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# Erosion Rate in Various Types of Agroforestry in South Tapanuli

Dita Susanty[1*], Yusriani Nasution[2], Sutan Pulungan[3] , Rasmita Adelina[4], Dewi Sartika[5]
Graha Nusantara University Padangsidimpuan
**Corresponding Author:** Dita Susanty : ditasusanty53@gmail.com

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A B S T R A C T
Soil erosion is a serious environmental problem, especially in areas with high rainfall and hilly topography. This process causes the loss of the top layer of soil rich in nutrients, thereby reducing land productivity. Agroforestry as a land use system that combines forestry and agricultural crops is believed to be able to reduce the rate of erosion through increasing vegetation cover. This study aims to determine the rate of erosion in various types of agroforestry in South Tapanuli. The method used is the Universal Soil Loss Equation (USLE) with parameters of rainfall erosivity (R), soil erodibility (K), slope length and slope (LS), land cover factor (C), and conservation factor (P). The results of the research are expected to be the basis for sustainable land management.

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## INTRODUCTION

Soil erosion is one of the most serious environmental problems, especially in areas with high rainfall conditions and hilly topography that are susceptible to surface flows. The erosion process can cause a lack of nutrient content and organic matter, especially in the root area. This condition has an impact on a significant decrease in land productivity, in addition to soil damage due to erosion can trigger various other problems such as salinization, soil saturation by water and degradation of soil physical properties which ultimately interfere with the overall functioning of the soil ecosystem. If not handled properly, soil erosion can accelerate the process of land degradation that is permanent and difficult to recover. Therefore, soil conservation efforts and sustainable land management are needed to minimize the negative impacts of soil erosion.

Erosion is the process of soil erosion by rainwater which results in the loss of the top layer of soil due to surface runoff. The erosion process begins with the destruction of soil aggregate by rainwater droplets into smaller particles (detachments), then these particles will undergo transportation and settle in lower places (deposition). Rainfall is a climatic element that has kinetic energy to the occurrence of surface flow and erosion. Indonesia as a tropical country with high rainfall has a great potential for erosion, especially on land with steep slopes and insufficient vegetation cover. High rain intensity can increase the amount of water that enters the soil in a short period of time so that the water content in the soil quickly reaches a saturated condition. When the soil is saturated, the soil's ability to absorb water is reduced and leads to greater surface runoff, which can carry soil particles and accelerate the erosion process.

The presence of vegetation has an important influence on reducing the rate of surface flow and soil transport. Agroforestry as a land use system that combines forestry crops with agriculture is believed to be able to reduce the rate of erosion through increasing vegetation cover and a more stable soil structure. Agroforestry was developed to improve the quality of natural resources, especially soil and water, improve biodiversity, increase food security and improve community welfare with more sustainable crop yields. This system is also one of the vegetative soil and water conservation techniques that has the potential to reduce soil loss due to erosion.

South Tapanuli is one of the districts in North Sumatra that has implemented an agroforestry development program. This program aims to utilize land without destroying forests and protect ecosystems and biodiversity. Communities in this region have implemented various types of agroforestry such as agroforestry silviculture, silvopastura, and silvofishery to increase economic income. However, there is not much scientific data that shows the extent of the effectiveness of each type of agroforestry in controlling the rate of erosion, especially in the South Tapanuli area.

Based on this background, this study was conducted to find out and compare the erosion rate in various types of agroforestry and analyze the relationship between the type of agroforestry and the rate of erosion that occurs.

The results of this research are expected to be the basis for choosing the most appropriate agroforestry system for soil conservation and sustainable land management in South Tapanuli.

## LITERATURE REVIEW

Soil erosion is the process of transporting or eroding soil particles from one place to another by hydropower or wind. In tropical areas such as Indonesia, the dominant erosion occurs is erosion by rainwater. The erosion process by water begins with the release of soil particles due to the kinetic energy of raindrops that fall to the ground surface. This energy causes soil aggregates to break down into smaller particles. This stage is known as the detachment process. Once the soil particles are released, they will be carried away by the surface flow formed by rainwater runoff. This process is called transportation. Furthermore, the carried soil particles will settle at a lower point when the speed of water flow decreases, known as the deposition process.

The magnitude of erosion is influenced by several main factors, namely rainfall, soil nature, length and slope, land cover, and conservation measures applied. Rainfall is a very important factor because it has kinetic energy capable of destroying soil aggregates. The intensity and duration of rain greatly determine the amount of surface flow that is formed. The higher the intensity of rain, the greater the potential for erosion. In areas with high rainfall, the soil is more often saturated so that infiltration ability is reduced and surface runoff increases.

The physical properties of the soil also greatly affect the level of soil erodibility. The texture of the soil determines the size of the particles that make up the soil, while the structure of the soil determines how the particles are arranged to form aggregates. Soils with good structure and high organic matter content tend to have more stable aggregates so they are more resistant to the detachment process. On the other hand, soils with poor structure and low organic matter content are more susceptible to erosion. Soil permeability also plays a role in determining the speed at which water infiltrates into the soil. Soil with high permeability is able to absorb water faster thereby reducing surface runoff.

The topography of the land, especially the length and slope of the slope, also determines the amount of erosion that occurs. Land with a steep slope has a higher surface flow speed than flat land. The high flow speed increases the carrying capacity of soil particles so that the soil loss becomes greater. The length of the slope also affects the accumulation of the volume of water flowing at the ground level. The longer the slope, the greater the volume of water that accumulates and the greater the potential for erosion.

Land cover is a very important factor in controlling erosion. The presence of vegetation can reduce the kinetic energy of rain that directly hits the ground surface. The plant's crown serves as a natural protector that reduces the intensity of raindrops. In addition, the roots of the plant help to strengthen the soil structure and improve the stability of the aggregate.

The litter that covers the soil surface also plays a role in slowing down the surface flow and increasing water infiltration. Thus, land that has good vegetation cover tends to have a lower erosion rate than open land.

Agroforestry is a land use system that combines forestry crops with agricultural crops in one land management unit. This system was developed to increase land productivity in a sustainable manner while preserving natural resources. In agroforestry systems, the combination of perennials and annuals creates a more diverse and layered vegetation cover. The presence of trees in this system serves to increase water infiltration, improve soil structure through the root system, and reduce the speed of surface flow. With this combination, agroforestry systems have greater potential to reduce the rate of erosion than monoculture farming systems.

To estimate the magnitude of soil loss due to erosion, one of the commonly used methods is the Universal Soil Loss Equation (USLE). This method calculates soil loss predictions based on rainfall erosivity (R), soil erodibility (K), slope length and slope (LS), land cover factor (C), and conservation action factor (P). The USLE model is used because it is able to provide an estimate of soil loss based on real conditions in the field by considering the main factors that cause erosion. By using this method, it can be known the magnitude of erosion rates in various types of agroforestry so that the effectiveness of each system in controlling erosion can be compared.

Based on this description, it can be understood that the interaction between climatic factors, soil characteristics, topography, land cover, and conservation actions determine the amount of erosion that occurs. Therefore, the implementation of proper agroforestry systems and good land management is needed to reduce the risk of land degradation due to erosion, especially in areas with high rainfall and hilly topography such as South Tapanuli.

## METHODOLOGY

This research was carried out in the South Tapanuli area on various types of agroforestry that have been applied by the community. The selection of research locations was carried out purposively by considering the existence of different types of agroforestry and land conditions that represent the characteristics of the research area. The types of agroforestry observed include agroforestry silviculture, silvopasture, and silvofishery. Each type of agroforestry has a different combination of vegetation and land management systems so that it is possible to make comparisons with the rate of erosion that occurs.

The research method used is a survey method with direct observation in the field and soil sampling to be analyzed in the laboratory. Field observations were carried out to obtain data on the condition of land cover, the type of vegetation growing, land management practices, and topographic conditions such as the length and slope of the slope. Slope slope measurement is carried out to determine the level of land steepness that affects the speed of surface flow. The length of the slope is also measured to determine the distance of water flow from the top to the bottom of the land.

Soil sampling was carried out on each type of agroforestry to determine the physical properties of the soil that affect erodibility. The obtained soil samples are then analyzed in the laboratory to determine soil texture, soil structure, permeability, and organic matter content. The data is used to calculate the value of the soil erodibility factor (K). The texture of the soil determines the size of the particles that make up the soil, while the structure of the soil indicates the level of aggregate stability. Soil permeability indicates the ability of the soil to pass water, and the content of organic matter plays a role in increasing the stability of soil aggregates.

Secondary data in the form of rainfall data was obtained from related agencies that provide annual rainfall records in the study area. The rainfall data is used to calculate the rain erosivity factor (R). High rainfall with great intensity has the potential to increase the kinetic energy of raindrops and increase the likelihood of surface runoff.

The calculation of the erosion rate is carried out using the Universal Soil Loss Equation (USLE) method with the equation:

$$A = R \times K \times LS \times C \times P$$

where A is the prediction of soil loss in tons per hectare per year, R is the factor of rainfall erosivity, K is the factor of soil erodibility, LS is the factor of length and slope of slope, C is the factor of land cover, and P is the factor of conservation action.

The LS factor is calculated based on the length and slope data obtained from measurements in the field. Factor C is determined based on the type and density of vegetation present in each type of agroforestry. A denser vegetation cover will result in a smaller C value because it is able to protect the soil surface from rain energy and reduce surface runoff. The P factor is determined based on the soil conservation practices applied, such as contour-following planting and ground cover maintenance.

After all factors are calculated, the erosion rate value (A) is obtained by multiplying all factors in the USLE equation. The results of the calculation are then compared between types of agroforestry to find out the difference in the rate of land loss. The data obtained were analyzed descriptively to explain the relationship between the type of agroforestry and the magnitude of the erosion rate that occurred.

Through this method, the research aims to provide an overview of the effectiveness of various types of agroforestry in controlling erosion and become a basis for choosing a more sustainable land management system in the South Tapanuli area.

## RESEARCH RESULT AND DISCUSSION

The results showed that the erosion rate in various types of agroforestry in South Tapanuli varied depending on vegetation conditions, slope slopes, physical properties of the soil, and conservation practices applied.

The difference was obtained from the results of calculations using the Universal Soil Loss Equation (USLE) method which took into account the factors of rainfall erosivity (R), soil erodibility (K), length and slope (LS), land cover factor (C), and conservation action factor (P). Each factor contributes to the magnitude of land loss that occurs in each type of agroforestry.

The rain erosivity factor (R) obtained from rainfall data shows that the South Tapanuli area has a fairly high erosion potential. Heavy rainfall increases the kinetic energy of raindrops that can destroy soil aggregates and accelerate surface runoff. When the soil receives a large amount of rainfall in a short period of time, the soil quickly reaches a saturated condition so that the infiltration ability decreases and surface runoff increases. This condition causes soil particles to be more easily detached and carried away by the flow of water. However, the presence of vegetation in agroforestry systems is able to reduce the direct impact of rain energy through the protection of canopies and litter that covers the soil surface.

The soil erodibility value (K) obtained from the results of laboratory analysis showed that there were variations in each research site. The difference in K values is influenced by soil texture, soil structure, permeability, and organic matter content. Soil with a higher content of organic matter has a more stable structure so that it is more resistant to erosion processes. In the type of agroforestry that has more litter accumulation, the content of soil organic matter is relatively higher so that the K value is lower. This shows that agroforestry systems not only play a role as land cover, but also improve the physical properties of the soil which affects the resistance of the soil to erosion.

The length and slope (LS) factors exert considerable influence on the rate of erosion. Land with steeper slopes has a higher surface flow speed which increases the transport capacity of soil particles. The longer the slope, the greater the accumulation of the volume of flowing water and the greater the potential for soil loss. However, in agroforestry systems that have a combination of annual and seasonal crops, the presence of plant roots helps to strengthen soil structure and increase water infiltration, so that the impact of slope slopes on erosion can be reduced.

The land cover factor (C) is one of the most decisive factors in erosion control. The results showed that agroforestry types with denser vegetation cover had lower C values compared to types with less sparsely populated vegetation. A low C value indicates the ability of vegetation to protect the soil from rain energy and reduce surface runoff. The plant's crown serves as a protector that reduces the intensity of rain that directly hits the soil, while litter helps to increase infiltration as well as reduce the speed of surface flow.

The conservation action factor (P) reflects the land management practices applied at the research site. In land that applies conservation techniques such as contour planting and ground cover maintenance, the P value is relatively smaller, so the erosion rate can be suppressed. On the other hand, on land that pays less attention to conservation techniques, the P value tends to be greater so that land loss increases.

This shows that the success of agroforestry systems in controlling erosion is not only determined by the type of vegetation, but also by the land management practices carried out.

When compared between types of agroforestry, systems with predominantly woody plants and denser vegetation cover show lower erosion rates. In silvicultural agroforestry, the presence of perennial plants with a deeper root system provides long-term protection of the soil. In silvopasture systems, livestock activities on some parts of the land can affect soil density and increase surface runoff, so the erosion rate tends to be higher than systems with more stable vegetation cover. Meanwhile, in silvofishery systems, the effectiveness of erosion control is highly dependent on the vegetation conditions around the water area and the land management practices applied.

Overall, the results showed that agroforestry types with denser vegetation cover and better conservation practices had lower erosion rates than other types. This proves that the agroforestry system plays an effective role in soil conservation and sustainable land management in South Tapanuli. With the proper implementation of agroforestry systems and appropriate land management, the potential for land degradation due to erosion can be significantly reduced.

## CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the study, the rate of erosion in various types of agroforestry in South Tapanuli shows differences influenced by land cover factors, length and slope slope, physical properties of the soil, and applied conservation practices. Calculations using the Universal Soil Loss Equation (USLE) method show that factors C and LS have a considerable influence on soil loss. Agroforestry types with denser vegetation cover and more complex root systems have lower erosion rates than types with less vegetation cover. The presence of vegetation in agroforestry systems has been proven to be able to increase water infiltration, improve soil structure, and reduce the speed of surface flow so that it plays an effective role in controlling erosion.

Therefore, the development of agroforestry systems with a combination of annual and annuals and the implementation of soil conservation practices needs to be improved as an effort to sustain land management in South Tapanuli. Counseling and assistance support to the community is also needed to increase the effectiveness of the implementation of agroforestry systems in reducing the rate of erosion.

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