The Rainfall Erosion Rate Analysis and Conservation Plan in the Catchment Area of Hera, Dili, Timor-Leste

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ABSTRACT

This study aims to assess the level of land erosion due to rainfall and analyze conservation efforts in the Hera area, Dili, Timor-Leste, using a combination of USLE models, Geographic Information Systems (GIS), and field surveys. The total area is around 14 hectares and the landscape area has surrounding by mountain in the south part. Based on the Topography survey, the slope area is ranging from 2-40%. The results showed that the application of vegetation can reduce the erosion rate by up to 90%, which has a positive impact on soil fertility, water quality, and infrastructure protection. However, the long-term effectiveness of this method can be affected by variations in soil conditions, climate, and socio-economic constraints. This study underlines the importance of further studies to identify optimal vegetation types, evaluate long-term impacts, and consider integration with other conservation methods and climate change scenarios. Adaptive and sustainable conservation strategies are needed to reduce erosion and support environmental sustainability in the catchment area of Hera.

Keywords: Erosion, Rainfall, Soil Conservation, Hera Catchment Area, USLE Model

1. Introduction

Land erosion is a significant environmental issue that can impact soil fertility, water quality, and infrastructure stability. Soil erosion disasters occur in various locations around the world, particularly in areas with steep topography, easily erodible soils, and high rainfall. Regions vulnerable to soil erosion include mountainous areas, deforested hillslopes, and poorly managed agricultural lands (Bryant, 2005). Countries vulnerable to soil erosion include (Crozier and Glade, 2005) the United States, particularly in the Appalachian Mountains, California, and the Pacific Northwest. Erosion and landslides often occur due to a combination of high rainfall and earthquakes. In Italy, the Alpine and Apennine Mountain regions frequently experience landslides, especially during the rainy season. In Japan, landslides occur in mountainous areas and hillslopes due to the high frequency of earthquakes and heavy rainfall. In Indonesia, high rainfall and significant seismic activity cause landslides on various islands, including Sumatra and Java. In China, the Sichuan and Yunnan regions are prone to landslides because of the combination of high rainfall and earthquakes. The impacts of soil erosion include socioeconomic effects such as material losses, displacement of populations due to loss of homes, and reduced agricultural productivity, which poses a threat to food security(Petley, 2012; Schuster and Highland, 2007). Environmental impacts include land degradation, sedimentation, and loss of biodiversity, which disrupt ecosystems. Health impacts involve contamination of water sources with sediment and pollutants, and the risk of disease outbreaks in affected areas (Crozier and Glade,

2005; Murillo-García et al., 2017; Petley, 2012; Schuster and Highland, 2007).

Timor-Leste is vulnerable to a variety of natural hazards, including soil erosion and land degradation which are exacerbated by climate change. The country's topography, combined with deforestation and unsustainable land practices, leads to increased susceptibility to erosion, landslides, and flooding (Beazley et al., 2023). The loss of vegetation is a significant factor contributing to pollution, erosion, and sedimentation in Timor-Leste. The deforestation and slash-and-burn practices leave the soil exposed and susceptible to erosion during heavy rains. Areas around densely populated regions such as Dili, Baucau, and Ermera are particularly affected, experiencing higher rates of forest loss compared to the rest of the country (GEF, 2016). Erosion in the upland areas leads to sedimentation downstream, impacting river systems and coastal areas. This sedimentation degrades water quality, which negatively affects aquatic life in rivers and coastal ecosystems, ultimately food security for the people of Timor-Leste (Beazley et al., 2023; GEF, 2016). Research indicates that by 1999, forest cover had drastically reduced to only 12%, while 24% of the land had been converted to agricultural use, 22% to degraded woodland, and 19% to woodland. During Indonesian occupation period, the global deforestation rate was approximately 0.3% per year, whereas in Timor-Leste, it was significantly higher at 1.1% per year (Bouma and Kobryn, 2004; GEF, 2016).

Timor-Leste experienced a significant rainfall event from March 29 to April 4, 2021, which triggered widespread flash floods and landslides, affecting all 13 municipalities to varying degrees. The capital, Dili, and its nearby low-lying areas bore the brunt of the devastation.

Approximately 31,337 households were affected, with 83% of them (25,928 households) located in Dili municipality. Furthermore, around 2,163 hectares of agricultural land were affected, posing a threat to food security in the upcoming lean season (Red Cross of Timor Leste, 2020; UNICEF, 2021). Land erosion which impacted from high intensity rainfall is a serious problem that can increase the risk of disasters such as landslides and floods. Therefore, to overcome land erosion, several approaches proposed in the literature include the application of soil and water conservation techniques, the use of ground cover vegetation, appropriate land use planning, as well as public education and awareness about sustainable practices (Crozier and Glade, 2005).

This research aims to assess the level of land erosion due to Rainfall and to analyze conservation efforts in the Hera catchment area. By using a combination of USLE model, Geographic Information Systems (GIS), and field surveys, this research is expected to provide a comprehensive picture of the dynamics of land erosion and the effectiveness of conservation efforts that have been implemented. This study is important because its findings can be the basis for formulating more effective and sustainable land management strategies. Additionally, a better understanding of erosion patterns and contributing factors can help governments and other stakeholders design policies that reduce the negative impacts of erosion and support soil and water conservation. Therefore, this research not only contributes to the scientific understanding of soil erosion but also offers practical benefits for environmental management and policy development in Timor-Leste.

2. Literature Review

Land erosion, a critical environmental issue, significantly impacts soil productivity, water quality, and ecosystem health. Understanding the factors contributing to land erosion and implementing effective conservation strategies are essential for sustainable land management, especially in vulnerable regions such as the catchment area of Hera, Dili, Timor-Leste.

2.1.1. Factors Influencing Land Erosion
a) Topography and Soil Characteristics

Land erosion is heavily influenced by topographical features and soil properties. Slope in 15°~35° slope area has significant effects on soil erosion. Steep slopes increase the velocity of surface runoff, which enhances the erosive force on the soil surface (Wu and Wang, 2011). Soil texture, structure, and organic matter content also play critical roles in determining soil erodibility. Sandy soils, for example, are more prone to erosion due to their loose structure, whereas clayey soils can resist erosion better (Morgan, 2005). The impact of climatic patterns on soil erosion in Timor-Leste, focusing on rainfall intensity and seasonal variability (ADB, 2021; Beazley et al., 2023). The monsoonal climate, characterized by intense rainfall

during the wet season, exacerbates erosion risks. The climate influences erosion processes and underscores the necessity for adaptive conservation strategies that account for seasonal changes (ADB, 2021). Timor-Leste is located about 500 km from northern Australia in the Lesser Sunda Islands and includes the eastern half of Timor Island. Timor-Leste has a slope of 40% or more. The soil in Timor-Leste comes from limestone and marine clay which have undergone metamorphosis so that it has low fertility and is fragile. Steep slopes are mostly covered by thin soils that have low organic matter and limited water retention capacity. Infrequent but heavy rainfall often causes flash floods, washing away the top layer of soil and leaving large areas of sloping land vulnerable to erosion and unsuitable for sustainable agriculture (Beazley et al., 2023; NAP UN, 2008).

b) Climate and Rainfall Patterns

The intensity and distribution of rainfall are pivotal in erosion processes. High-intensity rainfall events can cause severe erosion by detaching and transporting soil particles. Timor-Leste experiences a monsoonal climate with distinct wet and dry seasons, rainfall varies from as low as 500 mm/annum along the northern coast to as high as 2000 mm/annum in mountains, which leads to varying erosion rates throughout the year (Beazley et al., 2023). The correlation between rainfall intensity and erosion highlights the importance of considering climate variability in erosion studies (Rodrigo-Comino et al., 2020).

c) Land Use and Vegetation Cover

Land use changes, such as deforestation and agricultural expansion, significantly affect erosion rates. Vegetation plays a crucial role in stabilizing soil through root systems that bind soil particles together and canopy cover that reduces the impact of raindrops on the soil surface. Studies have shown that areas with dense vegetation cover experience lower erosion rates compared to barren lands (Morgan, 2005; Wu and Wang, 2011). Another research examined the role of vegetation cover in mitigating soil erosion and demonstrated that areas with dense vegetation experience significantly lower erosion rates compared to barren or sparsely vegetated lands (Vanacker et al., 2007). This study supports the implementation of reforestation and agroforestry practices in erosion-prone areas like Hera to enhance soil stability.

2.1.2. Conservation Strategies
a) Structural Measures

Structural measures include physical constructions like terraces, check dams, and contour bunds designed to reduce runoff velocity and capture sediment. These measures are particularly effective in hilly regions with high erosion risks (K., 2011). This study supports the adoption of terracing in the Hera region to mitigate erosion and enhance agricultural productivity.

b) Vegetative Measures

Reforestation and agroforestry are key vegetative measures for erosion control. Planting trees and shrubs can significantly reduce erosion by enhancing soil stability and increasing water infiltration. The research in the Comoro watershed, Dili has the opportunity to be easily affected by land erosion (very critical). However, after carrying out watershed conservation efforts using vegetative methods and mechanical methods, the erosion yield obtained low value, which means that the areas in the Comoro watershed have little chance of being affected by erosion land (Gomes, 2021). This study provides a practical approach to balancing land use demands with environmental protection in the Hera catchment area.

c) Management Practices

Sustainable land management practices, such as crop rotation, cover cropping, and conservation tillage, are vital for minimizing soil disturbance and maintaining soil health. Integrating these practices into local agricultural systems can help reduce erosion and improve long-term land productivity (Lai, 2001; Scholten and Seitz, 2019). This study underscores the importance of integrating sustainable agricultural practices into local farming systems to achieve long-term soil conservation.

2.1.3. Erosion Modeling and Assessment Techniques

Erosion modeling is essential for predicting erosion risks and planning conservation measures. Various models, such as the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE), are widely used to estimate soil erosion. These models consider factors like rainfall, soil type, topography, crop management, and conservation practices (Renard et al., 1997). The Universal Soil Loss equation is:

$$A = R \times K \times LS \times C \times P \qquad (1)$$

where **A** is the computed soil loss per unit area in tons per acre per year, but other units can be selected. **R** is the number of rainfall erosion index units, plus a factor for runoff. **K** is the soil erodibility factor. **L** is the slope-length factor. **S** is the slope-steepness factor, is the ratio of soil loss from the field slope gradient. **C** is the cover and management factor, **P** is the ratio of soil loss with a support practice like contouring, strip-cropping, or terracing to that with straight-row farming up and down the slope.

2.1.4. Rainfall Erosion Index (R)

The USLE equation determines that the R value is the annual destructive power of rain (rain erosion). Rain erosivity is the product of total rain energy (E) and maximum rain intensity in 30 minutes (I30) (Morgan, 2005). The relationship between soil loss and these parameters is linear, and the individual storm values are directly additive. The total El value of a storm in a certain period is a numerical measure of the erosion potential of rainfall in that period. The total annual average storm El value in a particular region is the rainfall erosion index for that region (Renard et al., 1997). To calculate rain

erosivity on land, various formulas can be employed. This study utilizes the formula developed by Lenvain, as it requires only monthly rainfall data (Renard et al., 1997; Sinaga et al., 2011). To determine erosivity, average monthly rainfall data spanning 10 years is necessary. The equation as follow

$$R_m = 2,21 \, Rain_m^{1,36} \qquad (2)$$

$$R = \sum_{m=1}^{12} Rm \qquad (3)$$

Where R_m is erosivity monthly rainfall; $Rain_m$ is monthly rainfall in cm; R is erosivity annual rainfall and m is month.

2.1.5. Soil Erodibility Index (K)

Soil physical properties such as texture, organic matter percentage, structure, and permeability significantly impact soil erodibility (Cen et al., 2022; Hua et al., 2019; Morgan, 2005). Soils with low erodibility typically have a low proportion of fine sand and dust, high organic matter content, good structure, and high infiltration rates (Lai, 2001; Lal et al., 2017). The soil erodibility index is determined for each land unit and requires data on soil particle size, organic matter percentage, soil structure, and permeability (Lai, 2001; Scholten and Seitz, 2019). This data should ideally come from laboratory analysis of soil samples taken from the field or from soil survey reports accompanying soil maps.

The K value, which represents soil erodibility, can be estimated using a nomograph. Generally, the K value estimated with a nomograph closely approximates the actual field value (Renard et al., 1997). The soil erodibility nomograph used is based on Wischmeier (1971), and modified according to Hamer (1980) (Renard et al., 1997). This nomograph incorporates factors like soil structure, permeability, and organic matter. Alternatively, to create an initial K estimate using the K-nomograph method, which is estimate using the equation as follow: .

$$K = [\,2,71 \times 10^{-4}\,)(12 - OM) \times M^{1.14} + 4.20\,(\,s\text{-}2\,) + 3.23\,(p\text{-}3)]\,/\,100 \qquad (4)$$

Where, K is soil erodibility; OM is percentage of organic matter (% C x 1.724); M is the grain size parameter obtained from (% dust + % very fine sand) (100 - % clay); s is the soil structure code and p is the soil permeability class.

2.1.6. Length-Slope Factor (LS)

Both the length and the steepness of the land slope substantially affect the rate of soil erosion by water. The two effects have been evaluated separately in research and are represented in the soil loss equation by L and %, respectively (Renard et al., 1997; Sinaga et al., 2011) . In field applications, however, considering the two as a single topographic factor, LS, is more convenient. The slope and length of sloping areas can be determined using topographic maps (Cen et al., 2022). Both the length (L) and slope (S) of a sloping area affect the amount of soil

lost due to erosion. The LS factor is the ratio between the soil lost from a plot with a certain value of length and slope. The LS value can be determined by the formula:

$$LS = \left(\frac{L}{22.1}\right)^{0,6} \times \left(\frac{S}{g}\right)^{1,4} \qquad (5)$$

where: LS is the slope factor (m); L is the length of the slope (m); S is the slope and g is gravity (m/sec)

2.1.7. Cover and Management Factor (C)

This factor represents the effect of crops and land management on erosion. Factor C describes the level of protection provided by soil cover (such as vegetation) against rain erosion (Renard et al., 1997; Yang, 2006). The C factor value ranges from 0 to 1. A value of 0 means the land is completely protected and no erosion occurs, while a value of 1 means the land is not protected at all and maximum erosion occurs. Low values of C (0 to 0.1) are usually associated with good vegetation cover, such as undisturbed forest or grassland. High values of C (0.5 to 1) are usually associated with exposed fields or intensive tillage. The C factor value can be obtained through research or reference from tables that classify various types of crops and land management practices (Xiong et al., 2023).

2.1.8. Support Practice Factor (P)

The P factor in the USLE (Universal Soil Loss Equation) method is a plant management factor or conservation practice factor. The P factor is the ratio of soil loss from land with certain conservation measures to soil loss from land cultivated up and down slope (Morgan, 2005; Yang, 2006). The P factor describes the effect of soil conservation activities in reducing the amount and speed of surface runoff and erosion. The P value ranges from 0 to 1. A P value = 1 indicates there is no conservation action, while a P value < 1 indicates the better the conservation action implemented (Renard et al., 1997). Conservation practices generally are cropping strips, contour cropping, bench terracing, ridge terracing. Determination of the P value is determined based on the type of conservation practices implemented in the field. if no terracing, contour tillage, or contour strip-cropping are used, then the P factor would be 1 or could be omitted from the calculation for simplicity. The P factor is an important component in USLE because it describes human efforts to control erosion through soil and water conservation practices.

2.1.9. The Performance of USLE Model

The Universal Soil Loss Equation (USLE) method is an empirical model used to predict soil erosion due to rainwater. The advantages of the USLE method is USLE uses relatively simple equations and variables that are easy to measure and easy to apply in the field (Renard et al., 1997). USLE model has successfully been applied to various countries and climatic conditions therefore it has a lot of supporting data and empirical validation (El Jazouli et al., 2017; Gomes, 2021; Morgan, 2005; Vrieling, 2006; Wu and Wang, 2011). Furthermore, USLE was developed from extensive empirical data (Wischmeier, W. H., & Smith, 1978) and its parameters can be adjusted for a variety of local conditions, including soil type, topography, and land management practices (Morgan, 2005). Despite the advantages of the USLE model, there are also several disadvantages, including being unable to capture the temporal and spatial dynamics that often occur in erosion processes, such as changes in rainfall or changes in land use (Benavidez et al., 2018; Renard et al., 1997). These models require fairly detailed and accurate data on factors such as rainfall, soil type, slope, slope length, vegetation, and land management practices, which are not always available (Benavidez et al., 2018; Kinnell, 2010; Wischmeier, W. H., & Smith, 1978).

3. Research Methodology
3.1. Location and Data
3.1.1. Study Area

The research located in Hera that part of Dili Municipality. The research location is planned to build a new building intended for the convent of the sisters as shown in the Figure 1. The total area is 14 hectares with coordinate located 125.675 E; -8.549 S. The elevation of location is 26.227 msl. The climate of Hera is tropical, with a wet season running from December to March and a distinct dry season for the remainder of the year. Mean monthly temperatures range from about 21°C in December to about 26°C in August.

The geology of the study area consists of metamorphic rocks from the Permian Protolith and Quaternary alluvial deposits. Geological mapping in the field, identified various lithologies distributed throughout the area. Metamorphic rocks, such as schist with soil cover and meta-igneous rocks with lateritic soil, are exposed in the uphill regions, while the foothill areas are characterized by alluvial deposits. Based on the field investigation, several locations were identified with occurrences of landslides, areas of easily eroded soil, and soil cover on steep slopes. The region also includes steep rock slopes prone to rockfalls, rapid sediment-laden flows during heavy rainfall, and instability of soil and rocks due to high slope gradients.

3.1.2. Data

The data used in this study are climate data, topography data, land use data/land cover and geological data. The rainfall data from rainfall station around Hera and considered give a contribution of rainfall in location. The
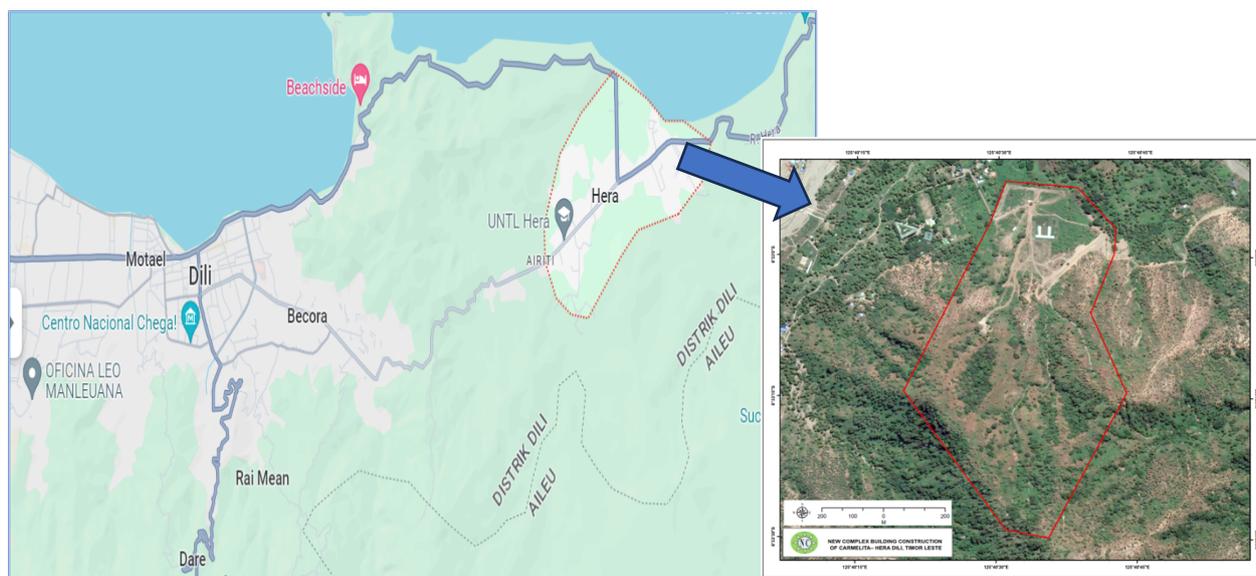
Figure 1. Localization of Research area (Google Map, 2022 and Niceles Lda. 2023)

rainfall data was taken from the 2 nearest rainfall stations from the project area: Dili Station, and Remexio Station. The rainfall stations data provide daily rainfall data of 13 years, from 2010 to 2022. The rainfall data to identify rainfall patterns and the total volume of rainwater falling in the catchment area. Rain Intensity data helps in analyzing the potential for heavy rain that impacting to severe erosion. High intensity rain tends to produce greater surface runoff and increasing the risk of erosion. Temperature and Humidity data was taken from Dili meteorological station. The data helps understand local climate conditions that influence evaporation rates and soil moisture, which impacting to soil stability and erosion rates.

Identify the slope of the land through the Topographic Maps that was established through Topographic survey in the study area. The slope of the land which is a major factor in determining the rate of erosion. The soil type data was defined through the geological and geotechnic survey in the location of study. Geology and Stratigraphy information provides an overview of the soil layers and bedrock, which helps in understanding soil structure and the erosion potential of the various layers.

The Hydrological data such river flow, land use and water quality were determined during the observation and from some of hydrology report in Dili. River flow data is needed to study water flow patterns in the catchment area. Land use information helps in assessing the impact of human activities, such as agriculture and urbanization, on soil erosion. Land cover such as vegetation plays an important role in reducing erosion by slowing surface runoff and holding soil. Information about vegetation type and density helps in assessing the effectiveness of vegetation in reducing erosion. Water quality data is used to identify the impacts of erosion on water quality in the catchment area, such as increased sedimentation and pollution.

The Community Land Use and Policies and Regulations was determined during the social survey and some information taken from the regulation and policy document of Timor Leste. This is important in planning sustainable conservation interventions. Information on policies and regulations provides guidance on the legal and policy framework that supports land and water conservation efforts. Conservation plan as an information provides insight into. Knowing the conservation techniques used, such as terracing, planting barrier vegetation, and creating drainage channels, helps in formulating effective conservation plans to reduce erosion.

3.2. Methodology

Erosion modeling is essential for predicting erosion risks and planning conservation measures. Various models, such as the Universal Soil Loss Equation (USLE) is widely used to estimate soil erosion. These models consider factors like rainfall, soil type, topography, crop management, and conservation practices (Renard et al., 1997). This study provides a valuable tool for assessing erosion risks and planning conservation measures in this landscape. Remote sensing and Geographic Information Systems (GIS) have enhanced erosion assessment by providing spatial data and facilitating the analysis of erosion patterns over large areas (Vrieling, 2006). The process of analysis as shown in the Figure 2.

3.2.1. Field Data Collection

Field survey was done to identify data collection locations based on topographic representation, soil type,

and land use. The rainfall measurement to collect rainfall data from local weather stations or other data sources. Soil sampling was taking at various locations for laboratory analysis of soil texture and structure. The topographic measurement has done to measure the slope and length of the slope using topographic survey tools and GIS data. The vegetation observation to documented the type and density of vegetation in the study area. For the conservation analysis through the evaluate land management practices by identify and record land management practices implemented, such as terracing or use of ground covers.

3.2.2. USLE Factor Analysis

The factors of USLE include R (Rainfall Erosivity Factor) Uses rainfall data to calculate rain erosivity based on a predetermined formula. K (Soil Erodibility Factor) Calculates soil erodibility based on laboratory analysis of soil texture, organic content, soil structure and permeability. LS (Slope Length and Steepness Factor) Calculates the slope length and steepness factor using topographic data. C (Cover and Management Factor) is determining land cover and management factors based on vegetation type and density. P (Support Practice Factor) is to determines soil management practice factors based on conservation techniques applied in the research area. Data Processing and Analysis Entering the collected data into the USLE formula. Evaluation of Results is to Analyze results and identify areas that require conservation intervention.

3.3.3. Development of a Conservation Plan

The development of a conservation plan in this research requires more detailed and specific steps to ensure that the solutions implemented are effective in reducing soil erosion. Identification of conservation techniques based on the results of the analysis, identify suitable conservation techniques for areas with high levels of erosion. Implementation planning is planning steps to implement conservation techniques such as terracing, planting buffer vegetation, and building erosion control structures. Evaluation is to evaluate the effectiveness of proposed conservation plans.

4. Result and Discussion
4.1. Field Observation

Hera is a village located in the Dili District of Timor-Leste, approximately 10 kilometers east of Dili, along the northern coast of Timor-Leste. In 2015, the total population was 8,853 (TLCensus, 2016) with area 41.24 km². Hera has a mix of rural and semi-urban populations, with many residents involved in agriculture, fishing, and small-scale trading. Hera's location near the capital city makes it strategically important for various development projects and administrative purposes.
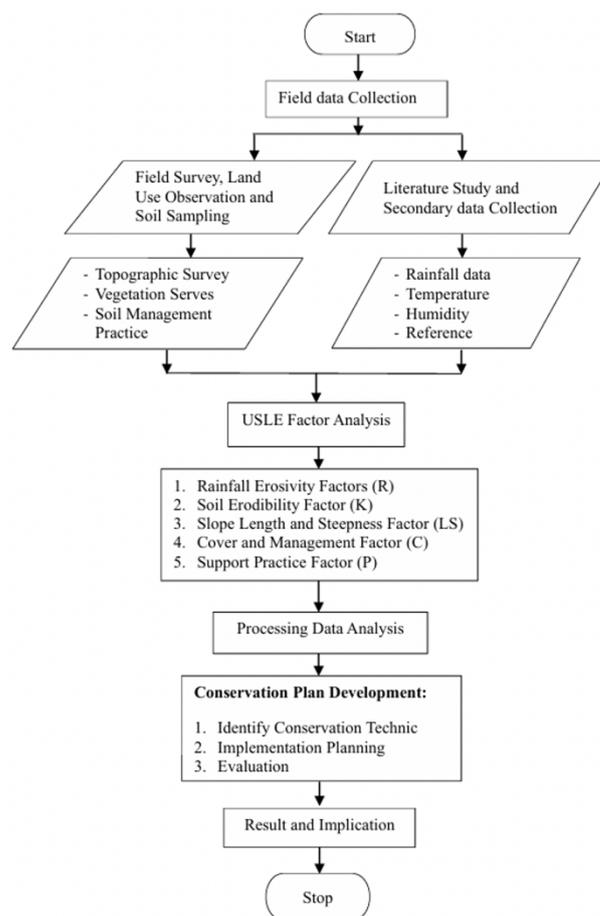

Figure 2. Scheme of Analysis Process

Hera's topography is characterized by a combination of coastal and inland features. The area around the coastline is generally at low elevation, gradually rising as one moves inland. Moving away from the coast, the terrain becomes more hilly and rugged. The inland areas feature rolling hills and valleys, with some areas having smooth gradients suitable for agriculture, while others are steeper and less accessible. Several small rivers and streams run through the area, originating from the hills and flowing towards the coast. The research area is located in Mota Ki'ik Village, Hera which is included in the Cristo Rei Administration Post, District Dili. In the study area, it is planned to build a new building intended for the convent of the sisters. The total area is around 14 hectares and the landscape area has surrounding by mountain in the south part. Based on the Topography survey, the slope area is ranging from 2-40%. The steeply area (hill) has high slope grade of 35%-40% slope were identified with easily eroded soil, steeply sloped soil cover, steep rock slopes, and rockfalls. This condition align with other study that found that slope degree in 15°~35° slope area has significant effects on soil erosion due to steep slopes increase the velocity of surface runoff, which enhances the erosive force on the soil surface (Wu and Wang, 2011). On the back side of the new building area, was found a relatively steep hill. This condition requires special

attention due to the risk of erosion that could threaten the area. By this problem, we have carried out a review in the field and found that the condition of the surface soil layer is relatively thin therefore the risk of massive landslides will not occur, however, between the gaps in the water flow on the hill there is a possibility of debris being carried by flood water to the construction location in Sister living area. The flowing water cuts through the clay and creates deep channels known as gullies on the surface of the mountain. Based on the Topographic survey and field observation shown that most gullies form along hillsides as shown in the Figure 3. From the observation showing that gully erosion has happened when runoff concentrates and flows strongly enough to detach and move soil particles. Other observation showing that the streambank

is formed in the downs of mountain. The runoff that flowing along the gully has scraped the down area and formed the new streambank that bring water to the community area in the East part. The erosion seems has happened in the streambank and impacted to the widening of the streambank. To protect the house area from the flooding and erosion, then the owner builds the retaining wall along the foothill, however it is not maximum solving the problem.

Based on field investigations, the physical properties of rocks were classified according to the following schema (Figure 4). Rocks were briefly described and categorized by their degree of erosion into low, moderate, and high. The degree of erosion significantly influences the sedimentation rate during heavy rainfall events.
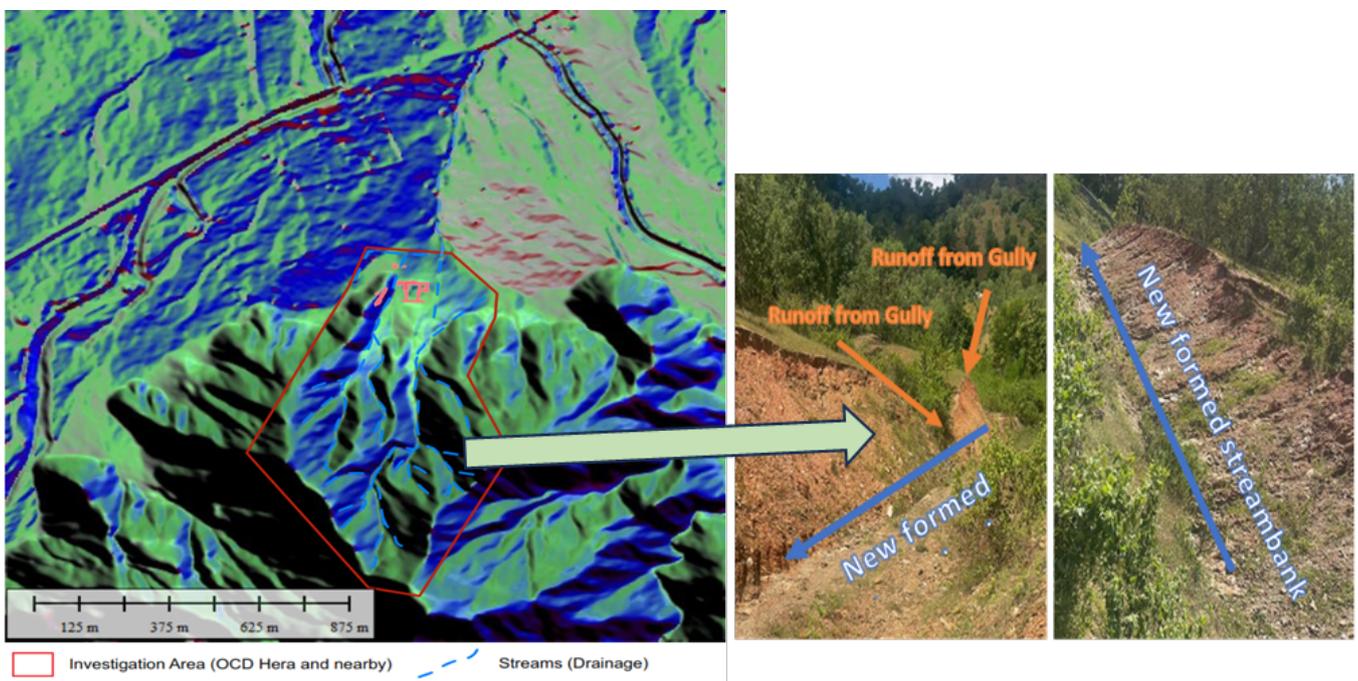

Figure 3. Topography area; Gully and New formed streambank in foothill (Niceles Lda.,2023)
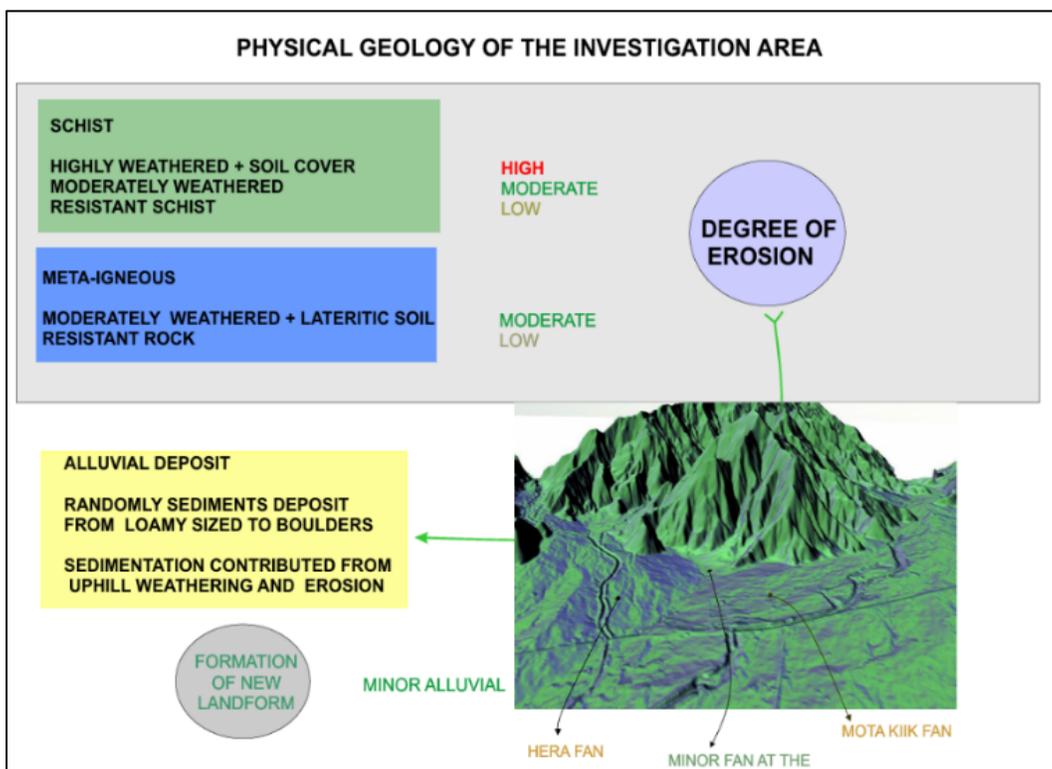
Figure 4. The physical Geology and Degree of Erosion in study area (Niceles Lda.,2023)

Hera's land use consists of a mix of residential, agricultural, commercial and public land. The relatively flat coastal plain is more suitable for urban and suburban development. The varied topography supports different types of farming, from coastal farming to hillside terraced farming. Crops such as corn, rice and vegetables are commonly grown. Natural vegetation includes coastal mangrove forests, tropical forests, and agricultural land. Vegetation cover is influenced by topography, with dense forests in hilly areas and agricultural land in flat areas. Based on the Land use observation and from satellite imaginary was found that the study area is consist of bare land in the new building area and forest in the hill. The mountainous area is forest area cover with vegetation which consists of 50% sparse vegetation area, 30% dense vegetation area, 18% Bare land area and 2% settlement area. The existing vegetation consists of grassland and eucalyptus trees planted on the uphill area. Another research examined that the areas with dense vegetation experience significantly lower erosion rates compared to barren or sparsely vegetated lands (Vanacker et al., 2007). The Land Use map has develop using multi criteria analysis approach Analytical Hierarchy Process (AHP) Method and GIS as shown in the Figure 5.
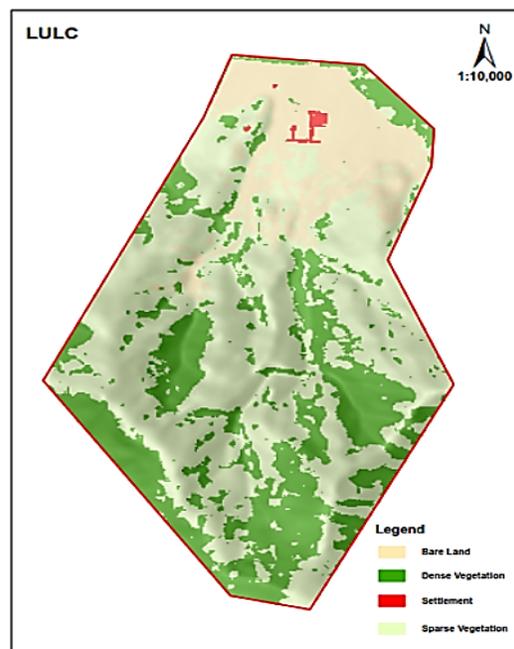

Figure 5. Land Use map of study area (Niceles Lda.,2023)

4.2. Metrological and Rainfall

Dili include Hera have tropical climate, characterized by stable high temperatures and high humidity. Humidity levels in Hera are consistently high throughout the year due to its tropical climate and proximity to the ocean. Average relative humidity typically ranges from 70% to 90% during the wet season and 60% to 80% during the dry season (ADB, 2021; WMO, 2019). High humidity levels contribute to maintaining soil moisture, which can enhance soil stability in certain conditions. However, prolonged periods of high humidity can also lead to saturation, making soil inclined to erosion during heavy rainfall events (Morgan, 2005). The temperature in Dili include Hera is fairly stable. Average temperatures typically range between day 28°C to 34°C and night 20°C to 33°C (ADB, 2021; WMO, 2019).

The rainfall pattern in Dili includes Hera, in wet season occur on November to April. The heaviest rainfall usually occurs from December to March (ADB, 2021; Takeleb and Ximenes, 2020). Intense rainfall can lead to surface runoff, which erodes exposed soil and carries sediment downstream. Dry Season occur on May to October. Rainfall is significantly reduced, with the driest months being June, July, and August (ADB, 2021). During this period, there can be prolonged dry spells with minimal precipitation. During the dry season, soil can become compacted and less permeable, increasing runoff when rainfall (Morgan, 2005). Lack of vegetation cover during this period will increase the risk of erosion, especially on slopes and degraded land (Morgan, 2005). The average monthly rainfall in Hera as shown in the Table 1.

Table 1. Monthly Rainfall in Hera

Month	Year												
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Jan	84	174	373	376	98	218	183	139	195	342	301	255	290
Feb	73	364	240	307	401	343	305	144	239	408	392	281	373
Mar	79	252	261	207	234	365	140	236	202	487	352	317	279
Apr	208	342	105	125	211	206	128	165	75	128	92	651	76
May	167	37	150	106	23	18	114	93	9	76	124	29	29
Jun	18	3	1	75	67	21	82	0	12	0	30	56	93
Jul	244	21	0	64	25	5	66	49	22	0	0	0	0
Aug	10	1	0	0	0	11	5	0	12	0	0	2	14
Sep	125	0	0	0	0	0	43	2	0	0	0	24	76
Oct	247	29	31	19	15	1	84	53	10	5	73	41	103
Nov	207	130	73	116	15	12	131	210	118	28	78	171	275
Dec	340	178	112	279	211	138	262	247	103	116	169	301	174

4.3. Soil Type

Based on the Geology survey, the soil types in Hera, a suburb of Dili, are influenced by coastal and inland topography, climate, and vegetation. The coastal areas of Hera typically have sandy soils, which are well-drained and low in organic matter. The inland area, the soils tend to have a higher clay content, resulting in clay loam soils. These soils have good water-holding capacity and fertility, making them suitable for a variety of crops and are important for erosion control. Based on Cone Penetration Test (CPT) in the bare land area (new building location), it can be seen that the condition of the soil layer is very dense, at a layer 0.5-0.8 m below the ground surface there is a mixture of sand, gravel and hard rock. This dense soil layer can reduce the rate of erosion, the overall erosion potential depends on the characteristics of the surface soil, the slope of the land, vegetation cover, and climatic factors such as rainfall intensity.

4.4. Erosion Rate Analysis

The Universal Soil Loss Equation (USLE) is widely used for estimating soil erosion rates. The factors of USLE have defined base on the observation result and the empirical approach.

a) Rainfall erosivity (R) factor

The R-factor measures the impact of rainfall on erosion in Ton/ha/year. Using the Lenvain formula to determine the erosivity monthly rainfall. Total erosivity monthly rainfall is 444 cm. The average erosivity monthly rainfall in centimeter unit as shown in Table 2.

Table 2. Average Erosivity Monthly Rainfall

Month	J	F	M	A	M	J	J	A	S	O	N	D
Rm (cm)	23	30	26	19	8	4	4	0	2	5	12	20
$Rm^{1.36}$	72	101	85	56	15	6	6	0	3	10	29	60

b) Soil erodibility (K) factor

The K value, which represents soil erodibility, estimated using a nomograph that closely approximates the actual field value. Base on the laboratory soil test, the permeability of soil is moderate to rapid (6.3-12.7 cmhr^{-1}). Soil structure is

medium and coarse granular. The soil is containing 70% silt. As a result, the K-factor erodibility of the catchment area is 0.18. The soil are highly affected by soil erosion due to high proportion of fine sand and dust and low organic matter content.

c) Slope length (L) and slope steepness (S) factor

Based on the Topography survey, The slope of the higher point to the decreases enough area in the location is 38 % with the length of slope is 840 metres. From the analysis of the the higher LS-factor values is 53.0

The Land Use Land Cover map, verified with field observations, categorized the catchment area into bare land and forest areas. The area is categorized to the Sparse Forest land and grassland with the C factor is 0.01 (Suripin, 2004).

d) Support practice (P) factor

The P factor value set for the entire area is 1, due to no erosion control practices in the studied area (Suripin, 2004). Based on the field survey was found that there is no terracing, contour tillage, or contour strip-cropping are used to control the erosion in the uphill area.

e) Annual soil erosion estimation

The erosion rate analysis in the Hera watershed was performed by the five USLE factor. The values of estimated soil erosion potential that were around 401.56 ton/ha/year occurred in the uphill due to their high LS-factor values and the Soil type factor. It is known that the analysis of soil erosion problems carried out using the USLE approach provides important synthetic and systematic information about the nature, intensity and spatial distribution of a phenomenon and thus allows the identification of affected areas and the dominant types of erosion. These quantitative results can be an indispensable tool for integrated soil management.

4.5. Conservation Plan

a) Identify Conservation Technic

Timor-Leste has a mountainous landscape with a slope of more than 40% covering about 44% of the country's total land area. Only about 155,000 hectares of land, which is 10.4% of the total land in Timor-Leste, is flat and used as agricultural land (Sutherland et al., 2005). Soil conservation in steep areas with a slope of 40% and fine sandy soil types and low organic matter content requires a careful approach to prevent erosion and increase soil fertility. Some conservation techniques that identify can be applied based on the condition of landscape are Planting cover crops such as legumes, vetiver grass, or clover to protect the soil from erosion and add organic matter. Strip Cropping by planting crops in rows parallel to the contour of the land to reduce water runoff and erosion. In Timor Leste, This is mostly practiced in steep hilly areas to conserve soil. (NAP UN, 2008; Paudel et al., 2022). Agroforestry by combining perennial crops with annuals to improve soil stability and increase organic matter. Agroforestry has been traditionally used to control erosion and reduce flood in hilly areas and providing a wide range of benefits to the local communities. (NAP UN, 2008; Paudel et al., 2022). Building small dams of rocks or other materials to slow the flow of water in ditches or streams (Gomez Settu et al., 2022).

b) Implementing Planning

The following are steps that can be taken to implement Strip Cropping and Agroforestry conservation techniques in hilly region

1. Land Analysis: Measuring slope and analyzing soil.
2. Planning: Determining contour lines and selecting crops.
3. Land Preparation: Clearing and plowing the land parallel to the contour.
4. Planting: Planting the main crop and cover crops in parallel rows.
5. Maintenance: Fertilizing, weed and pest control, and monitoring.

In addition to the implementation of conservation techniques, it is also necessary to strengthen laws and institutions that can regulate and control all land use activities in Timor Leste. Rehabilitation of degraded watersheds in Timor-Leste is prioritized by the National Biodiversity Strategy and Action Plan which is based on the Timor-Leste Environmental Constitution which aims to reduce pressure on natural resources and promote landscape conservation for ecosystem services (NAP UN, 2008).However, it is important to conduct continuous monitoring and surveillance of the level of erosion and the effectiveness of conservation efforts that have been carried out, therefore corrective measures can be taken in a timely manner.

c) Evaluation

Conservation efforts in the Hera landscape if carried out by vegetation, will affect the increase in land cover in the hilly area. In addition, it is expected to improve the quality of hilly soil which can reduce the rate of erosion. With the USLE method, the CP factor (land use and conservation effort factor), becomes undisturbed forest land with a value of 0.001 (Suripin, 2004) while other factors such as rain, topography, and soil type are considered constant. With this assumption, therefore the volume of annual soil erosion that occurs decreases to 40.16 tons / ha / year or erosion is reduced by 90%. Overall, the application of the soil conservation method using vegetation will not only drastically reduce the erosion rate, but also provide broad environmental, social, and economic benefits. This is a strategic step that can be adopted in the sustainable land management plan in the catchment area of Hera. This

conservation effort also supports government programs and strategies in overcoming land degradation due to natural factors and human error.

5. Conclusion and Implication

Analysis of the level of erosion due to rain in the Hera River Basin (DAS), Dili, Timor-Leste, shows that the level of erosion in this area is influenced by rainfall intensity, topography, soil type, and land use. Areas with steep slopes and minimal vegetation tend to have higher levels of erosion. Data shows that erosion can cause land degradation, loss of soil fertility, and sedimentation in rivers, which in turn can have negative impacts on water quality and downstream infrastructure. If the soil conservation method using vegetation is applied and proven to be able to reduce the erosion rate by up to 90%, this will have a very significant impact on environmental conditions and the welfare of the community in the area.

The implementation of soil and water conservation practices such as planting cover vegetation to reduce the rate of erosion in the area. Sustainable land management in the Hera River Basin needs to be implemented through involving the participation of local communities, government, and non-governmental organizations. The government needs to develop and implement policies that support sustainable land management, including land use regulations, incentives for environmentally friendly agricultural practices, and community education on the importance of soil conservation.

6. Limitation and Future Research

This study may face limitations in the effectiveness of different types of vegetation that may vary depending on local soil and climate conditions. In addition, erosion reduction may seem significant in the short term, but its sustainability needs to be monitored in the long term. Social and economic challenges, such as limited resources and lack of community awareness, can also hinder the implementation of effective soil conservation.

Future research should focus on comparing the most effective vegetation types, long-term studies to observe the sustainability of conservation effects, and integration of other conservation methods for more optimal results. In addition, evaluation of social and economic impacts and climate change scenarios need to be taken into account to develop more adaptive and sustainable conservation strategies.

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