Ecosystems & Development Journal 6(1): 3-10
April 2016 ISSN 2012-3612

Estimated Soil Loss of Makatipo Catchment Under Different Climate Change Scenarios

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ABSTRACT

Soil erosion threatens sustainability of watershed resources in the Philippines as it reduces not only the on-site fertility and productivity of the land but also adversely impacts domestic water supply of downstream communities. Since the movement and transport of soil particles are predominated by rainfall as its agent especially in the humid tropics, climate change can affect soil erosion process. For critical watersheds such as Makatipo Catchment which supplies water to downstream communities in the Municipality of Lucban, assessing potential impacts of climate change on soil erosion is very important. The study was conducted to model soil erosion in Makatipo Catchment using Universal Soil Loss Equation (USLE) as modified by David (1998). Biophysical parameters, as input to USLE, were collected and analyzed using GIS. A2 and B2 climate scenarios from Coupled Global Climate Model (CGCM2) were downscaled using SDSM 4.2 and used as inputs for soil loss assessment.

Projections using scenarios showed that soil loss in the study area could increase during the next decades due to climate change. A2 projected an average increase of 33.32% from present (1981–2010) estimated soil loss of 17.06 t h^{-1} yr^{-1} while B2 projected a relatively lower increase of 9.73 t h^{-1} yr^{-1}. Results also showed that areas experiencing high level or severe soil erosion would increase for both scenarios. The increase in soil erosion impairs water quality for various uses in downstream communities hence implementation of programs to rehabilitate erosion-prone areas, promote adoption of soil and water conservation strategies, and build climate resilient communities is highly recommended.

Keywords: *Climate Change, Mt. Banahaw, MUSLE, SDSM 4.2, Soil Erosion*

INTRODUCTION

In the Philippines, about 70% of the land falls within a watershed (ERDB 2011) that drains rain water into tributaries and provides a variety of ecosystem functions and services. There are about 419 principal river basins in the country where 127 are proclaimed watersheds protected under law (ERDB 2010). Unfortunately, the goods and services provided by the watershed have not been fully and sustainably provided as most watersheds in the country are in various states of degradation. In 2010, it was estimated that about 90% of proclaimed watersheds are hydrologically critical, degraded and have become risks to downstream infrastructure (ERDB 2010). Soil erosion takes away the soil nutrients on site and can adversely affect the physical and chemical properties of water in streams. These conditions decrease the potential of the watershed to provide benefits to its stakeholders.

Soil erosion is a process of wearing away of the land surface by running water, wind, ice or other geologic agents, including such processes as gravitational creep (Brady & Wiel 1999). It is influenced by the biophysical factors including soil types, variations in climatic and environmental factors (Beniston 2003). Vegetation cover influences soil erosion process by protecting the soil from impact of raindrops and reducing its erosive capacity. Litterfall from vegetation and its decomposition incorporate organic matter into the soil resulting to improved soil aggregation and infiltration (Casermeiro *et al*. 2004 as cited by Molina *et al*. 2007). Consequently, volume and velocity of overland flow are reduced.

Vegetation cover can also reverse the effect of increasing slope to soil erosion. Good ground cover in sloping areas can minimize actual loss and risk to soil erosion (Baja *et al*. 2014). Removal of forest cover in watershed areas can therefore increase soil erosion and consequently, sediment content of water flowing in rivers and streams. Furthermore, sedimentation can alter the quality of water supply in critical watersheds such as Makatipo Catchment and adversely affects its capacity to provide for the water demands of downstream community.

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Rainfall is an important factor in soil erosion process yet changing rainfall characteristics is rarely considered in soil loss prediction (Romkens *et al.* 2001). This may be because rainfall pattern and intensity generally remains unchanged for long periods and the complexity of measuring the influence of human activities in rainfall distribution. With the advent of climate change, however, rainfall patterns and distribution could change and drive variations in hydrologic and soil erosion processes. Since the impacts of climate change could differ with localities (Cruz *et al.*2007), understanding how it influences local rainfall patterns and intensity and its impacts on soil erosion need to be studied.

This study attempted to assess the potential impact of climate change on rainfall pattern and its effects on soil erosion in Makatipo Catchment. Although changes in rainfall and temperature patterns affect plant species distribution, land cover and consequently soil erosion process, the study assumed that no significant change in land cover occurred since the catchment is generally planted to perennial crops such as coconut and other fruit trees. The upstream of Makatipo Catchment is part of Mt.

Banahaw de Lucban, one of three peaks of Mt. Banahaw-San Cristobal Protected Landscape (MBSCPL) and protected under existing law. The study used models to downscale climate change scenarios and utilize it as input in predicting potential soil erosion on-site.

MATERIALS AND METHODS

Study Site

Makatipo catchment is a small watershed draining portion of MBSCPL towards Balanac sub-watershed of Pagsanjan-Lumban Watershed (Watershed Information Portal for the Philippines 2014) with Laguna Lake as its outlet. It is located in the Municipality of Lucban covering Barangays of Palola and Tinamnan. It lies at the northeast slope of MBSCPL. It is about 133 km south of Metro Manila via Sta. Cruz, Laguna or 154 km through Lucena City. Makatipo catchment covers an area of 1,828 ha. Figure 1 shows the location of the catchment.

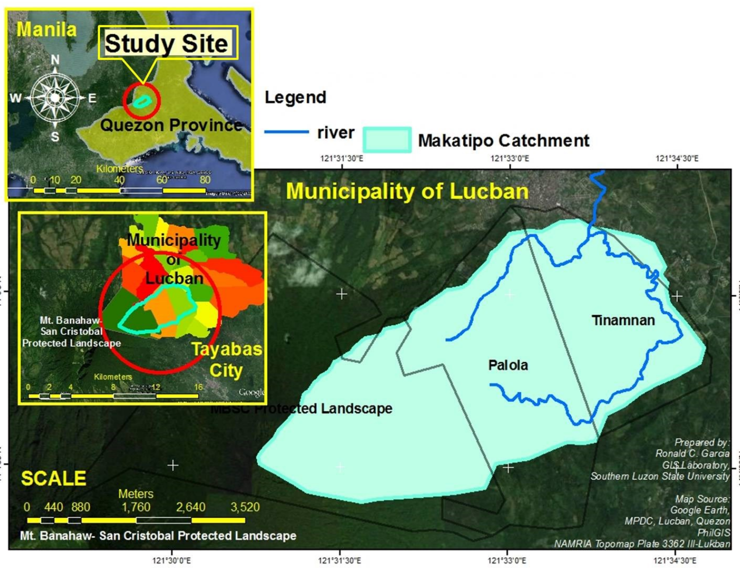

Figure 1. Location map of the study site.

Watershed Characteristics

Gascon (2002) described the physical, biological and management features of Mt. Banahaw. The topography of the area ranges from flat (0–8% slope) to steep (30–50%) slope with Type II climate under the Corona System of Classification. The annual precipitation is about 3,656.7 mm. Mean temperatures range from 24.4 to 26.1^{o}C during dry months of March and April but temperature range falls from 22.3 to 22.8^{o}C during November and December.

The soil is generally of Luisiana sandy clay loam. It is considered acidic at pH of 4.79 which contains 8.77% organic matter (OM), 392.44 ppm of Potassium (K), 0.464 ppm Phosphorous (P), and 0.41% Nitrogen (N). The acidity of the soil may be attributed to the continuous cultivation and inherent richness in iron oxides due to high amount of precipitation.

The upstream portion of Makatipo Catchment is a species rich forest with 26 families of trees and 62 tree species representing families of E*uphorbiaceae, Moraceae*, *Sapindaceae*, *Meliaceae*, *Rubiaceae*, *Lauraceae*, *Sapotaceae*, and *Rutaceae*.

Data Collection

Climate data. There is no meteorological station located within Makatipo Catchment. The nearest weather station with sufficient historical climate data is Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) Synoptic Station in Tayabas, Quezon located about nine kilometers away from the catchment. Forty-year record of daily rainfall and temperature from 1971–2010 was requested and served as input to Statistical Downscaling Model (SDSM 4.2) for downscaling climate change scenarios. The 40-yr climate data was divided into 30 years for model calibration and 10 years validation.

Maps and Spatial Data. Pertinent maps of land cover, soil, slope and land uses were requested from the Municipal Office of Lucban and were field validated. Land cover was also refined and adjusted from images in Google Earth. Slope map was also verified with NAMRIA [National Mapping and Resources Information Authority] topographic maps. Figure 2 shows the land cover, slope and topographic features of Makatipo Catchment. These maps were also digitized using ArcGIS 9.3 software in Southern Luzon State University (SLSU) GIS laboratory with soil, slope, and land cover characteristics as spatial attributes.

Downscaling Model

Downscaling model was selected and utilized based on its success in gauging catchment in previous studies in the country. Wilby & Dawson (2007) suggested that statistical downscaling methodology is a more promising option in situations where low–cost, rapid assessments of localized climate change impacts are required. SDSM 4.2 was used to generate climatic data of the study site using global climate model (GCM) – generated climate scenarios. Mullan *et al.* (2012) stressed that a key advantage in using SDSM is that its daily temporal resolution removes the requirement for temporal downscaling from a monthly resolution. These daily data are suitable for models used in estimating soil erosion.

National Center for Environmental Protection (NCEP) reanalysis data was utilized for calibration and to establish relationship between global and station (catchment–scale) data. NCEP reanalysis and predictors from 1961 to 2000 and two emission scenarios (A2 and B2) were utilized. A2 scenario envisions population growth to 15 billion by year 2100 with slow economic and technological development. B2 scenario envisions slower population growth with 10.4 billion by year 2100 with a more rapidly evolving economy and more emphasis on environmental protection producing lower emissions and less future warming than A2. These scenarios were downloaded for different time slices such as the present (1981–2010), the 2020s (2011–2040), the 2050s (2041–2070), and 2080s (2071–2100). These data were accessed online from Canadian Climate Impacts Scenarios generated by the Canadian Institute for Climate Studies (now the Pacific Climate Impacts Consortium [PCIC]).

Wilby & Dawson (2007) describe the statistical downscaling of daily weather series into seven discrete

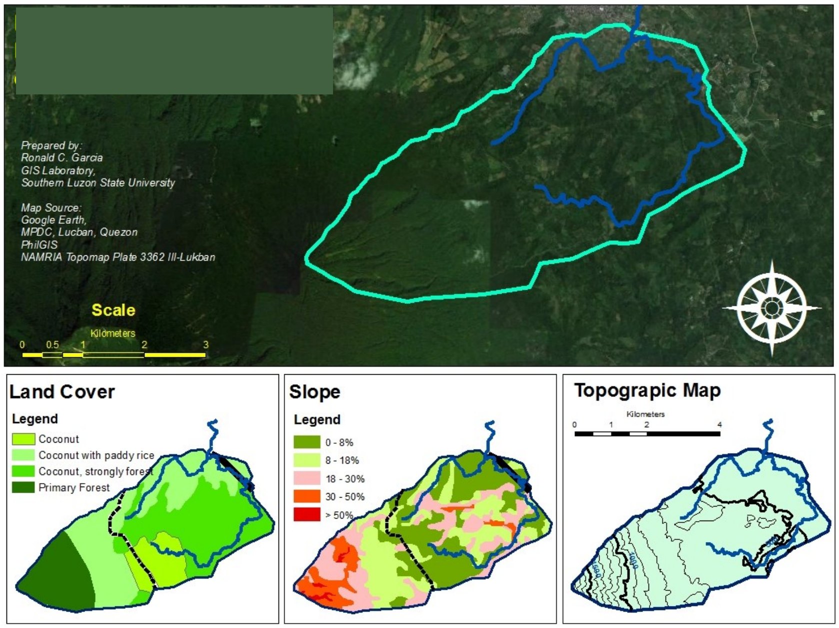

Figure 2. Biophysical characteristics of Makatipo Catchment.

steps namely: 1) quality control and data transformation; 2) screening of predictor variables; 3) model calibration; 4) weather generation (using observed predictors); 5) statistical analyses; 6) graphing model output; and 7) scenario generation (using climate model predictors). The SDSM 4.2 facilitated these steps. Quality controlling enabled identification of outliers and specification of missing data which can affect model calibration while screening was conducted to assist in the selection of appropriate predictor variables for identifying empirical relationship between predictors and single site predictands. Model calibration established empirical relationship between gridded predictors and station-based predictands using multiple regression equation. Weather generation produces ensembles of synthetic daily weather series given observed (or NCEP re–analysis) atmospheric predictor variables and enable the verification of calibrated models (using independent data) and the synthesis of artificial time series for present climate conditions. After assessing downscaled scenarios and observed climate data, ensembles of synthetic daily weather series given atmospheric predictor variables supplied by a climate model was produced using scenario generator.

Estimation of Soil Erosion Potential

The soil erosion potential in the study area was estimated using the Universal Soil Loss Equation (USLE) as modified by David (1988) and ArcGIS 9.3 to integrate biophysical attributes of the watershed. Sun *et al*. (2014) utilized USLE and described it as a statistical relationship model that correlates the amount of soil erosion and its impact factors (climate, soil, topography, vegetation and human activities), and it can be modified according to the local conditions of these factors. Fu *et al*. (2011) used USLE with localized parameters to assess soil erosion services of restoring vegetation cover. David (1988) modified USLE by integrating the slope length and slope gradient into a single factor combined with rainfall, soil, slope, cover and conservation practices on-site to suit prediction of soil erosion in the Philippines. The formula is given as follows:

$$\boldsymbol{E = R \times K \times LS \times C \times P}$$

Where $\boldsymbol{E}$ is the soil loss rate (in t ha^{-1} yr^{-1}), $\boldsymbol{R}$ is the rainfall erosivity factor, $\boldsymbol{K}$ is the soil erodibility factor, $\boldsymbol{LS}$ is the slope length and slope gradient factor, $\boldsymbol{C}$ is the cover factor and $\boldsymbol{P}$ is the conservation practices factor.

David (1988) also suggested determination of R value using daily rainfall data, K value from soil characteristics, LS value from slope characteristics, C value from land cover, and P value from conservation measures observed on site. These biophysical characteristics were interpolated from maps and R, K, LS, C, and P values were determined and adopted from David (1988). Adopted values of K were based on soil texture, pH, and organic matter (OM). Following this method and using Gascon's (2002) description of soil texture, pH, OM, and macronutrients of Mt. Banahaw, the K values from David (1988) adopted for the study were identified. P values based on observed soil conservation practices in different land cover were also identified and adopted. Furthermore, it was assumed that rainfall is uniformly distributed throughout Makatipo Catchment and one R value was used considering its small size. The R value was estimated using the formula below.

$$R = \mathrm{A} \cdot \sum_{n=1}^{n} \mathrm{Pi}^{\mathrm{m}}$$

Where $\boldsymbol{R}$ is the rainfall erosivity factor, $\boldsymbol{Pi}$ is the daily rainfall greater than 25mm, $\boldsymbol{A}$ and $\boldsymbol{m}$ 0.002 and 2, respectively.

The spatial distribution of potential soil erosion for present and future scenarios was determined using ArcGIS 9.3. The values of R, K, LS, C and P values were incorporated as spatial attributes in the digitized maps of soil, slope, and land cover. These maps were then integrated using Overlay Analysis. This process created a map composed of polygons representing areas in the catchment with associated R, K, LS, C, and P values as spatial attributes. Field calculations were then conducted in ArcGIS 9.3 to determine soil erosion potential.

The severity of soil erosion was classified based on ERDB (2011) soil erosion priority classes using USLE. It has five classes namely:

1) Very Low (for soil erosion >7 t ha^{-1} yr^{-1});
2) Low (for 8–12 t ha^{-1} yr^{-1});
3) Moderate (for 13–25 t ha^{-1} yr^{-1});
4) High (for 26–37 t ha^{-1} yr^{-1}) and
5) Very High (for soil erosion >37 t ha^{-1} yr^{-1}).

In this study, soil erosion below 12 t ha^{-1} yr^{-1} or classification of Very Low and Low (ERDB 2011) were considered acceptable. Hall *et al.* (1985), as cited by Centeri *et al.* (2001), explained that the 11 t ha^{-1} yr^{-1} rate of soil loss is acceptable since it approximates the maximum rate of A horizon development under optimum condition. Mandal & Sharda (2011) also reported an 11.2 t ha^{-1} yr^{-1} acceptable soil loss following the same explanation and cases where there is an absence of specific criteria to determine soil erosion based on soil quality and its resistance to water erosion.

Soil Loss Under Climate Change Scenario

SDSM 4.2 model was utilized to downscale global climate scenarios and generate local climate for Makatipo catchment. A2 and B2 global climate scenarios for present (1981–2010), the 2020s (2011–2040), the 2050s (2041–2070), and 2080s (2071–2100) were employed to generate local climate under these scenarios, including daily rainfall for the estimation of R values. David (1998) estimates R values from daily rainfall greater than 25mm.

RESULTS AND DISCUSSIONS

Performance of SDSM 4.2 model

SDSM 4.2 model performed well in simulating local climate in Makatipo Catchment as shown in calibration and validation between climate data collected from adjacent agro-meteorological station. Forty-year record of daily rainfall and temperature from 1971–2010 was requested from PAGASA Synoptic Station in Tayabas, Quezon. From 40-yr climate data, 30 years was utilized for model calibration and the other 10 years for validation. The model was used to simulate rainfall of the catchment which then served as input to soil erosion prediction model.

Climate Change Scenarios

A2 and B2 scenarios projected an increasing trend in annual rainfall for Makatipo Catchment from 2020s up until the end of this century (Figure 3). A2 scenario projected a mean annual rainfall of 5,823mm which was higher than B2 scenario with only 5,765mm. Although projections vary yearly, A2 projected an increase of about 1.18% while B2 estimated a 0.04% increase in annual rainfall by the end of 2100. Figure 3 also shows that the estimated annual rainfall varies among scenarios in all time slices.

Monthly rainfall is more critical for domestic and agricultural users (Jose & Cruz 1999). A2 and B2 scenarios projected an increase in mean monthly rainfall. Mean monthly rainfall was projected to increase by 1.41% under A2 scenario and 0.40% under B2 scenario by the 2080s. Figure 3 show the distribution of rainfall throughout the year and the monthly projected changes. These changes pose challenges to the distribution of rainfall whereby excesses in water may be experienced during wet months and shortage during dry months.

Figures 4 and 5 also show the projected mean monthly and projected changes in mean monthly rainfall in Makatipo Catchment by the 2080s. This may indicate a high variability in rainfall patterns and possibly extreme events for A2 and B2 scenarios. This seemed congruent with the findings of Segura *et al.* (2014) which stressed the significant variability in rainfall and extreme events which can vary spatially over large areas. Changes in spatial distribution of rainfall and extreme events affect spatial distribution of soil erosion.

The slight difference in projected rainfall may be attributed to assumptions of the two scenarios used in the study. A2 projected higher population growth but slow economic and technological growth resulting to slightly higher future greenhouse gas (GHG) emissions than present while B2 envisions better environment characterized by slower population growth, rapidly evolving economy and more emphasis on environmental protection generating lower emissions and less future warming (Wilby & Dawson 2007). As B2 projected less future warming, its impacts on rainfall characteristics would also be lower than that of A2 projections.

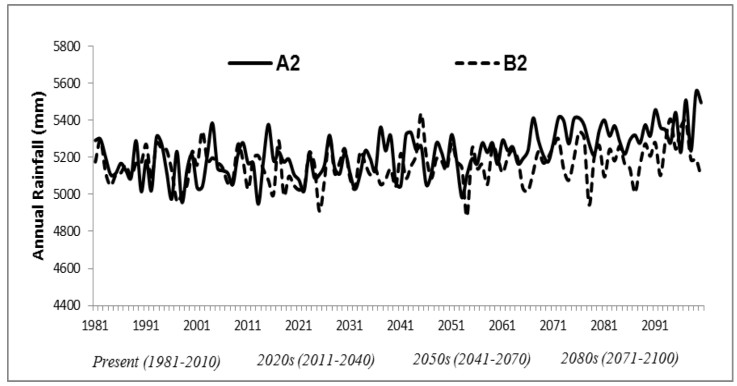

Figure 3. The projected annual rainfall of Makatipo Catchment under A2 and B2 scenarios.

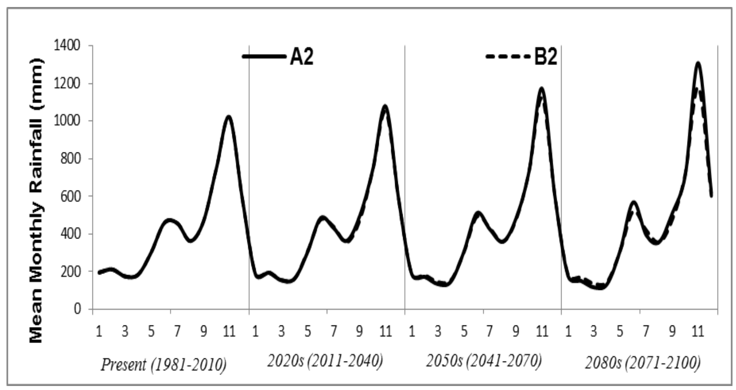

Figure 4. The projected mean monthly rainfall of Makatipo Catchment under A2 and B2 scenarios.

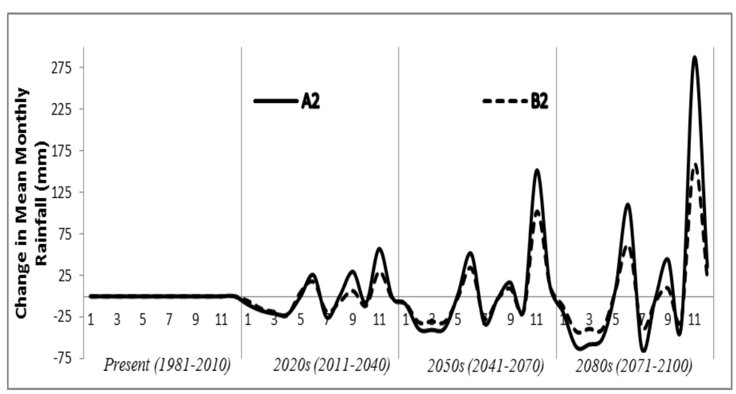

Figure 5. The projected changes in mean monthly rainfall of Makatipo Catchment under A2 and B2 scenarios.

Soil Erosion Potential

The average soil erosion of Makatipo Catchment at present was estimated to be 17.06 t ha^{-1} yr^{-1} although erosion rates vary from Very Low (less than 7 t ha^{-1} yr^{-1}) to Very High rates (>37 t ha^{-1} yr^{-1}). The estimated soil erosion was also high in two barangays under Makatipo Catchment. The present (1981–2010) estimates of soil erosion potential using USLE as modified by David (1988) in Barangays of Tinamnan and Palola were 14.67 t ha^{-1} yr^{-1} and 22.22 t ha^{-1} yr^{-1}, respectively. These exceeded the 12 t ha^{-1} yr^{-1} acceptable limit which allows regeneration of the top soil (Hall *et al*. 1985 as cited by Centeri, *et al*. 2001; Mandal & Sharda 2011). Likewise, 70.52% of barangays in Palola and 57.47% of barangays in Tinamnan within the catchment had an estimated soil erosion of more than 13 t ha^{-1} yr^{-1}. This implies that the two barangays are not utilizing the land on sustainable basis and continuing with business–as–usual scheme may further degrade soil and water resources in the catchment.

Soil erosion also appears to be higher in steeper slope, stream banks, and areas with very minimal vegetation cover. Results showed that areas with steeper slopes have potential to yield *"*High*"* rates of soil loss. This may be expected since the slope of the land can influence erosive force of surface runoff. Soil erosion significantly increases as slope gradient increases (Sun *et al.* 2014) which can be attributed to increasing velocity of runoff as it flows down the steep slope gradient. Soil erosion also varies significantly with slope gradient in different land uses. Furthermore, negligible runoff and very light or low soil erosion would be generated in flat lands even if it is cultivated.

Very Low soil erosion rate was estimated in the headwaters draining portion of Mt. Banahaw de Lucban which can be attributed to closed forest canopy covering the soil. The role of vegetation cover has been stressed in numerous studies. Sharma *et al. (2011)* considered forest cover as most effective barrier to soil loss and converting it to other uses such as cropland can be detrimental to watershed. Casermeiro *et al.* (2004) as cited by Molina *et al.* (2007) explain that vegetation reduces soil erosion by protecting the soil against impact of raindrops and lowers its erosive capacity. Furthermore, vegetation enhances soil aggregation by incorporating organic matter to the soil, and reduces overland flow velocity (Sun *et al.* 2014*)*. With improved soil structure and slower runoff, infiltration increases and volume of flow decreases resulting to lower soil erosion. Hence, it is expected that forest and areas of Makatipo Catchment with good vegetation cover will yield low values of potential soil loss.

Potential Impact of Climate Change on Soil Erosion

Climate change is expected to modify rainfall patterns, temperature extremes, weather extremes and other parameters of the atmospheric conditions. Rainfall is an active agent of soil erosion in the Philippines and changes in its patterns and distribution in time and space can potentially affect sustainability of soil resources.

Results suggest that change in rainfall characteristics such as volume and pattern will affect soil erosion in Makatipo Catchment. Table 1 summarizes potential changes in soil erosion in the area under climate change scenarios. Generally, soil erosion is projected to be higher by the end of 2100. Results also show that both scenarios projected increasing trend for soil erosion brought about by climate change although A2 projection is about two times higher than B2 soil erosion projections. A2 projected an average increase of about 33% which could peak to 78% by the end of 2100. B2 projected an average of 14% change in soil erosion attributed to climate change. The difference in projection may be due to the assumption under the climate scenarios. A2 scenario assumes higher population growth globally and slower and inequitable economic development. Higher population would result to greater emissions of GHG as more population utilizes resources, higher external forcing (Kumar *et al.* 2006*)* and more variable climate anomalies. B2 would have lower climate anomalies in hydrology compared with A2 scenario.

Results suggest that a certain change in the amount of rainfall can increase the rate of soil erosion. This study predicted that a 1% increase in the amount of rainfall can lead to 28.14% and 36.33% increase in soil erosion in Makatipo Catchment for A2 and B2 scenarios, respectively. This implies that the erosion process is very responsive to changes in rainfall. Zhang *et al.* (2012*)* reported similar findings where climate change may not significantly change annual precipitation but projected significant increases in mean annual runoff and soil loss by as much as 79% to 92% and 127% to 157%, respectively. The said increases in runoff and soil loss can be attributed to the increase in the frequency and intensity of extreme events. Routschek *et al*. *(*2014*)* also reported that increasing rainfall intensities can lead to increased soil erosion in watersheds. This means that although the amount of annual precipitation may not change, the occurrence and frequency of abnormal and extreme rainfall events can also enhance soil erosion.

Nearing *et al.* (2004) suggest that there may be other factors affecting the complex soil erosion process other than annual rainfall. Increase in rainfall can induce runoff generation but can promote vegetation growth. While annual rainfall increases amount of runoff and resulting soil erosion, it increases biomass and vegetation increases absorption, soil aggregation and roughness to overland flow which have opposing effects.

Table 1. Average soil erosion potential (SEP) of Makatipo Catchment under A2 and B2 scenario.

Time Slice	A2 Climate Scenario		B2 Climate Scenario	
	SEP (t ha^{-1} yr^{-1})	% Change	SEP (t ha^{-1} yr^{-1})	% Change
Present (1981-2010)	17.06			
2020s (2011 - 2040)	17.84	4.60	15.83	-7.20
2050s (2041 - 2070)	19.96	17.00	18.80	10.20
2080s (2071 - 2100)	30.36	78.00	21.53	26.20
Average	**22.72**	**33.20**	**18.72**	**14.53**

Spatial Distribution of Soil Erosion Under Climate Change Scenario

Figures 6 and 7 illustrate the distribution of soil erosion in Makatipo Catchment under A2 and B2 climate change scenarios. The study projected that climate change could put

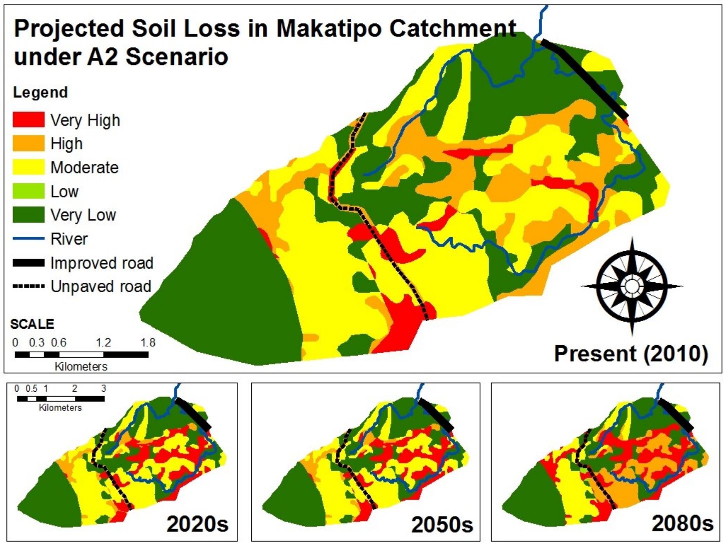

Figure 6. Soil erosion potential maps of Makatipo catchment under A2 scenario.

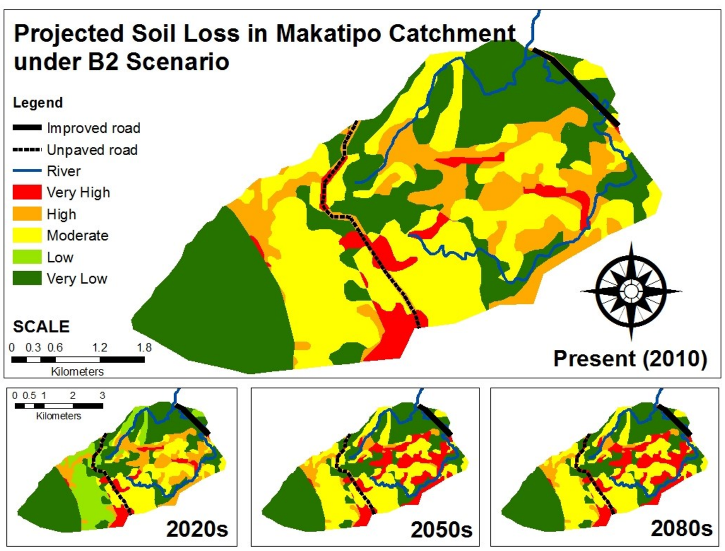

Figure 7. Soil erosion potential maps of Makatipo catchment under B2 scenario.

more pressure on the environment making more area less resistant to erosive power of rainfall. Results show that more area in the Makatipo Catchment would experience increasing rates of erosion as rainfall increases. Under A2 scenario, the portion of the catchment with "Very High" soil erosion is projected to increase from 5.72% to 24.38% by the end of 2100. Lower increase was projected under B2 scenario with an increase of "Very High" rates of erosion from 5.72% to 18.96% as more areas were projected to experience more soil erosion.

Furthermore, the portion of Makatipo Catchment with "Very Low" soil erosion rates appears to be less affected by the change in rainfall resulting from climate change. The extent of areas with "Very Low" erosion rates have remained the same throughout the simulation. The forested portion of Mt. Banahaw de Lucban exhibited Very Low soil erosion rates in all time slices and scenarios even though it is located in steep slopes. This can be attributed to the forest cover in the area which provides protection against raindrops. This stresses the significance of vegetation cover in mitigating impacts of climate change.

At barangay level, results suggest that soil erosion would increase by 2080s for the barangays under both scenarios. Under A2 scenario, soil erosion was projected to increase by 78% for the two barangays. Under B2 scenario, the soil erosion in Barangays Palola and Tinamnan were projected to increase by 26.39% and 59.50%, respectively. Furthermore, the areas that are projected to experience soil erosion greater than 25 t ha^{-1} yr^{-1} (including High and Very High) increases under A2 scenario. For Barangay Palola, the area experiencing High and Very High erosion rates doubled (109.14% increase) while Barangay Tinamnan revealed 69.29% increase. This implies that with the advent of climate change, the two barangays would need to consider appropriate land management practices including cover management and the use of soil and water conservation strategies to lessen adverse impacts of changing rainfall pattern.

The changes in the spatial distribution of soil erosion under different climate scenarios could also depend upon the biophysical characteristics of the area affecting the process. As biophysical characteristics vary throughout the catchment, its resistance to erosive power of rainfall also varies. Nearing *et al*. (2004) also explain that the variation in the impacts of climate change in an area may be attributed to the spatial distribution of rainfall and its influence on the growth of vegetation. Increase in rainfall enhances biomass and growth of vegetation and consequently soil aggregation and roughness. In some cases, changes in forest cover and vegetation dynamics can emerge as a key factor in quantifying and interpreting the hydrological and erosion response of watersheds (Nunes 2011). However, Makatipo Catchment has relatively small area hence rainfall distribution can be considered uniform throughout.

Policy Implications for Makatipo Catchment

The study shows that regardless of scenario used, future climate variability results to increased occurrence and changes in spatial distribution of soil erosion in Makatipo Catchment. Clearly, climate change may reduce the ability of the watershed to provide ecosystem services. Climate change does not only increase soil erosion but can also impair hydrologic process and entail additional cost in order to elicit ecosystem services such as provisioning of water, sedimentation, storage for hydropower (Bangash *et al.* 2013), and irrigation. Buytaert *et al.* (2011) also stressed that changes in precipitation patterns, increased evapotranspiration, and alterations of the soil properties will have a major impact on water supply. Increased rainfall in sloping agricultural areas may enhance soil erosion reducing soil fertility and consequently its productivity while impairing water quality and inducing risks of flooding in downstream communities in Tayabas City. As climate change and soil erosion threaten life and properties, they may also increase pressure on the use of resources and elicit additional input to meet demands on products and services provided by watershed and natural resources. These entail identification, formulation, and strict implementation of policies that enhance watershed resistance against erosion such as land use and land cover management, conservation practices, slope stabilization, and soil conservation.

Land use change and conversion from agricultural to settlement/ housing projects has increased in the municipality over the last decades. The extent of land use change needs to be assessed as it induces erosion by changing ground cover, increasing built-up while reducing recharge areas, and promoting soil disturbance. The study shows that stream bank was among the areas prone to soil erosion hence land cover management and stream bank stabilization projects should also be considered.

Policies and programs in the Municipality of Lucban should consider increasing resiliency of local communities and salient natural and agro-ecosystems to adverse impacts of climate change. With increased soil erosion resulting from climate variability, productivity of agro-ecosystems and its role in sustaining community development is threatened. Hence, formulating adaptation strategies against adverse impacts of climate change and soil erosion is essential.

CONCLUSION

The study assessed the soil erosion potential in Makatipo Catchment by downscaling A2 and B2 climate change scenarios and using it as input to USLE as modified by David (1988). With climate change, rainfall and its variability in pattern are projected to increase under the two scenarios by 2100. Although two scenarios projected an increasing trend in annual rainfall, A2 projected an increase of about 1.18% while B2 estimated a 0.04% increase in annual rainfall. As rainfall increases and its patterns and distribution change, potential soil erosion in Makatipo Catchment would also increase for both scenarios and more areas are projected to experience elevated rates of soil erosion. Soil erosion appears to be higher in steeper slope, stream banks, and areas with very minimal vegetation cover. This shows that aside from rainfall pattern and characteristics, land cover and slope characteristics are important considerations in determining future soil erosion in an area.

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ACKNOWLEDGEMENT

This paper is an offshoot of the author's Master's Thesis and accomplished through the use of SLSU GIS Laboratory.

Photo of Mt. Banahaw de Lucban, Quezon Province

Photo of Makatipo Catchment at Mt. Banahaw de Lucban, Quezon Province