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Soil erosion status of the three sub-watersheds in Bukidnon Province, Philippines

Rico A. Marin, Clydvinis V. Jamis

College of Forestry and Environmental Science, Central Mindanao University, University Town, Musuan, Bukidnon, Philippines. Corresponding author: R. A. Marin, ricomarin@yahoo.com

Abstract. Erosion is a naturally occurring process that is often aggravated by human activities and can lead to adverse impacts on watersheds. Continuous soil erosion in the watershed causes significant losses in soil fertility and productivity. This study was conducted to assess the extent of soil erosion on the three sub-watersheds in Bukidnon Province, Philippines. The experimental design used in this study was randomized complete block design where the three sub-watersheds (Maapag, Panlibatuhan, and Tigwa) represented the treatment with three replications. Results of the study show that Maapag sub-watershed had the highest erosion rate among the three sub-watersheds with 184.70 ton ha^{-1} yr^{-1}. It was noted that this watershed has wide area of cropland and soil compaction to grazing animals. The Tigwa sub-watershed showed the highest soil accumulation at 181.25 ton ha^{-1} yr^{-1} where most of the area is covered with natural vegetation such as grasses and a number of tree species. The result of this study conforms to the findings of previous investigations that the extent of erosion is affected by many factors such as the amount, intensity and duration of rainfall, slope, vegetation cover or land-use, and soil characteristics.

Key Words: Bukidnon, erosion bar, soil erosion, vegetation, watershed.

Introduction. Soil erosion is a naturally occurring process that affects all landforms. In agriculture, soil erosion refers to the wearing away of a field's topsoil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage. The implications of soil erosion extend beyond the removal of valuable topsoil. Crop emergence, growth and yield are directly affected by the loss of natural nutrients and applied fertilizers. Seeds and plants can be disturbed or completely removed by the erosion. Organic matter from the soil, residues and any applied manure is relatively lightweight and can be readily transported off the field (Ritter & Eng 2012).

The soil covering the surface of the earth has taken millions of years to form thus soil is formed at a rate of only 1 cm every 100 to 400 years and it takes 3,000 to 12,000 years to build enough soil to form productive land (Department of Agriculture 2008). Because soil is formed very slowly, this means that soil is being lost 13–40 times faster than the rate of renewal and sustainability (Pimentel & Kounang 1998).

Worldwide, erosion rates range from a low of 0.001–2 ton ha^{-1} yr^{-1} on relatively flat land with grass and/or forest cover to rates ranging from 1–5 ton ha^{-1} yr^{-1} in mountainous regions with normal vegetative cover (Patric 2002 as cited by Pimentel 2006). Myers (1993) as cited by Pimentel (2006) reported that approximately 75 billion tons of fertile soil is lost from world agricultural systems each year, with much less erosion occurring in natural ecosystems. In fact, the 75 billion tons is probably a conservative value. Wen (1997) as cited by Pimentel (2006) reported that 6.6 billion tons of soil per year are lost in India and 5.5 billion tons are lost annually in China. Considering these two countries together occupy only 13% of the world’s total land area, the estimated 75 billion tons of soil lost per year worldwide is conservative.

Bukidnon, a province in Mindanao Island of the Philippines, serves as the head water of the various watersheds of its neighboring provinces. These watersheds are composed of sub-watersheds that influence behavior of the main river system. Among these sub-watersheds are Maapag, Panlibatuhan, and Tigwa which are the major tributaries to the Pulangi River basin where the dam of the National Power Corporation (NPC) is located. If these sub-watersheds are not protected, it will be contributing to various problems affecting the physical, social and economic aspect of the region as well as the country. Thus, a need for intervention has to be undertaken in these sub-watersheds to prevent the problem in becoming worst. Therefore, the extent of erosion in these sub-watersheds needs to be determined as basis for future management interventions.

Material and Method

Location and description of the study site*.* The study was conducted at the two sub-watersheds in Valencia City, Bukidnon which are the Maapag and Panlibatuhan, and one subwatershed in San Fernando, Bukidnon which is the Tigwa (Figure 1).

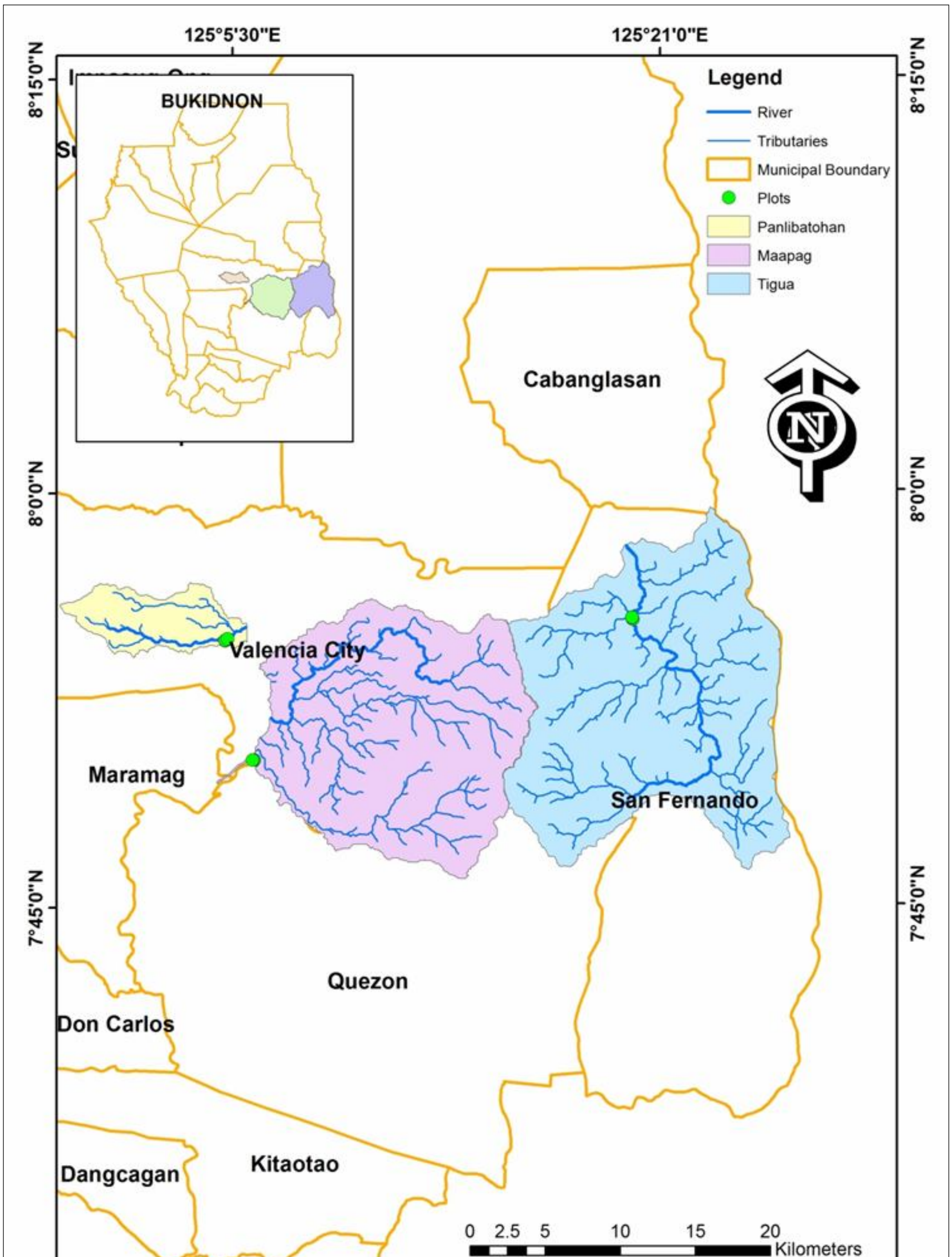

Figure 1. Location map of the sub-watersheds.

Maapag and Panlibatuhan sub-watersheds are located in Maapag and Poblacion Valencia City, Bukidnon, respectively. Valencia City Bukidnon lies on the geographic reference of 07°54'N 125 °05'E / 7.900°N 125.083°E. Tigwa subwatershed is located at San Fernando Bukidnon with a geographic reference of 07°55'N125°20'E / 7.917 °N 125.333 °E.

Maapag subwatershed has an area of 24,874 hectares with a stream length of 209.2 kilometers (Figure 2). The first plot, second plot, and third plot were established at the elevations of 316 m, 320 m, and 317 m with the geographic reference of N 07.83844°, E 125.10266°; N 07.83829°, E 125.10187°; and N 07.83831°, E 125.10170°, respectively.

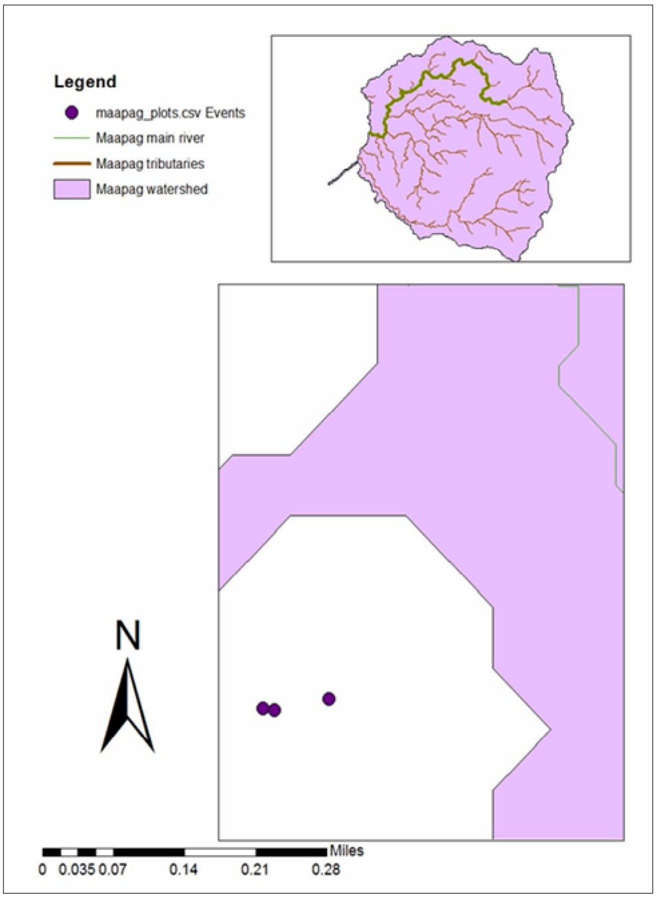

Figure 2. Maapag plots.

Panlibatuhan subwatershed has an area of 3,867 hectares with a stream length of 34.02 kilometers (Figure 3). Plots were established at the elevations of 324 m, 329 m, and 329 m with the geographic reference of N 07.91063°, E 125.08533°; N 07.91075°, E 125.08553°; and N 07.91157°, E 125.08671°, respectively.

Tigwa subwatershed has a total area of 30,318 hectares with a stream length of 224.1 kilometers (Figure 4). Plots were established at the elevations of 402 m, 397 m, and 391 m with the geographic reference of N 07.92242°, E 125.33171°; N 07.92317°, E 125.33125°; and N 07.92338°, E 125.33128°, respectively.

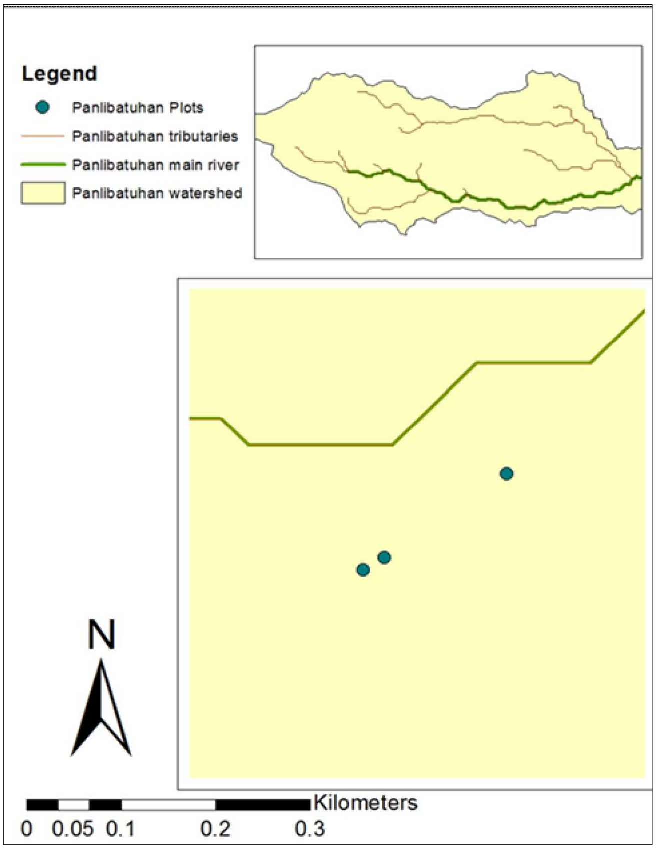

Figure 3. Panlibatuhan plots.

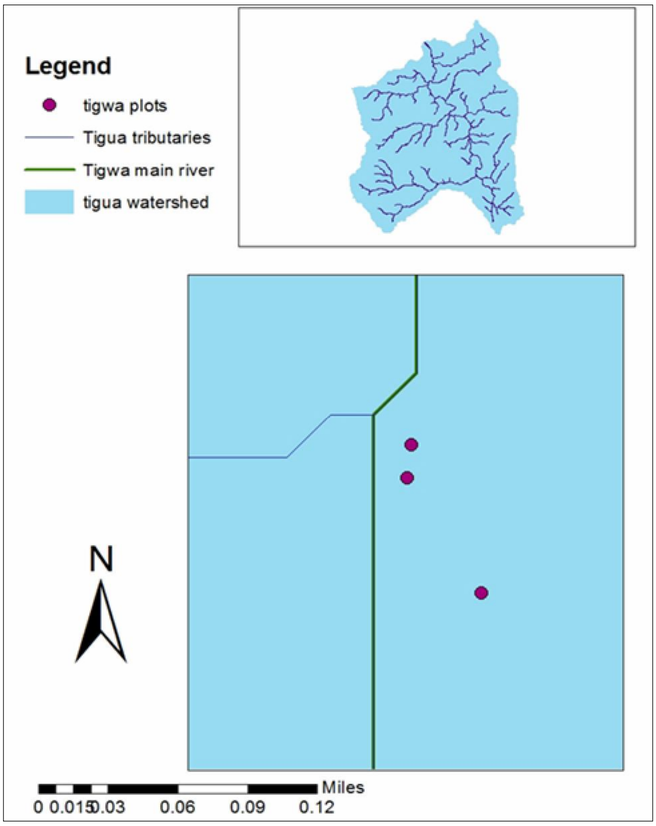

Figure 4. Tigwa plots.

Experimental design and duration of the study. The experimental design used in this study was Randomized Complete Block Design with the three sub-watersheds (Maapag, Panlibatuhan, and Tigwa) as the treatments replicated three times. Each study site had three sampling plots as replications representing the upstream, midstream and downstream plots. In every erosion plot, two posts of 60 centimeters long were driven into the ground leaving a portion of 15 centimeters above the ground. The study was carried-out for 8 months duration (June 2014 to January 2015).

Establishment of rain gauge. A rain gauge was established per sub-watershed to determine the amount of rainfall per month. It used an improvised instrument following the standard dimension of direct reading type rain gauge. The readings were taken in millimeters.

Data gathering

Soil loss. Data on soil loss were gathered twice every month. This was measured using a modified erosion bar used by Ramirez (1988). The method made use of a modified 2.5-meter long aluminum bar with 10 holes spaced at 15 cm apart throughout the whole length of the bar. During data gathering, the bar was laid on predetermined points and rested on top of the GI sheet bordering on each plots. Measuring pins of identical size and length (60 centimeters) were inserted in the holes of the bar. These pins were kept lightly rested on the soil surface during measurement by a carpenter's tape (Figure 5).

Figure 5. Data gathering on soil loss.

In determining the soil loss, the difference between the two (2) measurements served as the amount of soil loss. The data on soil loss were converted into tons per hectare by first determining the volume using the formula:

$$V_{plot} = \text{(depth of soil washed)} \times \text{(length of plot)} \times \text{(width of plot)}$$

The value of soil particle density and bulk density per treatment plot was used to determine the percent solid space. This percent solid space was multiplied by the computed soil volume loss giving the value of solid space (m^3). Using the conversion figures formulated by the Range and Management Division of the Ecosystems Research and Development Bureau (ERDB), the volume of solid particles were computed to its equivalent according to the particle size distribution. The ERDB conversion figures were as follows:

1 cu. m of clay	=	483 kilograms
1 cu. m of silt	=	1,046 kilograms
1 cu. m of sand	=	1,497 kilograms

Total erosion in tons per hectare was determined by adding the computed soil loss (tons ha^{-1}) of the three particle size distribution (clay, silt, and sand).

Rainfall. Data on rainfall were gathered every day and summed up to get the monthly rainfall volume. A calibrated measuring stick was used to measure the rainfall captured by the improvised rain gauge.

Data analysis. The test of significant difference among treatments was determined using the Analysis of Variance (ANOVA). Least significant difference ($p < 0.05$), and Tukey's, on the other hand, were used in comparing treatment means.

Results and Discussion. The volume of soil loss and the rate of erosion of the three sub-watersheds varied in all of the months throughout the duration of the study (Tables 1 and 2). This is due to the amount of rainfall that varies among sub-watersheds (Figure 6). Every plot of the three sites also varied with regards to their ground cover and land-uses. Though, the erosion plots are established on sites with relatively uniform slope (15%), these varied in terms of vegetation cover and current land uses. Thiemann et al (2005) stated that the major factor influencing soil erosion rate can be the amount and duration of rainfall accompanied by the ground cover and the textural classification of soil.

Table 1

Soil loss (ton ha^{-1}) from the months of June 2014 to September 2014

	June			*July*			*August*			*September*		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Maapag	-18.64	-12.46	-32.91	-21.65	3.57	-29.45	4.23	13.53	-66.30	-6.35	-3.92	2.90
Panlibatuhan	-27.42	-13.97	-14.56	-3.24	8.89	-1.43	-19.75	-6.99	2.86	2.36	-0.95	2.62
Tigwa	3.07	1.72	15.44	-10.73	-7.55	-12.52	-42.91	-12.01	-18.77	17.4	9.27	0.00
CV (%)		89.5			95.0			183.9			259	

Note: Negative sign indicates soil losses.

Table 2

Soil loss (ton ha^{-1}) from the months of October 2014 to January 2015

	October			*November*			*December*			*January*		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Maapag	-13.5	-6.1	-23.7	19.5	5.34	235.	0.42	-167.3	-228.9	-10.2	-2.1	-13.1
Panlibatuhan	4.4	3.2	2.4	-0.3	2.9	5.7	0.9	2.2	0.7	-5.9	2.2	-6.4
Tigwa	11.2	-11.0	-1.2	414.3	14.8	5.8	1.53	4.1	0.0	-14.3	6.5	-9.2
CV (%)		228			215			159			64	

Note: Negative sign indicates soil losses.

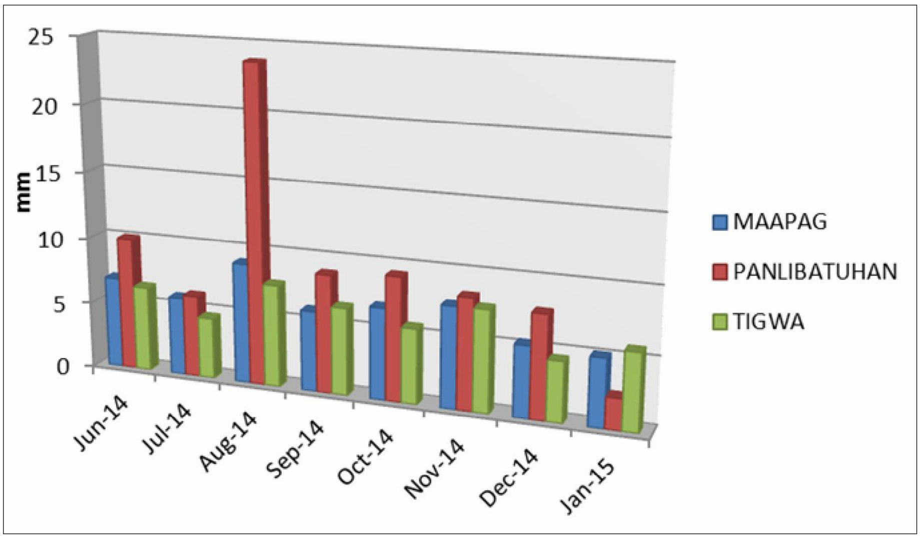

Figure 6. Total rainfall per month.

In June 2014, the recorded rainfall of the three sub-watershed are 6.88 mm, 10.01 mm, and 6.4 mm, for Maapag, Panlibatohan and Tigwa, respectively. During this month, plot 3 of Maapag sub-watershed showed the highest erosion rate with a mean of -32.91 $tonha^{-1}$. This high erosion rate could be attributed to the disturbances made by grazing animals. According to El-Swaify et al (1982), forest clearing, raising crops, trampling by domesticated animals, mining, and construction can accelerate erosion. This is then followed by Panlibatuhan sub-watershed (plot 1) with a mean of -27.42 ton ha^{-1}. This erosion rate could be attributed to the land-use of the area which is a residential or built-up site. Residential area has a large extent of erosion since the area can be disturbed by man related activities that will lead to compaction of soil and eventually increases the extent of erosion (Drzewiecki et al 2014). The least erosion rate was observed on the 3rd plot which is site for banana plantation (-14.56 ton ha^{-1}). Accordingly, the greater the area for vegetation, the lower will be the erosion rate since plants break the impact of a raindrop before it hits the soil. In addition, the root systems of the plant are able to hold the soil together (O'geen & Schwankl 2006). On the other hand, Tigwa sub-watershed which has the lowest recorded rainfall at 6.4 mm showed soil accumulation. Accumulation of soil resulted to the movement of the soil from the upper portion of the plot and these soil particles were deposited to the area where the plots are established. This could be due to the low rainfall and the presence of vegetation (grassland and significant number of trees). Smoot & Smith (1999) stressed that soil cover is the most significant factor in controlling the erosion process.

Bulk density provides a relative amount of soil compaction. High bulk density is an indicator of low soil porosity and soil compaction. Compaction can result in shallow plant rooting and poor plant growth, influencing crop yield and reducing vegetative cover available to protect soil from erosion. By reducing water infiltration into the soil, compaction can lead to increased runoff and erosion from sloping land or waterlogged soils in flatter areas. Cultivation destroys soil organic matter and weakens the natural stability of soil aggregates making them susceptible to damage caused by water and wind. When eroded soil particles fill pore space, porosity is reduced and bulk density increases. Generally, loose, porous soils and those rich in organic matter have lower bulk density. Sandy soils have relatively high bulk density since total pore space in sand is less than that of silt or clay soils. Finer-textured soils, such as silt and clay loams, that have good structure have higher pore space and lower bulk density compared to sandy soils (Brady & Weil 2008).

Thus, soil erodibility of the plots is expected to be low because of clayey, clayey-loamy and sandy-clayey soil texture. Furthermore, in Maapag plots 1-3 and Tigwa plot 1, bulk density is greater compared to other plots, so that soils within these plots are expected to be more erodible than the other plots. This explains why Maapag plot 3 has the highest erosion rate in the month of June that is also accelerated by the disturbances in the area.

Results from the month of July to September show no significant difference among the three sub-watersheds. However, in the month of July, the highest erosion rate was observed on the 3rd plot of Maapag with a mean of -29.45 ton ha^{-1}. This rate could be due to the continuous disturbances in the area and the high bulk density of the soil at 1.18 g cm^{-3} and the rainfall with 5.89 mm (Figure 7). This was followed by the 1st plot of Maapag (-21.65 ton ha^{-1}) that is devoted to agriculture. Tillage and cropping practices which lower soil organic matter levels, cause poor structure, and result to compaction that contributed to increases in soil erodibility (Wall et al 1987). On the month of August, the highest erosion rate was observed on the 3rd plot of Maapag subwatershed with a mean of -66.30 ton $ha^{-1}$and a rainfall of 9.02 mm. This scenario is just the same with the month of July. The second highest is the 1st plot of Panlibatuhan (-6.99 ton ha^{-1}) with a rainfall of 23.75 mm. The recorded rainfall is much higher than the other months while the erosion rate of this plot is still lower compared to the month of June (-27.42 ton ha^{-1}) that has a rainfall of 10.01 mm. This could be due to the litters of the bamboo that protected the soil from eroding. Plant and residue cover protect the soil from raindrop impact and splash which tend to slow down the movement of runoff water and allow excess surface water to infiltrate (Ritter & Eng 2012). On the month of September, the highest erosion rate was observed on the 1st plot of Maapag (-6.35 ton ha^{-1}) with a rainfall of 6.01 mm. This is due to the high bulk density (1 g cm^{-3}) of the area and the land cover that is planted with corn crop.

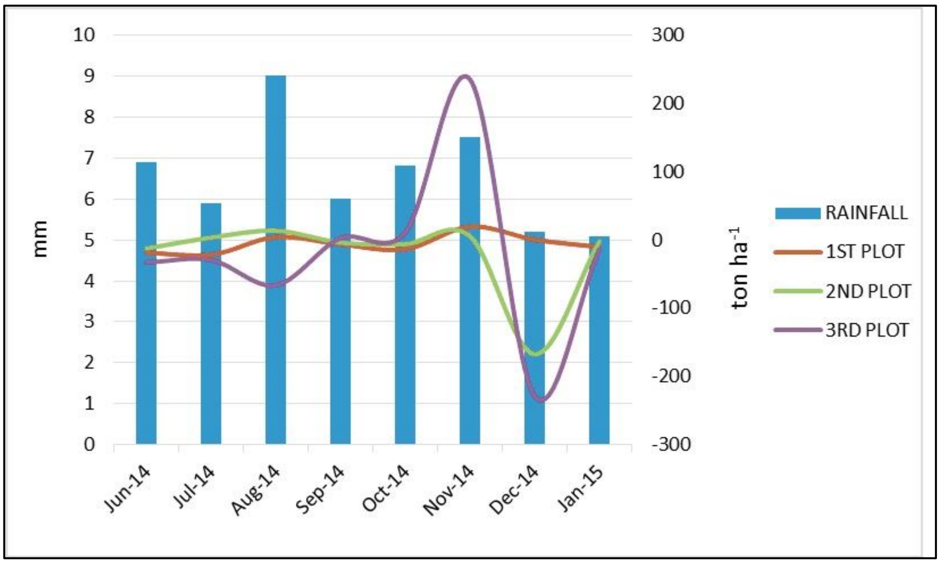

Figure 7. Soil erosion versus rainfall in Maapag subwatershed.

Soil erodibility is an estimate of the ability of the soils to resist erosion based on the physical characteristics of each soil. Texture, on the other hand, is the principal characteristic affecting erodibility, but structure, organic matter and permeability also contribute (Ritter & Eng 2012). Soils in all sampling plots have clayey texture, except Maapag plot 2, Maapag plot 3, and Panlibatuhan plot 3, where texture is silty clay loam, clay loam, and sandy clay, respectively (Table 3). The most erodible soils generally contain a high percentage of fine sand and silt. The presence of clay or organic material tends to decrease soil erodibility (Iowa Department of Natural Resources 2006). Clays are sticky and tend to bind soil particles together and resist erosion. But while clay resists erosion, they are easily transported once they have eroded (Iowa Department of Natural Resources 2006).

Table 3

Soil properties of Maapag, Panlibatuhan, and Tigwa sub-watershed plots

	Bulk density (g cm^{-3})	*Particle density (g cc^{-1})*	*% Sand*	*% Silt*	*% Clay*	*Textural classification*
Maapag						
Plot 1	1.00	2.32	40.30	19.02	40.68	Clay
Plot 2	1.12	2.74	27.51	21.32	51.17	Silty Clay Loam
Plot 3	1.18	2.42	39.91	21.46	38.63	Clay Loam
Panlibatuhan						
Plot 1	0.85	2.70	34.06	19.39	46.55	Clay
Plot 2	0.91	2.62	34.88	16.28	48.84	Clay
Plot 3	0.76	2.38	20.10	11.99	67.92	Sandy Clay
Tigwa						
Plot 1	1.03	2.43	61.93	21.15	16.92	Clay
Plot 2	0.94	2.30	35.73	22.80	16.92	Clay
Plot 3	0.90	2.41	50.38	24.81	24.81	Clay

Results from the months of October 2014 to January 2015 show no significant difference among means of the erosion rate. However, the highest erosion rate observed on these months is on the 3rd plot of Maapag with a mean of -23.71 ton ha^{-1} and with a rainfall of 6.85 mm. This could be due to the disturbance and the high bulk density of the soil (1.18 g cm^{-3}) in the area. On the month of November, only the Panlibatuhan plot 1 showed soil loss with the mean of -0.29 ton ha^{-1} and with a rainfall of 8.32 mm (Figure 8). On the month of December, highest erosion rate was observed on the 3rd plot of Maapag as well on the month of January. This could be due to the continuous disturbances by human, amount of rainfall and the high bulk density of the soil. In Tigwa, there were a number of plots that recorded soil accumulation (Figure 9). The highest among all is in plot 1 for the month of November 2014. It was noted that this subwatershed had the lowest amount of recorded rainfall. The presence of significant number of forest trees and underneath vegetation may have also contributed to the soil accumulation in the area.

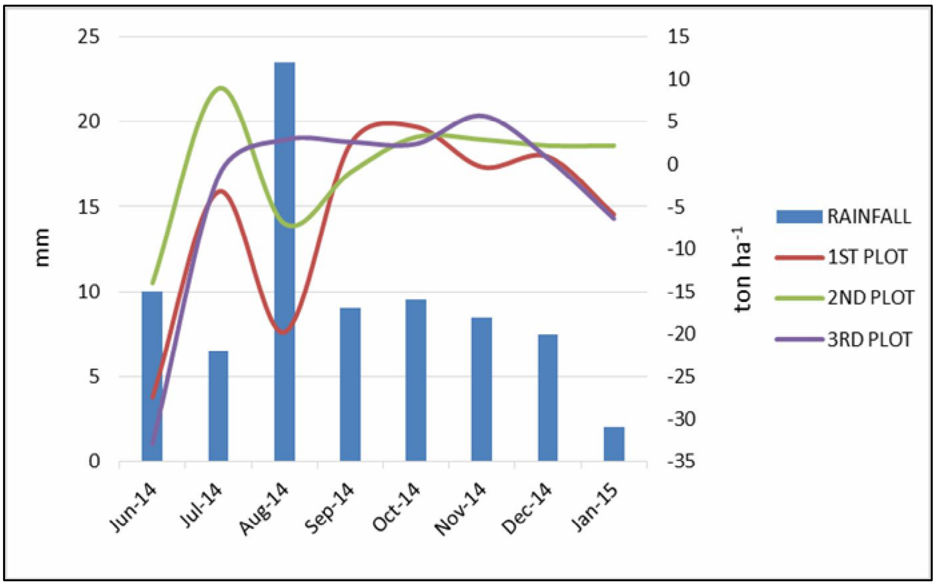

Figure 8. Soil erosion versus rainfall in Panlibatuhan subwatershed.

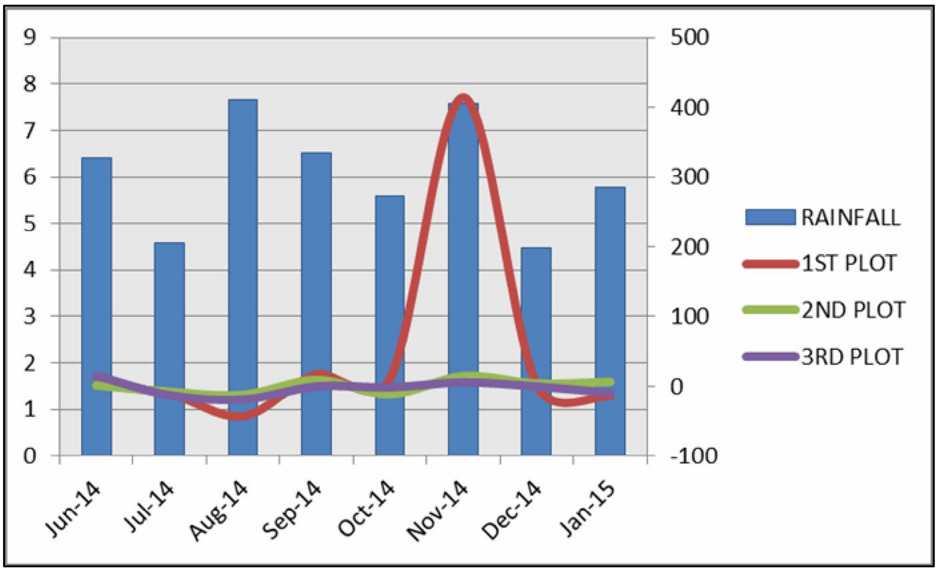

Figure 9. Soil erosion versus rainfall in Tigwa sub-watershed.

For eight months of study, Table 4 and Figure 10 show that Maapag sub-watershed had the highest mean of soil loss at -184.70 ton ha^{-1}. Most of the area is devoted to agriculture where intensive cultivation is applied. Disturbances caused by grazing animals and high bulk density had also contributed. According to the Department of Agriculture (2008), row crops such as corn offer little cover during the early growth stages and thereby encourage erosion. In addition, man's utilization and disturbance of the land has increased the rate of soil loss significantly. The erosion rates from agricultural lands, such as pastures and cultivated fields are 1.5 to 20 tons per acre per year, respectively (Smoot & Smith 1999).

Table 4

Soil loss ton ha^{-1} yr^{-1} of the three sub-watershed

Maapag			*Panlibatuhan*			*Tigwa*		
1st plot	2nd plot	3rd plot	1st plot	2nd plot	3rd plot	1st plot	2nd plot	3rd plot
-68.8	-252.4	-232.8	-72.9	-3.8	-232.8	565.5	8.7	-30.4
Mean	-184.7[c]			-103.2[b]			181.2[a]	

Note: Negative sign indicates soil losses

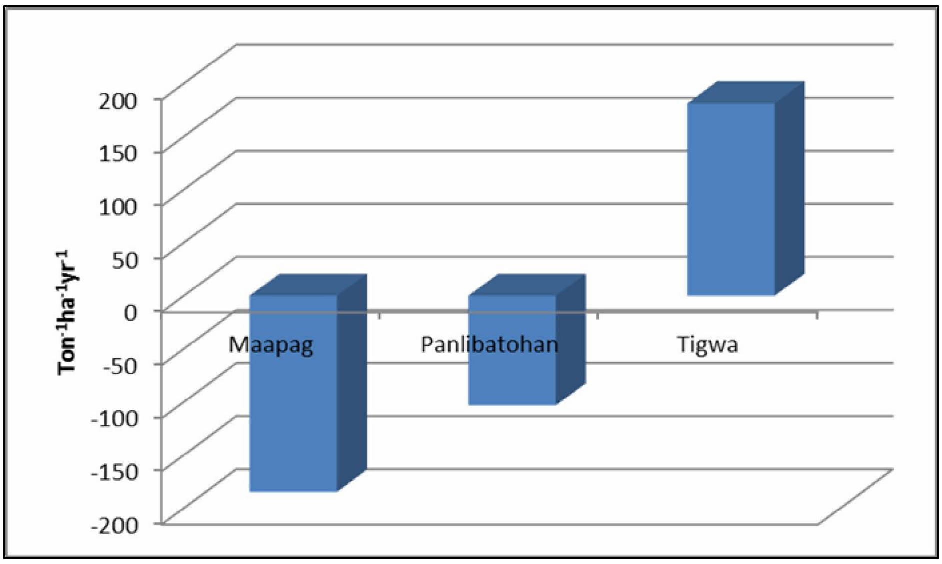

Figure 10. Total soil loss of the three sub-watersheds.

Panlibatuhan sub-watershed came next with a mean of -103.16 ton ha^{-1} yr^{-1}. The Tigwa sub-watershed showed the highest soil accumulation with 181.25 ton ha^{-1} yr^{-1}. This sub-watershed was surrounded by grasses and significant number of trees. According to the Department of Agriculture (2008), grass is the best natural soil protector against soil erosion because of its relatively dense cover.

Conclusions. Based on the result of the study, factors such as, rainfall, slope, vegetation cover or land-use, and soil textural characteristics can affect the extent of soil erosion. The stronger the intensity and the longer the duration of the rain and the higher the slope, the greater the possibilities of increasing soil erosion. If the area is being converted to cropland or is being disturbed by human activities, the greater will be the erosion rate. If the textural characteristic of the soil is clay or has the mixture of clay, the more it can resist to erosion especially if organic matter is high but it can easily be transported once surface run-off occurs. Maapag sub-watershed has the highest erosion rate since the site is being converted to cropland and is being disturbed by grazing livestocks.

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Authors:
Rico A. Marin, College of Forestry and Environmental Science, Central Mindanao University, University Town, Musuan 8710 Bukidnon, Philippines, e-mail: ricomarin@yahoo.com
Clydvinis V. Jamis, College of Forestry and Environmental Science, Central Mindanao University, University Town, Musuan 8710 Bukidnon, Philippines, e-mail: clydvinisvalendezjamis@yahoo.com

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