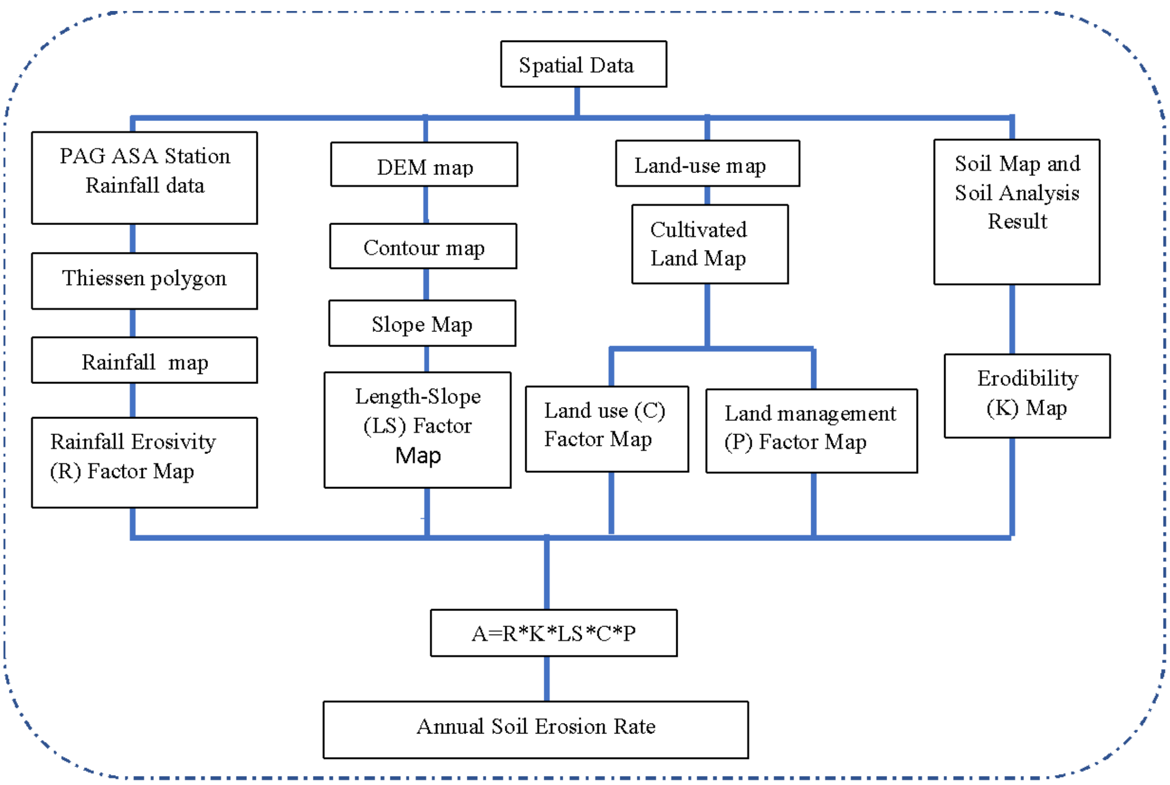

Figure 2. Estimation of soil loss using MUSLE and GIS techniques for conservation planning

Data Collection and Processing

Rainfall, topography, soil characteristics, land use, and management practices are the different factors that affect the rate of soil erosion in a watershed. Therefore, data needed for the calculation of soil loss were collected and consolidated using various methods.

Topography, Watershed Boundary and Tributaries

Digital Elevation Model (DEM) -- raster data in GeoTIFF format of Cagayan -- was requested and obtained from Lidar Portal 2019 (*https://lipad.dreams.upd.edu.ph/).* A 10 x 10 cell size digital elevation model (DEM) was manipulated in ArcGIS 10.3.1 to delineate first the streams of watersheds, which was used to characterize each site's watershed boundaries easily. In addition, DEM was used to generate slope models, and these maps were used to calculate the Length-Slope (LS) factor of each watershed.

Rainfall Data

Rainfall data were obtained from four Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) stations situated at Aparri, Tuguegarao City, Bayombong, and Echague City. The geostatistical tool "Thiessen Polygon" was used to determine the area coverage of each station. Precipitation data of the PAGASA station under the same polygon with the SWIP location was assumed to be the amount of precipitation experienced on the study sites. Rainfall data amounting to greater than 25 mm were considered in calculating the rainfall erosivity factor.

Soils Type and Characteristics

Soil sampling was done in the different study sites using a manual auger. Three samples per land use of the study sites were collected randomly. A mixed soil sample per study site was subjected to soil analysis at the Department of Agriculture – Cagayan Valley Integrated Agricultural Laboratory (DA-CVIAL) to determine organic matter content and pH accurately. In contrast, the soil particle distribution (i.e., Sand (%), Silt (%), and Clay (%) was interpolated from the soil model. These data were used for soil erodibility calculation for each site.

Land Use and Management Practices

Land-use models of the 19 watersheds were digitized and analyzed in a GIS environment. Land cover of each watershed was identified through site visits, interviews, geotagging using android software (Field Area Measurement Pro), and a GPS device so that digitization is more precise and accurate. On the other hand, management practices were gathered by visiting the sites and interviewing the President and or Board Members of each SWIP.

Soil Erosion Parameters

Rainfall Erosivity (R factor)

Rainfall erosivity factor (R factor) is described as the capacity of the rain to cause erosion (Lai et al., 2016). It is related to the rainfall's quantity, intensity, and duration, along with raindrop size and distribution. Rainfall erosivity factors for each site were computed based on the Rainfall data using the equation suggested by Mihara and Hudson, which was adopted by David and Collado for the Philippine setting as cited by David (1988).

$$R_j = 0.002\ x \sum Pi^2 \quad (2)$$

Where: R_j is the rainfall erosivity in (MJ mm ha^{-1} year^{-1}), and Pi is the precipitation that exceeds the threshold of 25 mm.

The average rainfall erosivity R factor for each site was based on the calculated rainfall erosivity of the nearest PAGASA station. Specifically the calculated R factor for the PAGASA stations in Aparri, Tuguegarao City, Echague City and Bayombong are 177.46118, 205.02292,157.78184, 101.086 respectively.

Soil Erodibility (K factor)

Soil erosivity factor (K factor) is the ability of the soil to resist erosion. Particle size distribution, organic matter content, and pH are the parameters that affect soil erodibility is shown in Table 2. The soil erodibility of each site was calculated using the simplified equation of Wischmeier and Mannering (1969).

$$K = \left[(0.043)(pH) + \frac{0.62}{OM} + 0.0082S - 0.0062C\right] Si \quad (3)$$

Where:

K - soil erodibility factor in Tons ha^{-1} MJ^{-1} mm^{-1}

OM - organic matter content in percent,

S - percent sand

C - clay ratio=% clay/(%sand +% silt)

Si - Silt =, % silt/100

Table 2. Soil characteristics and K factor of each site.

Sites	pH	% OM	% Sand	% Silt	% Clay	K factor
Cagayan						
Afusing Daga1	5.85	0.62	55	31	14	0.5275
Afusing Daga2	5.85	0.62	15	39	56	0.3983
Alaguia	5.3	2.24	38	32	30	0.2604

Bacring 1	5.28	1.65	60	26	14	0.2844
Cabuluan 1	6.07	1.48	53	32	15	0.3503
Cabuluan 2	5.67	1.58	56	32	12	0.3624
Isabela						
Kaligayan Pritil	5.5	1.58	60	12	28	0.1342
Matakayan	5.47	2.2	16	30	54	0.1923
Malakab	6.67	2.3	16	30	54	0.2041
San Andres1	5.57	2.68	60	29	14	0.2789
San Andres2	5.57	2.68	60	12	28	0.1153
Kasabay	5.6	1.89	16	30	54	0.2078
Nueva Vizcaya						
West Dullao1	6.3	2.8	35	35	30	0.2718
West Dullao2	6.3	2.8	35	35	30	0.2718
Munguia	5.67	1.48	35	35	30	0.3315
Cabra	5.54	1.79	35	35	30	0.3041
Darapidap	5.73	1.65	35	35	30	0.3173
Quirino						
San Salvador	4.58	1.48	35	35	30	0.3151
Divisoria1	4.31	2.24	16	30	54	0.1758
Divisoria2	4.31	2.24	35	35	30	0.2613
Divisoria3	4.31	2.24	35	35	30	0.2612
Cajel	5.08	1.93	35	35	30	0.2884
Pinaripad	4.27	2.27	16	30	54	0.1742

Length Slope Factor (LS factor)

Length Slope factor varies directly with the percent slope raised to a power greater than one (Wang et al., 2013). Slope (in percent) was obtained by processing the DEM in ArcGIS software. LS factors were calculated using this formula:

$$S = a + b\, {S_l}^{4/3} \qquad (4)$$

Where: a and b are approximately 0.1 and 0.21, respectively, S_L is the slope in percent.

Crop Cover Coefficient (C factor)

Cover management (C factor) significantly affects the soil erosion on a watershed. The denser the vegetation is, the lesser the eroded soil, since vegetative cover reduces the kinetic energy of the raindrops. Hence, the cover coefficient of the watershed was based on (David, 1988), which range varies from the different vegetation and land use of each watershed (Table 3).

Table 3. Crop cover coefficient or C values for common cover conditions of Philippine watersheds

Land Cover	**C Factor**
Bare soil	1
Primary forest	0.001
Secondary growth forest with good undergrowth and high mulching	0.003
Second growth forest with patches of shrubs and plantation crops of 5 years or more	0.006
Industrial Tree Plantation	0.007
Grassland	0.15
Annual cash crops	
Corn, sorghum, and sugarcane	0.45
Rice	0.15
Peanut, mungbean, and soybean	0.40
Tobacco	0.50
Pineapple	0.35
Diversified Crops	0.30
New kaingin areas, diversified crops	0.30
Old kaingin areas, diversified crops	0.80
Others	

Built-up rural area, with house	0.20
Riverwash	0.50

Conservation management factor (P factor)

P value of the different conservation practices such as terracing, contouring, contour strip cropping, and tillage practices such as conventional, zoned, mulch, and minimum tillage is shown in Table 4 (David, 1988).

Table 4. Conservation practice or management factor

A. Tillage, terracing, contouring, and strip cropping.

Land Slope (%)	Terracing		Contouring	Contouring Strip Cropping
	Bench	Broad-based		
1-2	0.10	0.12	0.60	0.30
3-8	0.10	0.10	0.50	0.15
9-12	0.10	0.12	0.60	0.30
13-16	0.10	0.14	0.70	0.35
17-20	0.12	0.16	0.80	0.40
21-25	0.12	0.18	0.90	0.45
>25	0.14	0.20	0.95	0.50

B. Tillage and residue management

Tillage Practice	P Value
1. Conventional tillage	1
2. Zoned tillage	0.25
3. Mulch tillage	0.26
4. Minimum tillage	0.52

Thematic Modeling

GIS Modeling of the different parameters was carried out using ArcGIS 10.3 to finalize the thematic maps. Calculated MUSLE factors were incorporated into its corresponding thematic map by integrating the data in a model/ map representation. It was further processed and analyzed using spatial analyst tools and calculations on ArcGIS software – ready for final modeling.

Soil Erosion Modeling

After the integration of MUSLE factors to its corresponding thematic models, land use model (C factor), soil erodibility model (K factor), Slope-Length model (LS factor), rainfall erosivity model (R), management practice model (P factor) were overlayed to each other. The annual soil erosion rate calculation was carried out by multiplying these five factors using the field calculator on the attribute table. Consequently, the resulting outputs were annual soil erosion rate of each SWIP watershed.

Data Analysis

Calculated mean soil erosion rate was reclassified based on the classification soil erosion rate by Beskow and per land use class.

Results

The study attempted to measure the annual erosion rate 19 watersheds of SWIP watershed within Cagayan using Modified Universal Soil Loss Equation integrated on Geographical Information System software. The limitations of the study include lack of statistical validation, and based merely on the soil erosion GIS modeling tool utilizing data collected and obtain primary and secondary sourcing. Thus, the result of the analysis is the following:

Annual Soil Erosion Rate of Assessed 19 SWIP Watersheds in Cagayan Valley

The average annual soil erosion potential (A) is computed by multiplying the MUSLE factors on the overlayed thematic models. Table 5 - 8 shows the computed soil erosion rates of the SWIP watersheds.

Annual Soil Erosion Rate of Assessed SWIP Watersheds in Cagayan

SWIP watersheds of Afusing Daga, Cabuluan 1, Cabuluan 2, and Bacring 1 possess annual erosion rate higher than 100 tons/ha/year which are categorized as extremely high. In contrast, the erosion rate of Alaguia SWIP watershed is categorized under high erosion (Table 5). The mean annual soil loss for entire SWIP watersheds of Afusing Daga, Alaguia, Bacring 1, Cabuluan 1, and Cabuluan 2 is 163.17, 15.21, 100.61, 182.84, and 117.28 tons/ha/year, respectively. This implies that the average annual soil loss in mm (depth of eroded topsoil) occurs in the SWIP watershed of Afusing Daga, Alaguia, Bacring 1, Cabuluan 1, and Cabuluan 2 are approximately 10, 0.96, 3.79, 11.22, and 7.19 mm, respectively. Overall, these findings are in accordance with findings reported by (Kosmas et al., 1997)

Table 5. Annual Erosion Rate of the Study Sites in Cagayan.

Study Site	Erosion (tons/year)	Erosion (mm/year)	Area (Hectare)	Erosion Rate (ton/ha/year)
Afusing Daga	25843.40	10.00	158.38	163.17
Alaguia	638.26	0.96	41.97	15.21
Bacring 1	8061.00	6.17	80.12	100.61
Cabuluan 1	32863.79	11.22	179.74	182.84
Cabuluan 2	8531.89	7.19	72.75	117.28

Annual Soil Erosion Rate of Assessed SWIP Watersheds in Isabela

SWIP watersheds of Kasabay, Malakab, and Matakayan possesses annual erosion rate higher than 100 tons/ha/year which are categorized as extremely high. In contrast, the erosion rate of San Andres and Kaligayan SWIP watersheds are categorized under high and very high erosion (Table 6). The mean annual soil loss for entire SWIP watersheds of Kaligayan Pritil, Kasabay, Malakab, Matakayan, and San Andres is 99.48, 124.12, 104.07, 101.35, and 22.68 tons/ha/year, respectively. This implies that the average annual soil loss in mm (depth of eroded topsoil) occurs in the SWIP watersheds of Kaligayan Pritil, Kasabay, Malakab, Matakayan, and San Andres are approximately 6.22, 8.33, 6.98, 6.80, and 1.42 mm, respectively.

Table 6. Annual Erosion Rate of the Study Sites in Isabela

Study Site	Erosion (tons/year)	Erosion (mm/year)	Area (Hectare)	Erosion Rate (ton/ha/year)
Kaligayan Pritil	3028.69	6.22	30.44	99.48
Kasabay	47899.94	8.33	385.92	124.12
Malakab	23838.3	6.98	229.06	104.07
Matakayan	20176.98	6.8	199.07	101.35
San Andres	5862.16	1.42	258.51	22.68

Annual Soil Erosion Rate of Assessed SWIP Watersheds in Nueva Vizcaya

SWIP watersheds of Cabra, Darapidap, San Antonio South, and West Dullao possess annual erosion rate higher than 100 tons/ha/year which is categorized as extremely high. In contrast, the erosion rate of Munguia SWIP watershed is categorized under high to very high erosion (Table 7). The mean annual soil loss for the entire SWIP watersheds of Cabra, Darapidap, Munguia, San Antonio South, and West Dullao are 195.70, 230.57, 11.89, 222.05, and 171.93 tons/ha/year, respectively. This implies that the average annual soil loss in mm (depth of eroded topsoil) occurs in the SWIP watershed of Cabra, Darapidap, Munguia, San Antonio South, and West Dullao are approximately 12.23, 14.41, 0.74, 13.88, and10.75 mm, respectively.

Table 7. Annual Erosion Rate of the Study Sites in Nueva Vizcaya

Study Site	Erosion (tons/year)	Erosion (mm/year)	Area (Hectare)	Erosion Rate (ton/ha/year)
Cabra	18818.4	12.23	96.16	195.7
Darapidap	22721.75	14.41	98.55	230.57
Munguia	3711.45	0.74	312.06	11.89
San Antonio South	15852.47	13.88	71.39	222.05
West Dullao	29396.98	10.75	170.98	171.93

Annual Soil Erosion Rate of Assessed SWIP Watersheds in Quirino

San Salvador SWIP watershed possesses annual erosion rate higher than 100 tons/ha/year which is categorized as extremely high; while, Cajel, Divisoria, Pinaripad possess annual erosion rate from 25-100 tons/ha/year which is categorized as very high (Table 8). The mean annual soil loss for the entire SWIP watersheds of Cajel, Divisoria, Pinaripad, and San Salvador are 71.50, 46.30, 91.73, and 132.14 tons/ha/year, respectively. This implies that the average annual soil loss in mm (depth of eroded topsoil) occurs in the SWIP watershed of Cajel, Divisoria, Pinaripad, and San Salvador are approximately 4.47, 3.11, 6.16, and 8.87 mm, respectively.

Table 8. Annual Erosion Rate of the Study Sites in Quirino

Study Site	Erosion (tons/year)	Erosion (mm/year)	Area (Hectare)	Erosion Rate (ton/ha/year)
Cajel	1097.1093	4.47	15.3431	71.5055
Divisoria	13545.0791	3.11	292.5694	46.2970
Pinaripad	4050.0575	6.16	44.1522	91.7295
San Salvador	1456.1667	8.87	10.9604	132.1367

Soil Erosion Rate per Land Use Class of SWIP Watersheds in Cagayan

Corn production and grassland portion of Afusing Daga, Bacring1, Cabuluan 1, and Cabuluan 2 SWIP Watersheds possess an erosion rate greater than 100 tons/ha/year, categorized as extremely high erosion (Table 9). Thus, these areas should be prioritized for development. Moreover, soil erosion on corn producing areas of Alaguia SWIP Watershed is categorized as high erosion (22.99 tons/ha/year) and moderate erosion (6.99 tons/ha/year) for grassland. These basic findings are consistent with research showing that as the watershed cover is disturbed and reduced, sediment yields increase and fluctuate considerably (David, 1988).

Table 9. Soil Erosion Rate per Land Use Class

Land use	Erosion (tons/year)	Area (Hectare)	Erosion Rate (ton/ha/year)
Site 1: Afusing Daga SWIP Watershed			
Bare soil	6.17	5.61	1.10
Second Forest	415.31	51.11	8.13
Corn Production	17227.23	42.69	403.58
Open Grassland	8193.70	52.62	155.72
Site 2: Alaguia SWIP Watershed			
Bare soil	0.40	0.36	1.10
Second Forest	1.94	6.17	0.31
Corn Production	587.73	25.56	22.99
Open Grassland	47.88	6.85	6.99
Rice Production Area	0.30	0.39	0.78
Site 3: Bacring 1 SWIP Watershed			
Bare soil	4.31	3.92	1.10
Second Forest	52.50	15.32	3.43
corn production	4569.18	18.81	242.96
open grassland	3435.01	41.30	83.16
Site 4: Cabuluan 1 SWIP Watershed			
Bare soil	11.40	10.37	1.10
Second Forest	250.65	39.08	6.41
Corn Production	21602.52	52.87	408.59
Open Grassland	10998.94	70.12	156.87
Site 5: Cabuluan 2 SWIP Watershed			
Bare soil	2.00	1.82	1.10
Second Forest	230.23	30.59	7.53
Corn Production	6012.94	20.45	294.07
Open Grassland	2286.73	17.61	129.87

Soil Erosion Rate per Land Use Class of SWIP Watersheds in Isabela

The corn production and grassland portion of Malakab, Matakayan, Kaligayan Pritil, San Andres, and Kasabay SWIP Watersheds possess an erosion rate greater than 25 tons/ha/yr categorized very high to extremely high erosion (Table 10). Thus, these areas should be prioritized for development.

Table 10. Soil Erosion Rate per Land Use Class (Isabela)

Land use	Erosion (tons/year)	Area (Hectare)	Erosion Rate (ton/ha/year)
Site 1: Malakab SWIP Watershed			
Corn Production Area	18181.31	77.45	234.75
Open Grassland	5254.52	53.52	98.17

Secondary Forest	402.47	92.48	4.35
Site 2: Matakayan SWIP Watershed			
Corn Production Area	11024.02	81.48	135.30
Open Grassland	9135.45	101.00	90.45
Secondary Forest	6.84	2.43	2.81
Rice Production	10.67	5.96	1.79
Site 3: Kaligayan Pritil SWIP Watershed			
Corn Production Area	1874.39	9.07	206.62
Open Grassland	1099.97	8.95	122.90
Secondary Forest	54.34	11.44	4.75
Site 4: San Andres SWIP Watershed			
Open Grassland	1952.85	122.33	15.96
Secondary Forest	68.61	57.38	1.20
Corn Production Area	3834.36	64.59	59.36
Site 5: Kasabay SWIP Watershed			
Corn Production Area	37611.32	185.03	203.27
Open Grassland	9980.70	124.54	80.14
Secondary Forest	307.92	73.46	4.19

Soil Erosion Rate per Land Use Class of SWIP Watersheds in Quirino

Corn production and grassland portion of San Salvador, Pinaripad, Divisoria, and Cajel SWIP Watersheds possess erosion rate greater than 25 tons/ha/yr which is categorized very high to extremely high erosion (Table 11). Thus, these areas should be prioritized for development.

Table 11. Soil Erosion Rate per Land Use Class

Land use	**Erosion (tons/year)**	**Area (Hectare)**	**Erosion Rate (ton/ha/year)**
Site 1: San Salvador SWIP Watershed			
Corn Production Area	799.93	2.95	270.74
Open Grassland	652.92	6.56	99.52
Secondary Forest	3.31	0.82	4.06
Site 2: Pinaripad SWIP Watershed			
Corn Production Area	3269.03	15.79	207.06
Open Grassland	728.84	10.17	71.65
Secondary Forest	50.85	15.65	3.25
Rice Production	1.33	0.46	2.90
Site 3: Divisoria SWIP Watershed			
Corn Production Area	10749.98	82.97	129.57
Open Grassland	2459.12	87.78	28.01
Rice Production Area	74.10	40.02	1.85
Secondary Forest	261.88	76.02	3.44
Site 4: Cajel SWIP Watershed			
Corn Production Area	1027.31	8.18	125.66
Open Grassland	65.30	2.16	30.24
Secondary Forest	4.51	1.83	2.46

Soil Erosion Rate per Land Use Class of SWIP Watersheds in Nueva Vizcaya

Corn production and grassland portion of San Antonio and Cabra SWIP Watersheds and the grassland area West Dullao, Munguia, and Darapidap SWIP watersheds possess an erosion rate greater than 100 tons/ha/yr, which is categorized as very high to extremely high erosion (Table 12). Thus, these areas should be prioritized for development.

Table 12. Soil Erosion Rate per Land Use Class

Land use	**Erosion (tons/year)**	**Area (Hectare)**	**Erosion Rate (ton/ha/year)**
Site 1: San Antonio South SWIP Watershed			
Corn Production Area	344.76	0.73	472.34
Secondary Forest	101.99	15.54	6.56
Open Grassland	15405.73	53.56	287.61
Site 2: West Dullao SWIP Watershed			
Open Grassland	29100.18	125.22	232.40
Secondary Forest	296.80	41.68	7.12
Site 3: Munguia SWIP Watershed			

Open Grassland	3689.07	260.76	14.15
Secondary Forest	22.39	50.06	0.45
Site 4: Darapidap SWIP Watershed			
Open Grassland	22366.61	65.96	339.07
Secondary Forest	355.14	31.17	11.39
Site 5: Cabra SWIP Watershed			
Corn Production Area	5757.18	12.14	474.17
Open Grassland	12929.24	58.29	221.81
Secondary Forest	131.48	22.06	5.96

Conclusion and Future Works

Based on the results, SWIP watersheds of Afusing Daga, Bacring 1, Cabuluan 1, Cabuluan 2, Kasabay, Malakab, Matakayan, San Salvador, Cabra, Darapidap, San Antonio South, and West Dullao possess extreme high erosion (greater than 100 tons/ha/year), and the SWIP watersheds of Kaligayan Pritil, Cajel, Divisoria, and Pinaripad possess very high erosion (25-100 tons/ha/year); hence, must be prioritized for watershed development, specifically the grassland and corn production areas of these sites. Although it is strategized in the conservation plan that some of the grassland areas will be cultivated to be agricultural production areas (applying diversified cropping and contour cropping scheme), it is not necessary to convert grassland into agricultural production areas since cultivating these areas will accelerate erosion. Grassland must still serve as pasture area for animals, and it must be planted with hedgerows of fruit-bearing and forest trees. On the other hand, capacitating upland farmers on conservation farming (e.g., contour farming and minimum tillage) on SWIP watersheds of Alaguia, San Andres, and Munguia should be conducted to lessen the soil erosion on corn production areas, though erosion on the watersheds is already minimal. Furthermore, generated information should be served as baseline information for watershed planning, development, management, and policy-making. Incentive-based mechanisms for watershed development (tree planting and growing) must be strengthened and take into action.

Ethical Consideration

During the conduct of this study, ethical procedures were observed. Respondents and key informants gave their consent to engage in the study voluntarily, and they were not harmed in any way. They, too, were thoroughly briefed on the study's aims.

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