Environmental services of Adlay (*Coix lacryma-jobi* L): a potential agroforestry crop in the uplands

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**Abstract.** This study was conducted to assess the soil erosion rate and soil carbon stock of an adlay (*Coix lacryma-jobi* L.) farming system at varying slope gradients. The study was carried for a 10-month period following the completely randomized design. The erosion rate was measured using an improvised erosion bar, the infiltration by an infiltrometer, and soil carbon was analysed through a laboratory facility. Findings revealed that erosion rates in the adlay farming system are far beyond the tolerable limit. The slope > 20 % had an erosion rate of 66.49 tons ha\(^{-1}\) yr\(^{-1}\) while the gentler slope (< 10%) had only 12.5 tons ha\(^{-1}\) yr\(^{-1}\). Soil carbon stock of the area ranged from 1.684 tons ha\(^{-1}\) to 2.2 tons ha\(^{-1}\) across the slope gradients of the farm. The infiltration rate was also found to be higher in a gentler slope (< 10%) at 106.67 mm hr\(^{-1}\) as against 91.33 mm hr\(^{-1}\) in steeper slope (> 20%). Adlay crop may be planted along areas steeper than 10% slope but this requires minimal tillage to minimize soil erosion. The technologies for soil and water conservation measures need to be adopted by the farmers in steeper areas.

1. **Introduction**

Upland and rolling areas are prone to soil erosion occurrences. Extent of erosion in these areas is influenced by the activities done by the people. Lal and Stewart (1990) [1] reported that erosion rates are high especially on marginal and steep lands that are being converted from forests to agricultural use to replace the already eroded, unproductive cropland. On the other hand, Pimentel *et al.* (1995) [2] revealed that the impacts of erosion are intensified on sloping land, where more than half of the soil contained in the splashes is carried downhill to valleys and waterways.

Sloping land need to have perennial vegetation to reduce soil erosion. However, instead of protecting these areas from soil disturbances, many of the farmers are cultivating sloping lands for livelihood purposes. Crops that need less tilling are indeed appropriate and recommended in these areas. One of these crops is Adlay that is known to have many uses apart from its being an alternative staple crop to the local people. This crop is important not only as food but has also potentials in providing ecological services to a certain farm area/site. Hence, the extent of determining the soil erosion of this crop and its function in soil carbon sequestration is worth investigating and researching.
2. Methodology

2.1. Location of the study
The study was conducted in the old agroforestry farms of the Forest Resources Enterprise Office (FREO) (Figure 1). This is located in the North-western part of Central Mindanao University. It has an elevation of around 430 meter ASL with varied slope gradients.

![Figure 1. Location map of the study](image)

2.2. Establishment of plots and research design of the study
Adlay crop was planted following the standard spacing in various sloping gradients used in the study. The study was conducted for two cropping seasons of which the first cropping was the seed crop and
the second cropping was basically the ratoon crop. The experimental design of the study employed was Complete Randomized Block Design (RCBD) with three treatments replicated three times. The different treatments were as follows:

- Treatment 1: < 10% slope
- Treatment 2: 11% to 20% slope
- Treatment 3: > 20% slope

For each slope treatment, there were three erosion plots that were established that served as replicates.

2.3. Data Collection

2.3.1. Soil Erosion. Soil erosion was measured using a modified erosion bar (Ramirez, 1988 as cited by [3]). The modified method was employed using a 1.5-meter long aluminum bar with 10 holes spaced at 15 cm apart. During data gathering, the bar was laid on predetermined points and rested on top of the Galvanize Iron Sheet bordering on each plots. Measuring pins of identical size and length (1-foot) were inserted in the holes of the bar which were kept lightly rested on the soil surface during measurement.

The soil loss was measured once a month for 10 months. The difference between each measurement served as the amount of soil loss per month.

The data on soil loss per month were converted into tons per hectare by first determining the volume using the formula:

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

The value of soil particle density and bulk density per treatment plot were used to determine the percent solid space. This percent solid space was multiplied by the computed soil volume loss that resulted to the value of solid space (m³). Using the conversion figures formulated by the Range and Management Division of the Ecosystems Research and Development Bureau (ERDB), the volume of solid particles was 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 kilogram

Total erosion in tons per hectare was determined by adding the computed soil loss (tons/ha) of the three particle size distribution (Clay, Silt, and Sand).

2.3.2. Soil organic carbon. Within the established erosion plots, soil samples were collected for soil carbon determination. Soil samples were obtained within the 0-30 cm depth. Soil samples were collected for determination of carbon sequestration in each treatment. The composite soil samples were brought to Laboratery for soil organic matter and bulk density determination.

The result of the soil analysis, specifically soil organic matter content was used to compute the soil organic carbon (SOC) (de la Cruz, nd):

\[
\% \text{SOC} = \% \text{Organic Matter}/1.724; \quad \text{Eq (1)}
\]

In order to express the amount of SOC from percent to tons C/ha, the following formula were used (de la Cruz, nd):

\[
\text{Weight of soil/ha} = 10,000m^2 \times 0.30 \text{ m} \times \text{bulk density}; \quad \text{Eq (2)}
\]

\[
\text{Ton C in soil/ha} = \% \text{SOC} \times \text{wt of soil in kg/ha} \times 1 \text{ ton/1000kg}; \quad \text{Eq (3)}
\]
2.3.3. Infiltration rates. Infiltration rate was measured using a micro-infiltrometer. This was measured in various slope gradient of the study site.

2.3.4. Plant height measurement of the adlay crop. The height of adlay crop was measured monthly upon the measurement schedule of the soil erosion. The height measurement was reckoned from the base of the crop towards the tip of panicle at termination time.

2.3.5. Data analysis. All data gathered were analysed using F-test Analysis of Variance to determine the level of significance among treatments. Significant differences among treatment means were compared using the Tukey’s Honestly Significant Difference (HSD) test.

3. Results and discussions

3.1. Soil erosion of the adlay farm.
The monthly soil erosion rates of the various slope gradients of the adlay farm is shown in Figure 2. The general trend of the soil losses were higher on slope > 20%. The highest erosion rates occurred place on slopes > 20% during the months of December 2017 and June 2018 (Figure 3) as attributed by high amount of rainfall. Rainfall is an agent of erosion and according to Ziadat and Taimeh (2013)[4], rainfall intensity was the most important factor affecting soil erosion and that erosion could occur at a relatively small intensity on wet soils as a result of subsequent rainfall events. Slopes < 10% exhibited lower soil losses compared with the steeper slopes. Kateb et al. (2013) [5] reported that the slope gradient had an impact on the runoff and soil loss: the greater the slope gradient the higher the potential for runoff and soil loss. During the month of May 2018, all slopes showed soil accumulation due to heavy disturbance since was the harvesting period of adlay. The soil was loosened due to trampling may have coincidentally accumulated in the plots.

Figure 2. Monthly erosion rates of the 3 slope gradients

Rainfall was quite abundant during November and December 2017 at 133.8 mm and 236.3 mm respectively. Towards summer, rainfall decreased particularly on March 2018 with only 29.8 mm. Rainfall pattern increased from April 2018 towards August 2018 with highest rainfall on June 2018 (322.1 mm). Erosion was recorded high on slopes > 20%. This finding conforms to the result of [6] who said that higher and longer rainfall events had the most erosive effects. The authors stressed further that rainfall characteristics are decisive for the relative importance of different storm runoff generation mechanisms. [7] also reported that rainfall intensity together with runoff coefficient and slope angle have positive influence on sediment concentration and sediment detachment.
Figure 3. Rainfall data during the whole duration of the study

Figure 4 presents the summary of the erosion rates among the three slope gradients of the study sites. It shows that erosion rate in the slope of > 20% was highest (-66.49 ton ha\(^{-1}\) yr\(^{-1}\)), followed by between 10 – 20% (-29.92 ton ha\(^{-1}\) yr\(^{-1}\)). On the other hand, the least erosion rate was recorded at slope < 10% with -12.5 ton ha\(^{-1}\) yr\(^{-1}\). This finding conforms with that of [8] who stressed that when slope gradient is steep, soil erosion is increasing significantly. [6] also mentioned that bed-load transport by rolling of medium to large-sized sediment particles (coarser than 0.152 mm) was enhanced by increased slope.

Figure 4. Total soil erosion rates of the three slope gradients

Figure 5 shows the heights of adlay crops and ratoon crops. On the first month (November 2017), the adlay had an average height of 18.2 cm the erosion rate was quite high (-104 ton ha\(^{-1}\) yr\(^{-1}\)). The soil
disturbance due to cultivation and the extent of rainfall may have contributed to the high erosion rate. As the crop increased in height, erosion rates decreased conservatively due to crop cover that prevented the impact of raindrops. [9] said that soil erosion can subsequently be controlled by changing land use and increasing the ground cover as one of the basic approaches in controlling soil erosion in all types of land. [10] also reported about the role of vegetative cover in reducing runoff and erosion from rehabilitated mined land. Erosion was greatly reduced by vegetative cover, declining from 30–35 t/ha at 0% vegetative cover to 0.5 t/ha at 47% cover.

In April 2018, erosion rates increased, especially on slope > 20%, despite minimal rainfall. This phenomenon can be attributed to the disturbance and due to loss of soil cover during harvesting.

Infiltration rates among the slope gradients showed significant difference. Slope < 10 % had the highest infiltration rates of 106.67 mm hr⁻¹ (Figure 6). Slope between 10-20% had infiltration rate of 98.33 mm hr⁻¹ but was not significant infiltration rate in slope < 10%. On the other hand, the slope gradient > 20% had the least infiltration rates among the three gradients (91.33 mm hr⁻¹) but did not show significant difference with slope between 10-20%. [11] mentioned that the amount of infiltration was highest at the crest of a slope. However, [12] reported that on steep slopes, the horizontal component of the kinetic energy is transformed into shear stress, hampering the development of crusts so that water can still infiltrate. The researchers added that on steeper slopes, the water film was thinner, thereby limiting the role of such that the relationship between slope gradient and infiltrability depend on the nature of the soil and be examined in terms of surface crusting processes.

![Figure 5. Height of Adlay](image-url)

3.2. Infiltration rates of the three slope gradients of the adlay farm.

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3.3. Soil carbon of the three slope gradients of the adlay farm.
Carbon stocks of the soil in the site ranged from 1.68 to 2.2 ton ha$^{-1}$ (Figure 7). No significant difference was observed among the slope gradients in soil carbon stocks before and after the cropping. Soil carbon stock changed before and after the cropping period of which the slope of 10-20% had a slight increase of 0.27 ton ha$^{-1}$, while the slope < 10% and > 20% had a reduction of -0.002 and -0.005 ton ha$^{-1}$, respectively, however, there was no significant differences among slopes in this parameter. The soil organic matter of the area was just minimal, thus, the soil carbon content also reflected to be of minimal amount. [13] stressed that the amount of soil carbon has something to do with the presence of organic matter in the soil. The adoption of recommended technologies influence the rate of soil organic carbon sequestration but is highly dependent on soil texture and structure, rainfall, temperature, farming system, and soil management. Strategies to increase the soil carbon pool include soil restoration and woodland regeneration, no-till farming, cover crops, nutrient management, manuring and sludge application, improved grazing, water conservation and harvesting, efficient irrigation, agroforestry practices, and growing energy crops on spare lands.

![Figure 6. Infiltration rates of the 3- slope gradients](image-url)
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4. Conclusions

Adlay crop, as an alternative staple food, is being promoted for planting in many parts of the country. It has promising importance to the food and security program, thus made this plant an important commodity for research and development works. This recent study aimed to assess the extent of soil erosion rates of the crop when planted in the farm of various slope gradients and its capacity to store soil carbon. The study had the following conclusions:

1. Due to cultivation practices of the farm, the erosion rates exceeded beyond the tolerable limit. The average soil erosion was recorded highest in the area with a slope of > 20% at 66.49 tons ha\(^{-1}\) yr\(^{-1}\). The slope with < 10% had only an erosion rate of 12.5 tons ha\(^{-1}\) yr\(^{-1}\). The slope gradient influences soil losses and the steeper the slope, the higher is soil movement and loss.

2. Infiltration rate influenced the extent of soil erosion. The area with > 20% had an infiltration rate of 91.33 mm Hr\(^{-1}\) as against the 106.67 mm Hr\(^{-1}\) in a gentler slope (< 10%). The steeper the slope, the lesser would be the possible infiltration rate.

3. Soil carbon in the adlay farm ranges from 1.684 tons ha\(^{-1}\) to 2.2 tons ha\(^{-1}\) across slope gradients but no significant difference on the soil carbon stocks before and after each cropping period. This could be attributed to very minimal soil organic matter content of the area.

5. Recommendations

The finding of the study draws the following recommendations:

1. The planting of adlay in sloping areas (> 10%) requires minimal tillage only to minimize soil erosion rates.

2. Appropriate farming technologies that promote soil and water conservation measures must be considered to reduce extent of soil erosion.

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