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Soil erosion rate estimate using USLE of corn producing areas in Barangay Vitali, Zambonga City, Philippines

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Abstract The rate of soil erosion using the universal soil loss equation (USLE) in seven (7) corn producing areas in Barangay Vitali, Zamboanga City, Philippines was estimated. The area is characterized as hilly with slope ranged from 20-43% and patches of banana, coconut and fruit trees where soil erosion has been a persistent problem. The corn areas and number of respondents were determined using the purposive sampling and descriptive statistics to compare the predictive variables. The USLE was used to estimate the rate of soil loss (A) measured in ton ha^{-1} yr^{-1} (t ha^{-1} yr^{-1}) by the compounding effects of various factors such as the rainfall erosivity (R), soil erodibility (K), length of slope (L), steepness of slope (S), vegetation cover (C), farming practices and management (P). Accounting all these factors, of the 7 areas, Sitio Sta. Fe obtained the highest erosion rate measured at 214.86 t $ha^{-1}yr^{-1}$ followed by Sitios Pico, Camalig, Gemelina, Linduman, Tagpangi and Cansilayan with respective rate at 176.0, 111.51, 92.04, 88.05, 86.20 and 67.0 t $ha^{-1}yr^{-1}$, which gave the average of 119.62 t $ha^{-1}yr^{-1}$. Rainfall erosivity, length and slope gradient are factors which contributed to high erosion rates. Suitable, ecologically sound, climate smart-soil restorative technologies should replace the soil-erosive-monoculture corn farming in the uplands of Barangay Vitali. Substantial effort has to be in placed with strong interventions from government and local communities to help curb the increasing soil erosion problem in these fragile upland ecosystems in Zamboanga City, Philippines.

Keywords: Soil erosion, Rainfall erosivity, Length slope gradient, USLE, Farming practices and management

Introduction

Soil erosion is defined as the removal of fertile topsoil that results in the decline of the productive capacity of the soil (Asio, 1997). It is affected by natural factors affecting soil erosion by water that includes rainfall, vegetative

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cover, the slope of the land and soil erodibility (Lal, 1984; Presbitero, 1995). Soil erosion considered as the most common form of soil degradation (Lal, 2003).

In global scale, 75 billion tons of soils are eroded from earth ecosystem annually (Pimentel and Kounang, 1998). It threatens the global food production as 10 million hectares of cropland are lost result to significant reduction of crop lands vital for food production as soil lost is 10-40 times faster than the rate of soil formation (Pimentel andBurgess, 2013). Soil erosion renders the soil unproductive as a result when productive capacity of the soil is depleted. Protecting our crop land is so vital because it's the main source of food calories with 99.7% taken from land and only 0.3% from oceans and other aquatic ecosystems (Pimentel and Burgess, 2013). If soil erosion is left unchecked, global food production loss will be as high as 190 $x10^6$ Mg of cereals, $6x10^6$ Mg soybeans, $3x10^6$ Mg of pulses and 73×10^6 Mg of roots and tubers (Lal, 1998).

One of the common drivers of soil erosion is farming activities. Soil erosion is a four-stage process involving detachment, breakdown, transport/redistribution and deposition of sediments. It has a strong impact to the environment as it affects the global carbon cycle that happens when organic matter which is basically soil organic carbons are transported during erosion (Lal, 2003). Cropping and tillage systems used also influence the soil to loss of sequestered carbon (Salang, 2010).

The problem of soil erosion in the Philippines is quite obvious the fact that more than half of the country's land area having a slope exceeding 18 percent considered as the Philippine uplands. Factors like heavy rainfall, improper land use and management, excessive and improper logging, shifting cultivation and road construction have aggravated the problems (Paningbatan, 1990). In long term effect, common appearance in the most upland all over the country is the reddish appearance of soil when iron oxide rich soil appears after the removal of the humus-rich topsoil due to erosion (Asio, 1997).

Soil erosion is a serious threat to the sustainability of agricultural systems in the Philippines, the same is true with the other intensively cultivated regions of the developing world, yet the ultimate causes of erosion are complex and poorly understood. Policy makers and farmers should look at the root causes of the problem to appropriately deal the problem. Soil erosion can be adequately controlled even at the farm level if appropriate technologies are applied. Thus, there is a need to a more systemic understanding on the root cause of soil erosion if one's objective is to create a sustainable soil management strategy (Olabisi, 2012). It is possible to achieved corn productivity in the uplands through abatement of soil erosion with appropriate approaches (Rola *et al.,* 2009).

Corn ranked second to rice as the most important crop in the Philippines, with one-third of Filipino farmers or 1.8 million, depend on maize as their major source of livelihood. White corn variety is an important substitute staple in periods of rice shortage, especially for people in rural areas while yellow maize is the primary source of feed for the Philippines' animal industry and is being increasingly used by the manufacturing sector (Gerpacio *et al.,* 2004).

Upland areas, where corn is mainly grown, refer to a hilly and rolling topography (Gerpacio *et al.,* 2004). This hilly or sloping areas are usually rugged terrain usually 18% slopes or greater which are highly vulnerable to soil erosion which would result to loss of fertility in three (3) years-time of continuous subsistence farming (Lantican, 2001).

In Zamboanga City, corn is one of the major crops grown mostly in the upland communities within the corn cluster areas. Inappropriate farming practices like burning of crops stubbles and plowing along the steep sloping areas have contributed to the dwindling productivity of the area brought by soil erosion. The growing problem on soil erosion has been observed by the farmers as a result of their inept farming activities (Lantican, 2001). The problem on soil erosion needs to be determined for the purpose of designing appropriate measures applicable to certain locality (Cramb *et al.,* 2000). Currently in Zamboanga City, Philippines, there is no available soil erosion data on this fragile ecosystem. Even at the national level there is a need to have a thorough evaluation of soil erosion problems as observed in the reports of World Bank (1989) showing rates of soil loss ranging from 1.0 ton ha^{-1} yr^{-1} under undisturbed forest to around 300-400 t ha^{-1} yr^{-1} on kaingin (slash and burn) or shifting cultivation (FAO, 1998). On the average, soil erosion rate across the country is estimated at 81 t ha^{-1} yr^{-1}, although this value might be an underestimation of the real soil erosion rate (Asio *et al.*, 2009).

The city's overall topography can be described as rolling to very steep while there are some narrow strips of flat lands along the east coast. The urban center is characterized by mostly flat areas with a gentle slope on its inner parts of the city ranging from 0-3%. A major portion of the city, around 38,000 hectares have slopes ranging from 18-30%, while 26,000 hectares are level to nearly level. On the other hand, a total of 52,000 hectares has slopes ranging from 30-50%. The soils of Zamboanga City can be categorized into three groups, namely: the residual soil embracing the undulating and mountainous portion, alluvial soil located in level to nearly level areas which are devoted mainly to agricultural crop cultivation, and the swamp lands which are mainly used for fishpond development. The city has a total physical area of 6,218 hectares planted to corn in two (2) corn cluster areas covering a total of 2,482.5 hectares with 1,276 farmers and the intensity is two cropping season per year mostly planted with OPV variety with an average area of 1.0 hectare to 3.0 hectares per farmer. The study was conducted to estimate the rate of soil erosion using USLE and account the various factors that affects the rate of soil erosion in various corn producing areas of Barangay Vitali, Zamboanga City, Philippines.

Materials and methods

Site selection

Vitali is situated at approximately 7°22’15”N and 122°17’18”E in the island of Mindanao, Philippines. Elevation at these coordinates is estimated at 10.3 meters or 33.8 feet above mean sea level. One of the corn clusters identified is located in barangay Vitali (Figure 1). Barangay Vitali is in the eastern part of the city, it has a total land area of 5,409 hectares of which 30% or 1,633.7 hectares is considered hilly or mountainous, 50% or 2,704.5 hectares is flat, while the remaining 20% or 1,081.8 are coastal areas.

Respondents of the study

The selection of respondents was based on the following certain criteria: actual corn grower and should be a resident within the target area. Based on the data gathered from Zamboanga City Corn Cluster Development Plan (http://www.zamboangacity.gov.ph), the total number of farmer members of the LindumanVitali Corn Cluster Area totals to 120 covering a total area of 200.5 hectares (Table 1). Of this total, 30% or an equivalent of 41 farmers were used as respondents during the conduct of the study using a structured questionnaire.

Table 1. Corn cluster association

Name of Corn Cluster Association	Agricultural District	Physical Area, Hectares	No. of Corn Farmers	Year Established
Linduman - Vitali Farmers Association	Vitali District	200.5	120	2000

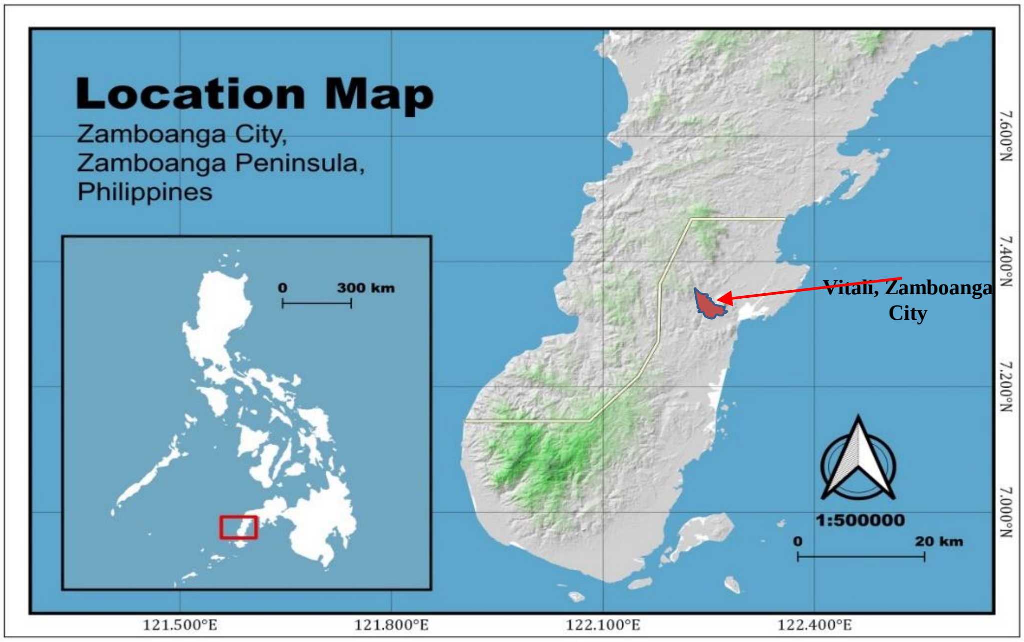

Figure 1. Location of the study

Sampling procedure

Sampling unit was selected using purposive sampling approach in which the sampling methodology was based on the researcher's judgment basing on the actual scenario of the target area. A total of 41 representative farms were surveyed across the corn cluster area.

Data gathered

During the conduct of the field survey, information such as the degree of slopes, length of slope, soil samples per farm, tillage system of the farmers and vegetation cover were gathered, while the rainfall data was obtained from local weather stations.

Calculating soil erosion rate

The rate of soil erosion was determined using the Universal Soil Loss Equation (USLE.). Various equations and procedures were adopted from the work of Cooper (2011) Mitchell and Bubenzer (1980), Stewart *et al.* (1975), Robert and Hilborn, (2000). Different factors were determined like the rainfall erosivity, soil erodibility, tillage system, vegetation covers and the length and degree of slopes. Their predicted variables were compared in terms of means and percent.

Results

The rate of soil erosion of various corn producing areas in Barangay Vitali, Zamboanga City, Philippines is shown in Table 2. Of the seven (7) identified corn producing areas, the highest soil erosion rate was observed in Sitio Sta. Fe at 214.86 ton ha^{-1} yr^{-1}, followed by Sitios Pico, Camalig, Gemilina, Linduman, Tagpangi and Cansilayan with soil loss rate measured at 176.81, 111.51, 92.04, 88.05, 86.20 and 67.89 ton ha^{-1} yr^{-1}, respectively which gave an average rate of 119.62 ton ha^{-1} yr^{-1}. The corn growing areas has been under monoculture system using conventional methods which leave the soil bare and unprotected in time of heavy rains. The slope length and steepness of slopes of these areas are the major contributors to high erosion rates. Findings also suggests that as the degree of slopes increases the rate of erosion increases and for every 2% increment in steepness of the slopes could results to a much higher erosion rate (Krusekopf, 1943). Also, the type of vegetation cover found in these areas at time the condition exacerbates the burning of crops stubbles, continued plowing along the steeper slopes. The burning of stubble will translate to lower soil organic matter build-up, while constant plowing destroys the soil structures.

Table 2. Soil Erosion Rate of various corn producing areas in Linduman-Vitali Corn cluster area, Zamboanga City, Philippines

Corn Production Areas	Estimated Erosion Rate (tons ha^{-1} yr^{-1})
Sta Fe	214.86
Pico	176.81
Camalig	111.51
Gemilina	92.04
Linduman	88.05
Tagpangi	86.20
Cansilayan	67.89
Average	**119.62**

Discussion

The corn cluster areas were characterized with similar tillage practices among farmers which is a practice by plowing across the slopes. Common vegetation covers found within these production areas during the production season are corn, patches of banana, coconut and fruit trees, while grasses including shrubs and broadleaves are teeming during the offseason.

The equivalent value for the tillage practice or P factor is 0.65 (Robert and Hilborn, 2000), while the equivalent value for vegetation cover or the C factor is 0.75 **(**Mitchell and Bubenzer 1980). The soil textural class is sandy loam with an average soil organic matter content (OM) of 3.02%, which gives a value of 0.24 in terms of soil erodibility index or the K index (Stewart *et al.*, 1975). The highest organic matter (OM) content is 3.85%, while the lowest is 2.41% giving a range of 1.44% organic matter (OM) content.

The area doesn't have pluviographic records of rainfall intensity and only the available rainfall records were used in computing rainfall erosivity using the equation of Bols (1978), thesame equation used by Teh (2011) as cited by Cooper (2011) that many parts of the world don't have detailed rainfall data and many studies are performed to estimates rainfall erosivity (R-factor) using available rainfall data. The average rainfall in Zamboanga City is 2,600.53 mm yr^{-1}, which translate to 216.7 mm monthly average rainfall. Using the rainfall data, the erosivity factor was computed. The higher rate of erosion in Sitio Sta Fe is attributed to the higher degree of slopes observed in the area. The degree of slopes is one of the major contributors to high erosion rate in the area, as noted by Krusekopf (1943) that an increment of 2% in steepness of the slopes could result to much higher soil erosion rate. Zingg (1940) established a relationship between the length of slopes and the rate of erosion in which an erosion increases exponentially by 0.6 with the length of slopes. The amount of run-off water required to erode one (1) pound of soil decreased rapidly as the slope increased from one (1) percent up to about 10 percent, after which the decrease was gradual and slight (Duly and Domingo, 1932). Assouline and Ben-Hur (2006) also noted that soil erosion during rainfall is greatly affected by runoff and slope steepness which can be mitigated by establishment of plant covers (Elwell, 1981). Fornis *et al.* (2005) also stated that soil erosion is due to the action of erosive agents that detach and transport individual particles from the soil mass.

Soil erodibility is another factor which also exerts influence on the amount of soil loss. The erodibility of a soil is defined by its resistance to two energy sources: the impact of raindrops on the soil surface and the shearing action of runoff between clods in grooves or rills (FAO,). Soil erodibility depends largely on the amount of organic matter in the soil, the texture of the soil, especially sand of 100-2000 microns and silt of 2-100 microns, and lastly the profile, the structure of the surface horizon and permeability (Wischmeier and Smith, 1960), which means that this can be manipulated by properly designing the intervention especially the addition of organic matter in the soil. Dumas (1965) discussed that soil erodibility depends on the amount of pebbles, the amount of organic matter and the equivalent humidity of the soil, which depends in turn on its texture. Significant reduction of 80% on the rate of erosion is possible even if only 40% of the soils are covered (Elwell, 1981). Full plant covers ensure a high level of soil and water conservation whatever the slope gradient might be. If cover is not complete, the gradient of the slope exercises the next greatest influence on the amount of soil loss. Another important factor is the tillage which exert influence on soil erosion as during tillage soil structure are greatly disturbed (Roose, 1996). Mannering and Burwell (1968) reported that when corn was continuously grown for five years with minimum tillage, soil aggregation and infiltration increased by 24%, while erosion fell by 34% in comparison with the conventional treatment (full tillage). The vegetation covers also exerts influence on the rate of soil erosion as vegetation cover act as a cushion in the soil absorbing the kinetic energy of raindrops. And the degree of runoff depends largely on the proportion of soil not covered by plants before the heaviest rains (Roose,1996).

The computed rate of soil erosion shows that the area is potentially at risk of permanent soil degradation if measures are not employed. The current average rate of erosion of the Linduman-Vitali Corn Cluster area was measured 119.62 tons ha^{-1} yr^{-1} is 48% higher than the reported national standard of 81.0 tons ha^{-1} yr^{-1} (FAO, 1998). This also means that out of the seven (7), only one area is below the national standards (Cansilayan at 67.89 ha^{-1} yr^{-1}) while the rest of the sitios are way higher than the national standards.

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