Univ. of Min. Intl. Mult. Res. Jour. vol. 1, no. 1, pp. 182-195
Received: November 5, 2015; Accepted: December 10, 2015; Released: January 15, 2016
www.uminjournals.org

Rate and cost of soil erosion in Monkayo, Compostela Valley Province Philippines

[1]Sunshine G. Paulin and [2]Ireneo P. Amplayo
[1]Municipal Agriculture Office, Local Government Unit of Monkayo
P-8, Poblacion, Monkayo, Compostela Valley, 8805
Email: sgp_rpae@yahoo.com
[2]University of Southeastern Philippines, Apokon, Tagum City, Davao del Norte
Email: ipamplayo@yahoo.com

ABSTRACT

Soil erosion is a major agricultural and environmental problem in the Philippines that is primarily caused by rainfall under upland, subsistence rain-fed farming. The study sought to compare the degree of erosion as influenced by different upland tillage systems using soil erosion plots and MUSLE model, and estimate the cost of soil erosion in Monkayo, Compostela Valley. The erosion plots were laid on a 31.45 percent slope with a seasonal rainfall intensity of 2,314 mm. Corn (*Zea mays L.*) planted through conventional tillage generated a mean soil loss of 2.64 t/ha/cropping, which is higher than the reduced tillage with a mean of 1.20 t/ha/cropping. The weighted on-site soil loss was 12 percent lower than the obtained soil erosion using the modified Universal Soil Loss Equation that is 2.97 t/ha. The study developed equations to estimate soil loss (t/ha) per seasonal rainfall on three tillage systems using linear regression analysis which are: (1) E= -0.0031+0.0003R, (2) E= -0.0406+0.0011R, and (3) E=0.2249+0.0034R in corn grown on undisturbed land with natural vegetation, corn grown on bare soil through dibble method and corn planted through conventional planting system, respectively. On-site cost of erosion ranged from Php 1,473.42/ha/cropping to Php 1,938.81/ha/cropping. The amount of soil eroded can be attributed to the higher erositivity of rains, higher erodibility of the soil surface, and the poor soil cover.

Keywords: *cost of erosion, modified Universal Loss Equation, soil erosion rate,*

INTRODUCTION

Soil degradation implies long-term decline in soil productivity and its environment-moderating capacity (Lal, 2001; Asio et al., 2009). As defined by Oldeman (1994) and Reeves (1997), soil degradation is the process which lowers the current or future capacity of the soil to produce goods or services which are due to is due to the displacement of soil material such as soil erosion by wind and water.

As stressed by Olabisi (2012), soil erosion is a serious threat to the sustainability of agricultural systems in the Philippines. In addition, Obalum et al. (2012) emphasized that the removal of the topsoil shown to have many deleterious effects on the productive capacity of the soil as well as on ecological well-being. Furthermore, Tujan (2000) tagged soil erosion as the country's worst environmental problem. As cited by Schmitt (2007), the Philippine Forest Management Bureau (1998) estimated that between 71 and 84 million tons of soils are eroded from the country's agricultural lands every year. The Updated Philippine National Action Plan (2004) reveals that about 45% of the arable lands in the Philippines have been moderately to severely eroded, triggering the movement of subsistence farmers to marginal lands with the hope of meeting their day-to-day food requirement.

In the Philippines, Cramb, et al. (2000) observed that the rapid population growth and widespread rural poverty induced lowland farmers to migrate into steeply sloping upland areas where their cultivation technique are inappropriate and causes accelerated erosion. And the on-site effects are particularly important on agricultural land where the redistribution of soil within a field, the loss of soil from a field, the breakdown of soil structure and the decline in organic matter and nutrient result in a reduction of cultivable soil depth and a decline in soil fertility (Morgan, 2005).

According to Kinnell (2005), soil erosion is a hydrologically driven process and it depends on sediment being discharged with runoff. Corollary to this, Elbasit et al. (2011) suggested that rainfall represents the major driver of soil detachment in this process. Likewise, Parlak and Parlak (2010) demonstrated that when the falling raindrops hit the soil surface, they detach soil particles and cause them to splash into the air and transported through flowing water. Morgan (2005) added that the continuous exposure to intense rainstorms considerably weakens and loosens the soil.

In 1989, World Bank reported that the estimated on-site soil fertility losses in the Philippines due to unsustainable land management are equal to one per cent of Philippine GDP per year. While Barbier and Bishop (1995), as cited by San and Rapera (2010), estimated that the annual cost of land degradation in developing countries varies from less than one percent to more than 15 % of its gross national product (GNP). Morgan (2005) warned that the on-site costs of erosion may be passed on in part to the community in terms of higher food prices as yields decline or land goes out of production.

Monkayo has an effective single-cropping production area of 1,063 hectares planted with corn from floodplains to higher elevations. Since soil is one of the few resources available for economic exploitation in this municipality, it is therefore timely to reconsider an approach to quantify the severity of erosion on a local scale for more effective soil and water conservation planning as an alternative strategy to address the problem. The objectives of this study are, therefore, to compare the degree of erosion as influenced by the different upland corn planting systems, determine the correlation of soil erosion with the corn yield, and estimate the cost of soil erosion.

MATERIALS AND METHODS

Location and Duration of the Study

As shown in Figure 1, the study area was carried at Palina, San Isidro, Monkayo, Compostela Valley (N $07^{0}49'44.4''$, E $126^{0}59'59.4''$) at a seasonal rainfall in April – July 2013. The nine experimental plots were situated at an altitude of 211 masl up to 220 masl. The slope gradient of all plots was 17.460 (31.45%), soil type is sandy clay loam and strongly acidic with low organic matter content (1.9%), very low phosphorous content (2 ppm) and possibly deficient potassium content (205 ppm).

In the climate map of the Philippines based on modified Coronas classification, the municipality of Monkayo falls under Type IV, which is characterized by a more or less even distribution of rainfall throughout the year. Its average monthly rainfall is 245 mm.

Univ. of Min. Intl. Mult. Res. Jour. vol. 1, no. 1, pp. 182-195
Received: November 5, 2015; Accepted: December 10, 2015; Released: January 15, 2016
www.uminjournals.org

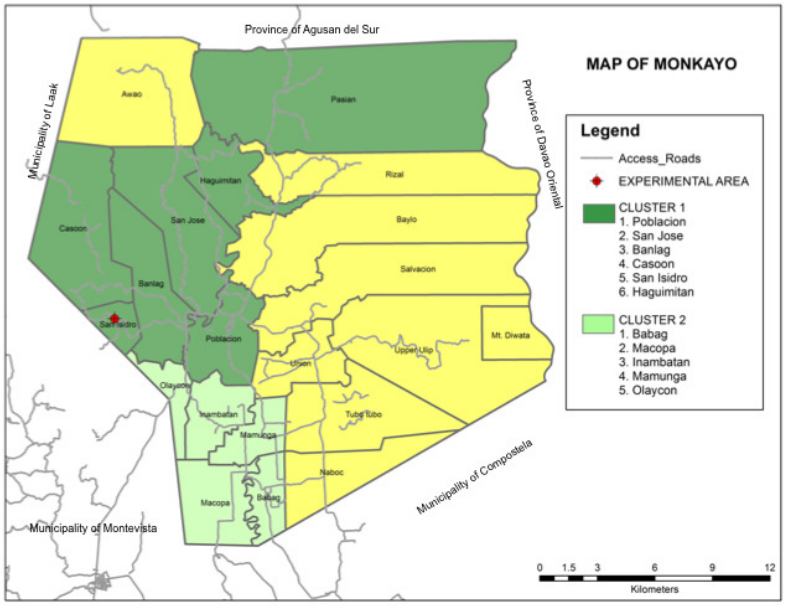

Fig 1. The map of the municipality of Monkayo showing the location of the study area and corn production clusters.

Data Collection

Preparation of the Experimental Area

An area of 108 m^2 along the 31.45 percent slope was initially cleared and 1 m x 2 m soil erosion plot was established within the treated plots as shown in Figure 2 based on Randomized Complete Block Design (RCBD) with three treatments and replicated three times. Each plot was parallel with one another with a distance of 1.5 m. The sides were partitioned with bamboo sticks and demarcated by a solid strip of pre-cast plain galvanized iron sheets around 160 mm high and buried to a depth of 25-30 mm to prevent the entry of soil and runoff water from adjacent areas. As suggested by Ines, et al. (2008), at the end of each soil erosion plot, a collecting drum was positioned to accommodate sediment and runoff peak rain storms with intensity of more than 100 mm/day.

Three tillage systems were considered, natural vegetation, reduced tillage and conventional practice as treatments and were laid out. Corn (*Zea mays*) was

Univ. of Min. Intl. Mult. Res. Jour. vol. 1, no. 1, pp. 182-195
Received: November 5, 2015; Accepted: December 10, 2015; Released: January 15, 2016
www.uminjournals.org

grown in the established plots as the staple food in the barangay. USM Var 10 certified corn seeds were planted along the slope with a planting distance of 70 cm between furrows and 25 cm between hills and labelled according to the experimental layout.

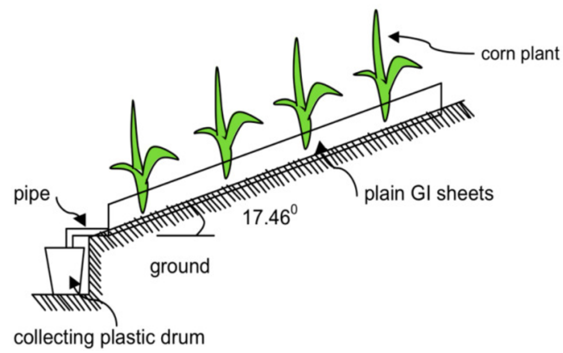

Fig 2. Cross-section of the soil erosion plot.

Erosion Measurement and Prediction

To analyze, evaluate and present the results accurately, measurements of different variables and sets of data were monitored and gathered on a weekly basis. A standard-type non-recording rain gage was installed at the experimental site in gathering rainfall depth following the suggested time for gathering agro-meteorological data at 8 AM daily. As suggested by Ines et al. (2008), after every rainfall, the runoff water together with the displaced soil in the collecting drum was transferred to a transparent plastic bag. The sediments were allowed to sink at the bottom, and then the water was removed until no water remains above the settled sediments (saturated soil). The weight of the settled soil was obtained using a digital weighing scale to represent the actual amount of soil loss for the particular rainfall event. Further, Ordinary Least Square was employed in the generation of soil erosion equations.

The erosion from the study area was also predicted using the Modified Universal Soil Loss Equation (David, 1988) as adapted by . The equation is:

$$E = R \cdot K \cdot L \cdot S \cdot C \cdot P \tag{1}$$

where:

E = soil loss rate in tons/ha/yr
R = rainfall erosivity index value
K = soil erodibility value
LS = length-slope factor which may be approximated on the basis of percent slope
C = cover factor value
P = product of the conservation or management factors being practiced

Comparison of Tillage Systems

The actual yield was gathered and computed to determine the differences between the different tillage systems and determine its mutual relationship with soil loss.

Valuation of Soil Erosion

Estimation of the cost of soil erosion was accomplished indirectly by looking at what cost society has to pay in retaining the land productivity at levels prior to the erosion. As adapted by San and Rapera (2010), the amount of P and K lost due to soil erosion was calculated using the replacement cost in estimating the on-site cost of erosion. The replacement cost method assumed that the on-site cost of soil erosion due to a decline in soil fertility may be estimated by the monetary cost of restoring or replacing the lost soil fertility.

RESULTS AND DISCUSSION

Monkayo has a total land area of 69,289 ha and it is classified as level to hilly with mountainous portions in eastern and western edges of the municipality ranging from 30-50%. Flat areas are mostly situated in the central part of the municipality. Soil erosion is apparent in the hilly areas where siltation in some parts of Agusan River is very evident, especially during the rainy season that causes the diversion of water movement.

Table 1 revealed that the amount of on-site soil sediments collected from each soil erosion plot during a seasonal rainfall (April to July 2013) located under the same slope length and steepness, soil characteristics and rainfall amount and intensities. Therefore, the differences in the soil loss were attributed to the plot treatment only.

Univ. of Min. Intl. Mult. Res. Jour. vol. 1, no. 1, pp. 182-195
Received: November 5, 2015; Accepted: December 10, 2015; Released: January 15, 2016
www.uminjournals.org

Table 1. Soil losses caused by seasonal rainfall (April – July 2013).

EVENT	Rainfall (mm)	ACTUAL SOIL LOSS, (t/ha)		
		Natural Vegetation	Reduced Tillage	Conventional Tillage
1	155	0.0170	0.1778	0.4600
2	159	0.0440	0.0887	0.3037
3	106	0.0730	0.1192	0.1648
4	175	0.0792	0.1988	0.4690
5	118	0.0367	0.0947	0.2693
6	176	0.0365	0.1643	0.3122
7	120	0.0257	0.1080	0.2087
8	113	0.0192	0.1017	0.1608
9	154	0.0163	0.0545	0.1160
10	115	0.0172	0.0477	0.1145
11	103	0.0233	0.0493	0.0803
TOTAL		0.3881	1.2047	2.6593

As gleaned in Table 1, there were 2.66 t ha^{-1} of actual soil losses due to rainfall were weighted on conventional tillage as it incorporated animal drawn plow and harrow to break the soil during land preparation, off-barring and hilling-up, leaving it bare and unprotected during the seedling and vegetative period of the corn and severely affected by erosion due to higher detrimental impacts of raindrop, rainfall intensity and high amounts of runoff causing detachment and transportation of the soil. Some 1.20 t ha^{-1} soil sediments were collected in reduced tillage system where weeds were cleared and corn seeds directly dibbled in uncovered soil surface susceptible to the direct rainfall impact. The lowest soil loss was obtained from natural vegetation with 0.39 t ha^{-1} which grass covers acts as a protective layer or buffer between the atmosphere and the soil (Morgan et al. 1997; Morgan, 2005). Hussain et al. (1998) also attributed that land cover have marked effects on both soil erosion and runoff. Soil loss is closely related to rainfall partly through the detaching power of raindrops striking the soil surface and partly through the contribution of rain to runoff as suggested by Morgan (2005).

David (1988) adapted the six parameters of USLE to Philippine conditions. According to this empirical formula, the annual soil loss of the site was estimated from 0.29 to 2.97 t/ha. The study likewise developed equations to

Univ. of Min. Intl. Mult. Res. Jour. vol. 1, no. 1, pp. 182-195
Received: November 5, 2015; Accepted: December 10, 2015; Released: January 15, 2016
www.uminjournals.org

estimate soil loss (t/ha) on different planting systems using linear regression analysis, to wit: E=-0.0031+0.0003R, E=-0.0406+0.0011R and E=-0.2249+0.0034R. These generated equations used the data on rainfall depth as a factor of soil erosion and also estimate the volume of soil eroded that will serve as a benchmark for policy makers/planners, agricultural extension workers, researchers and farmers.

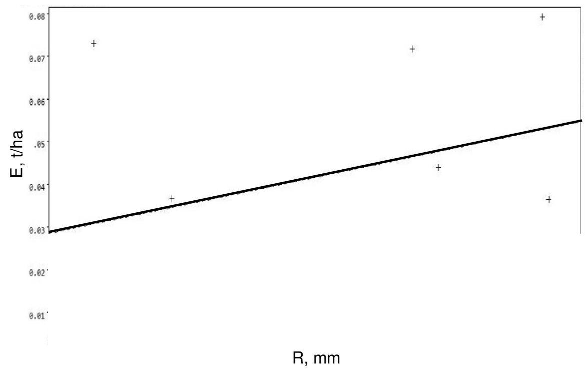

Fig 3. Scatter diagram of rainfall depth as a factor of soil loss for undisturbed land with natural vegetation.

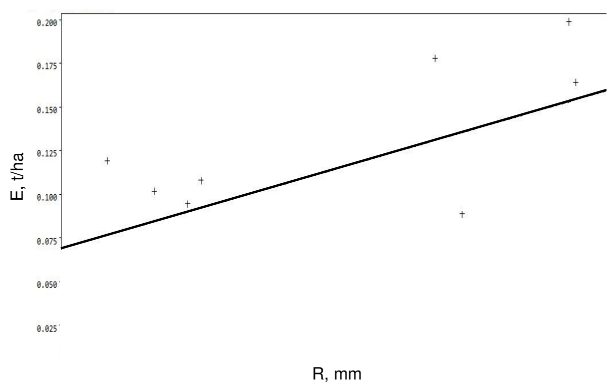

Fig 4. Scatter diagram of rainfall depth as a factor of soil loss for reduced tillage practice.

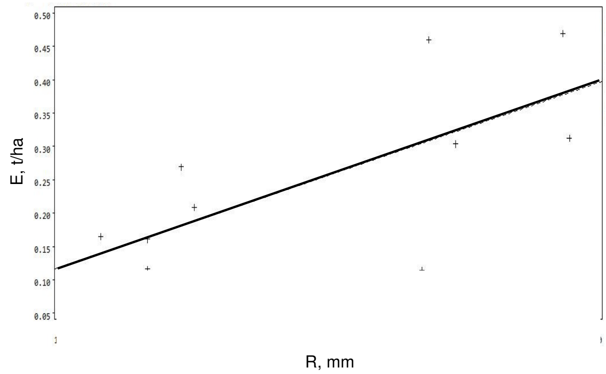

Fig 5. Scatter diagram of rainfall depth as a factor of soil loss for conventional tillage system.

Since MUSLE can be used to compute the total average annual soil loss within a particular location, the soil loss from this erosion feature was calculated to compare with the weighted sediments during April – July 2013 seasonal rainfall. Table 2 displays the true soil loss, the adjusted soil loss was calculated utilizing the generated equations and the results of predicted soil erosion rate. It showed that the adjusted weighted soil sediments of corn planted on natural vegetation and reduced tillage system were higher than the MUSLE with 29% and 43%, respectively.

Table 2. Comparison between the weighted and predicted soil loss.

TREATMENT	ACTUAL SOIL LOSS	ADJUSTED SOIL LOSS	PREDICTED SOIL LOSS
	t/ha		
Natural Vegetation	0.39	0.41	0.29
Reduced Tillage	1.20	1.20	0.69
Conventional Tillage	2.66	2.61	2.97

However, statistical analysis showed no significant difference between the two erosion models. This is an indication that the MUSLE can still be useful tool in the approximation of soil loss because of precipitation and be utilized as a guide rather than being considered absolute values. Moreover, a simple empirical model is often more successful in predicting soil erosion and is usually easier to use (De Roo, 1996; Morgan, 2005).

Univ. of Min. Intl. Mult. Res. Jour. vol. 1, no. 1, pp. 182-195
Received: November 5, 2015; Accepted: December 10, 2015; Released: January 15, 2016
www.uminjournals.org

The maximum on-site soil loss due to seasonal rainfall and as affected by different upland planting systems were perceived at 1.64 t/ha/yr, 4.80 t/ha/yr, and 10.64 t/ha/yr. Soil erosion rate in conventional tillage classified as highly eroded as suggested by Morgan (2005). However, both reduced and conventional tillage systems exceeded the tolerance level of soil annual losses of 3 t/ha, which correspond to the annual rate of soil renewal as suggested by Ailincai (2010).

Comparison of Different Farming Systems

The study harvested 3.089 tons of corn in conventional tiilage system while 0.983 tons of corn was harvested natural vegetation and no other cultural management practices performed. Statistical analysis manifested significant difference among treatment means between corn planted in natural vegetation and conventional tillage system. However, reduced tillage and conventional tillage systems showed no significant difference between treatment means and it means that the corn yield does not vary whether the corn is planted on bare surface or plowed soil.

Moreover, the correlation coefficient measured the strength of the linear relationship between the actual soil loss and corn yield. The coefficient estimates revealed that there is an increase in the soil loss of 0.84 ton/ha on every additional yield made. On the other hand, a reduction of almost 0.36 t/ha in soil loss when no yield is made. Thus, the actual soil loss is highly correlated to the corn yield which also suggested by Schumacher et al. (1999) as adapted by Papiernik et al., (2007) that in undulating landscapes, tillage and erosion can combine to induce large variabilities in soil productivity at the fieldscale.

Table 2. Corn yield as affected by different planting systems.

TREATMENT	YIELD, t/ha			TREATMENT TOTAL	TREATMENT MEAN
	1	2	3		
1	0.991	1.109	0.850	2.950	0.983[b]
2	2.684	2.859	1.488	7.031	2.344[a]
3	2.630	3.450	3.187	9.267	3.089[a]
Replication Total	6.305	7.418	5.525		
Grand Total				19.248	
Mean					6.416

Univ. of Min. Intl. Mult. Res. Jour. vol. 1, no. 1, pp. 182-195
Received: November 5, 2015; Accepted: December 10, 2015; Released: January 15, 2016
www.uminjournals.org

Treatment means with a common superscript are not significantly different from each other at 5% level of significance based on Duncan's Multiple Range Test (DMRT).

Cost Estimation of Soil Erosion

The replacement cost method was employed in estimating the total weights of P and K that were carried away by soil erosion. Based on Table 3, it shows that soil erosion employing conventional tillage costs PhP 1,473.42 to PhP 1,938.81 in terms of nutrient losses. The farm with natural vegetation incurred natural erosion and nutrient losses in lesser degree. This valuation of on-site effects of soil erosion could convince upland farmers to observe soil conserving farming practices.

Table 3. Replacement cost of lost P and K.

TREATMENT	PROJECTED NUTRIENT LOST (ppm/ha/cropping)		REPLACEMENT COST (PhP/ha/cropping)	
	Lost P	Lost K	Lost P (P_2O_5 form)	Lost K (K_2O form)
1	20,000	591,667	231.00	270.00
2	33,333	691,667	796.00	770.69
3	28,333	666,667	1,473.42	1,938.81

CONCLUSION

Soil erosion is a serious threat to the sustainability of agriculture in the Monkayo. At an intensity of rainfall, vegetation and a variety of farmers' practice affects the erosion magnitude of certain sloping undulating land. Soil cover can decrease soil erosion, whose effectiveness can be greatly increased if it is combined with good land management practices. It can be concluded that the establishment of soil erosion plots and MUSLE were an important methodology to quantify soil loss at field level since there was no significant difference between the two empirical models. As an estimate of cost of soil erosion, replacement cost values find their best use as inputs into policy-making regarding soil erosion control.

Univ. of Min. Intl. Mult. Res. Jour. vol. 1, no. 1, pp. 182-195
Received: November 5, 2015; Accepted: December 10, 2015; Released: January 15, 2016
www.uminjournals.org

REFERENCES

Ailincai, C., Jitareanu, G., Bucur, D., & Ailincai, D. (2010). The impact of the cropping systems on yield, erosion and soil fertility in the Moldavian plain. Cercetări Agronomice în Moldova Vol. XLIII , No. 2 (142).

Asio, V. B., Jahn, R., Perez, F. O., Navarrete, I. A., & Abit Jr, S. M. (2009). A review of soil degradation in the Philippines. *Annals of Tropical Research*,*31*(2), 69-94.

Barbier, E. B., & Bishop, J. T. (1995). Economic values and incentives affecting soil and water conservation in developing countries. *Journal of Soil and Water Conservation*, *50*(2), 133-137.

Cramb, R. A., Garcia, J. N. M., Gerrits, R. V., & Saguiguit, G. C. (2000). Conservation farming projects in the Philippine uplands: rhetoric and reality.*World Development*, *28*(5), 911-927.

David, W. P. (1988). *Soil and water conservation planning: policy issues and recommendations* (No. JPD 1988 Vol. XV No. 1-c). Philippine Institute for Development Studies.

De Roo, A. P. J., Anderson, M. G., & Brooks, S. M. (1996). Validation problems of hydrologic and soil-erosion catchment models: examples from a Dutch erosion project. *Advances in hillslope processes: volume 1.*, 669-683.

Elbasit, M. A. A., Salmi, A., Yasuda, H., & Ahmad, Z. (2011). *Impact of Rainfall Microstructure on Erosivity and Splash Soil Erosion Under Simulated Rainfall*. INTECH Open Access Publisher.

Forest Management Bureau (1998). *Philippine forestry statistics*. Department of Environment and Natural Resources, Quezon City, Philippines.

Hussain, I., Olson, K. R., & Siemens, J. C. (1998). *Long-term tillage effects on physical properties of eroded soil. Soil Science, 163(12)*, 970-981.

Ines, R. L., Lacayanga, J. E., Valdez, W. G., Viray Jr, E. A., & Rillon Jr, G. S. (2008). Degree of soil erosion in Bataan [Philippines] upland areas covered with pineapple using different planting system. *Philippine Agricultural Mechanization Journal (Philippines).*

Kinnell, P. I. A. (2005). Why the universal soil loss equation and the revised version of it do not predict event erosion well. *Hydrological Processes*, *19*(3), 851-854.

Lal, R. 2001. Soil degradation by erosion. *Land Degradation and Development* 12: 519-539.

Morgan, R. P. C., McIntyre, K., Vickers, A. W., Quinton, J. N., & Rickson, R. J. (1997). A rainfall simulation study of soil erosion on rangeland in Swaziland.*Soil Technology*, *11*(3), 291-299.

Morgan, R.P.C., Rickson, R.J., McIntyre, K., Brewer, T.R. and Altshul, H.J. (1997). Soil erosion survey of the central part of the Swaziland Middleveld. *Soil Technology* 11: 263–89.

Morgan, R. P. C. (2005). Soil erosion and conservation. National Soil Resources Institute. Cranfield University.

National Action Plan (2010). *The updated Philippine national action plan to combat desertification, land degradation, drought, and poverty (DLDDP) for 2010-2020*. Department of Agriculture, Department of Environment and Natural Resources, Department of Science and Technology, and Department of Agrarian Reform, Manila, Philippines.

Obalum, S. E., Buri, M. M., Nwite, J. C., Watanabe, Y., Igwe, C. A., & Wakatsuki, T. (2012). Soil degradation-induced decline in productivity of Sub-Saharan African soils: The prospects of looking downwards the lowlands with the sawah ecotechnology. *Applied and Environmental Soil Science*, *2012*.

Olabisi, L. S. (2012). Uncovering the Root Causes of Soil Erosion in the Philippines. *Society & Natural Resources*, *25*(1), 37-51.

Oldeman, L. R. (1994). The global extent of soil degradation. *Soil resilience and sustainable land use*, *9*.

Papiernik, S. K., Lindstrom, M. J., Schumacher, T. E., Schumacher, J. A., Malo, D. D., & Lobb, D. A. (2007). Characterization of soil profiles in a landscape affected by long-term tillage. *Soil and Tillage Research*, *93*(2), 335-345.

Parlak, M., & Parlak, A. O. (2010). Measurement of splash erosion in different cover crops. *Turkish Journal of Field Crops*, *15*(2), 169-173.

Reeves, D. W. (1997). The role of soil organic matter in maintaining soil quality in continuous cropping systems. *Soil and Tillage Research*, *43*(1), 131-167.

San, C. C., & Rapera, C. L. (2010). The on-site cost of soil erosion by the replacement cost methods in Inle Lake watershed, Nyaung Shwe Township, Myanmar. *Journal of Environmental Science and Management*, *13*(1).

Schmitt, L. K. (2009). Developing and applying a soil erosion model in a data-poor context to an island in the rural Philippines. *Environment, Development and Sustainability*, *11*(1), 19-42.

Schumacher, T. E., Lindstrom, M. J., Schumacher, J. A., & Lemme, G. D. (1999). Modeling spatial variation in productivity due to tillage and water erosion. *Soil and Tillage Research*, *51*(3), 331-339.

Tujan, A. (1997). *The State of the Philippine environment*. IBON Foundation.