Land Suitability Evaluation & Regional Potential Mapping

Development of Agriculture, Livestock, Fisheries, & Forestry Commodities Dili Municipality

LAND SUITABILITY EVALUATION AND REGIONAL POTENTIAL MAPPING FOR THE DEVELOPMENT OF AGRICULTURE, LIVESTOCK, FISHERIES, AND FORESTRY COMMODITIES IN DILI MUNICIPALITY

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FOREWORD

MINISTER OF AGRICULTURE, LIVESTOCK, FISHERIES, AND FORESTRY OF TIMOR-LESTE

With gratitude to God Almighty, we proudly welcome the publication of the book titled "***Land Suitability Evaluation and Regional Potential Mapping for Agricultural Commodity Development in Dili District, Timor-Leste***." This book is a tangible result of the collaboration between the Ministry of Agriculture, Livestock, Fisheries, and Forestry (MAPPF) of Timor-Leste and the Faculty of Agriculture, Udayana University, supported by funding from the Government of Timor-Leste through Contract No. 24/MAPPF/IV/2024.

As a country rich in natural resource potential, Timor-Leste faces significant challenges in optimizing land use amidst limited resources and the impacts of climate change. This book is presented to address the urgent need for land resource management focused on food security, environmental sustainability, and poverty alleviation. Through a data-driven approach, this research has successfully mapped the potential of regions for the development of food, plantation, horticultural, and forestry commodities, and has developed relevant strategies to support rural economic growth and create new employment opportunities.

Covering the five main Sub-Districts of Cristo Rei, Dom Aleixo, Metinaro, Nain Feto, and Vera Cruz, this book offers a strategic guide for utilizing the predominantly dry land of Dili District. The proposed land suitability zoning approach provides solutions to challenges such as land degradation, erosion hazards, and soil fertility decline. Furthermore, this book emphasizes the importance of integrating environmental conservation and modern technologies to support sustainable land productivity.

We believe that the recommendations presented in this book not only provide direct benefits for food security in Timor-Leste but also contribute to the achievement of the Sustainable Development Goals (SDGs), particularly related to the elimination of hunger (SDG 2), climate action (SDG 13), and biodiversity protection (SDG 15).

I invite all stakeholders, from the government, academics, to the general public, to use this book as a reference for land resource management and agricultural sector development planning. Through synergy and close cooperation, we can ensure that agricultural development in Timor-Leste progresses in harmony with natural resource conservation, ecosystem sustainability, and improved community welfare.

In closing, I would like to express my gratitude to all those who have supported the realization of this book. May this work serve as an important milestone in Timor-Leste's journey toward robust food security, inclusive economic development, and environmental sustainability.

Sincerely,

Eng. Marcos da Cruz, M.AgSt
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Fisheries, and Forestry
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EXECUTIVE SUMMARY

A. OVERVIEW OF THE STUDY AREA

This chapter provides an overview of Dili District as an important background for evaluating land suitability and the potential for developing agricultural, plantation, horticultural, and forestry commodities. The information presented includes demographics, soil types, land use, and existing field conditions, with a data-driven approach that is thorough and comprehensive.

1. Demographics: The Foundation of Human Resource Potential

Dili District consists of five Sub-Districts: Cristo Rei, Dom Aleixo, Metinaro, Nain Feto, and Vera Cruz. According to the latest data, the population is recorded at 277,240 people, with an area of 226.88 km², resulting in an average population density of approximately 1,222 people per km².

The population distribution shows the highest concentration in urban areas, particularly in Dom Aleixo Sub-District, which serves as the center for economic, governmental, and service activities. Meanwhile, peripheral areas such as Cristo Rei, a tourism destination, and Metinaro Sub-District, continue to play a vital role in providing agricultural labor and utilizing land for food production.

2. Soil Types: The Basis for Land Suitability Evaluation

The Dili District is predominantly composed of Inceptisol soils, covering 191.27 km² (84.27%), which are suitable for intensive agriculture. Additionally, there are 32.20 km² (14.19%) of Entisol soils and 3.50 km² (1.54%) of Alluvial soils. Inceptisols are productive but prone to fertility decline if not properly managed, while Alluvial soils are generally fertile due to their formation from sediment deposits. The diversity of soil types presents both opportunities and challenges for sustainable agricultural management.

3. Geological Formation

The lithology of metamorphic rocks such as phyllite, schist, and amphibolite predominates in Dili District, covering 17,476 ha (77%). Alluvial formations make up 5,221 ha (23%), primarily in lowland areas such as Metinaro (2,281 ha) and Dom Aleixo (1,641 ha). The geological formations in this area influence the potential and limitations of agricultural land.

4. Land Use: Ecosystem Dynamics and Human Activities

Land use in Dili District is predominantly forested, with lowland forests of single-species plantations covering 43.04%. Agricultural land includes dryland used for food crops (0.15%) and paddy fields (1.58%). Commercial agriculture occupies 2.62%, while unused dryland accounts for 4.02%. Additionally, urban areas cover 14.39%, reflecting significant urbanization.

5. Slope Gradient: Risks and Potential

The slope classes range from flat (0–8%) to very steep (>45%), with varying distribution across each Sub-District. The largest flat area is found in Metinaro, covering 10.03 km² (8.73%), which supports intensive agriculture. Steep slopes (25–45%) are quite dominant, such as in Metinaro (13.92%) and Cristo Rei (10.71%), making them prone to erosion. Very steep slopes (>45%) cover 4–10% of certain Sub-Districts and are more suitable for environmental conservation.

6. Agro-climatic Zones: Regional Potential Classification

Dili District is divided into three main agro-climatic zones: Zone A, covering 93.95 km² (41.39%); Zone B, covering 209.21 km² (44.63%); and Zone C, covering 31.73 km² (13.98%). Zone A is suitable for seasonal crops such as corn and legumes in lowland areas. Zone B supports mixed agriculture with perennial crops and livestock at mid-elevation. Zone C, with its mountainous terrain, is suitable for conservation, agroforestry, and deep-rooted perennial crops.

7. Field Conditions: Issues and Potential

The upland areas in Dili are planted with commodities such as banana, cassava, mango, and taro, with agroforestry systems in place. Irrigated rice fields in Hera support agricultural diversification, while marginal lands are still prevalent. Dryland areas in Bairro Pite are planted with jackfruit, avocado, and corn. Additionally, there are community forests and mixed gardens that serve both ecological and economic functions.

8. Utilization of *Chromolaena odorata*: From Challenge to Opportunity

Chromolaena odorata is an invasive weed that has spread since the 1980s in Timor-Leste, threatening agriculture. This plant grows rapidly, reducing the productivity of corn, coffee, and horticultural crops, and is toxic to livestock. Its spread also disrupts ecosystems, reduces biodiversity, and increases the risk of fires. However, the biomass of this weed has potential to be processed into organic fertilizer, vermicompost, or traditional medicine.

B. RESEARCH METHODS

This research approach uses a survey method that includes field observations, interviews, and laboratory analysis to comprehensively evaluate land suitability. The study utilizes Land Units as the basis for delineating regions based on thematic map data, such as land use, soil types, climate, geology, and slope gradient maps. Data analysis is supported by Geographic Information System (GIS) technology to produce accurate and informative map visualizations.

Research Procedure

1. Soil Sampling
    - Soil samples were taken composite at the following depths:
        - 0–30 cm for seasonal crops.
        - 0–60 cm for perennial crops.
2. Laboratory Analysis

    The physical and chemical soil parameters analyzed include:
    - C-organic (%): Walkley and Black method.
    - Total N (%): Kjeldahl method.
    - Soil Texture: Pipette method.
    - Soil pH: Potentiometric method *(H_2O 1:2.5)*.
    - Available P & K (ppm):
        - Bray-1 method for pH < 7 (converted to mg/100 g).
        - Olsen method for pH > 7 (converted to mg/100 g).
    - Salinity: dS/m with potentiometer *(H_2O 1:2.5)*.
    - Cation Exchange Capacity (CEC) (cmol/(mg/100g)) and Base Saturation (BS) *dengan NH_4OAc 1N* pH 7.
    - Total Phosphorus (mg/100 g) and Total Potassium (mg/100 g) determined using the 25 % HCl method.
    - Total Zinc (ppm) determined using the DTPA extraction method and Available Zinc (ppm) determined using the HNO3-: $HClO_4$ digestion method.
    - Total Sulfur (ppm) and Available Sulfur (ppm) determined using the spectrophotometric method.
    - Soil Fertility Status: Based on the PPT (1995) method.

- Erosion Risk: Field observations and using the Universal Soil Loss Equation (USLE).

Stages of Land Suitability Classification

1. Actual Land Suitability
   The initial classification is conducted to assess land suitability under existing conditions without any improvements.
2. Land Improvement Recommendations:
   Steps for improvement are identified to address limiting factors, including the management of inputs such as fertilizers and soil and water conservation techniques.
3. Potential Land Suitability:
   The suitability assessment is carried out after considering improvements to maximize land potential.
4. Commodity Development Potential Zoning:
   Zoning is determined by integrating the Agroecological Zones of Dili District, based on land suitability and specific agroecosystems.

C. CHARACTERISTICS OF AGRICULTURAL AND FOREST LAND

1. Temperature

Air temperature is a key parameter in land suitability evaluation, with analysis based on the integration of field measurement data and the SRTM Digital Elevation Model (DEM) using the Braak approach. Dili District is dominated by high temperatures above 26°C, particularly in the Cristo Rei coastal area, which is suitable for tropical crops such as corn, peanuts, and cassava. Temperatures between 24–26°C support horticultural crops such as tomatoes, chili, papaya, and banana. The moderate temperature zone of 21–24°C is limited to Vera Cruz and is suitable for crops like potatoes, cabbage, carrots, and strawberries. However, high temperatures increase the risk of drought, necessitating efficient irrigation and heat-resistant crop varieties.

2. Rainfall

Rainfall analysis based on CHIRPS data shows that rainfall distribution in Dili District varies greatly. Cristo Rei and Vera Cruz receive annual rainfall between 1,000–1,500 mm, supporting naturally irrigated agriculture. In contrast, Dom Aleixo receives only 500–1,000 mm, influenced by its coastal location and mountains that block rain clouds. The low rainfall conditions require artificial irrigation interventions and drought-resistant crop varieties. Climate-based water optimization becomes a crucial strategy for agricultural sustainability.

3. Dry Months

Cristo Rei, Metinaro, Vera Cruz, and Nain Feto experience more than 6 dry months per year. This is influenced by the dry southeast trade winds and flat topography that hinder cloud formation. Dry areas require efficient technologies such as drip irrigation or sprinklers. Community-based water conservation is crucial for climate change adaptation.

4. Altitude

Most of Dili is located at low elevations along the coast, supporting government centers, settlements, and economic activities. The mid-elevation areas are found in Cristo Rei and Vera Cruz, which function as catchment areas and green spaces. These mid-elevation areas can still be used for dryland agriculture. However, the dominance of lowlands increases the risk of flooding and saltwater intrusion.

5. Drainage

Drainage conditions are generally good in Cristo Rei, Vera Cruz, and Metinaro, which support soil aeration and plant growth. However, drainage is impeded in Dom Aleixo, Nain Feto, and parts of Vera Cruz, leading to waterlogging and reduced productivity. Waterlogging can cause soil toxicity and hinder growth. An eco-drainage approach can reduce water runoff by up to 51% and improve infiltration.

6. Coarse Fragment

Most soils contain less than 3% coarse fragment, making them suitable for crops such as corn, sorghum, and tomatoes. Areas with 3–15% coarse fragment remain productive with crop rotation and organic management. Areas with 15–35% and 35–60% coarse fragment are more prone to erosion and are suitable for peanuts and cassava. Conservation management, such as terracing, is necessary to maintain productivity.

7. Effective Depth

The soil in Cristo Rei has an effective depth of 90–120 cm, making it highly suitable for intensive agriculture. This depth supports deep root systems, optimal water retention, and nutrient absorption. The uniformity of this condition facilitates the application of mechanization and precision irrigation. Agronomically, this land is highly suitable for modern farming systems.

8. Surface Rocks

The distribution of surface rocks in Dili is varied, with some areas having low content (<20%). Low rock content facilitates soil cultivation for plantations and intensive agriculture. However, the presence of rocks can reduce the effective soil volume and water retention. Soil conservation management is required to maintain productivity.

9. Rock Outcrops

Most of the area has moderate rock outcrops (5–25%), which still allow for dryland farming. Outcrops >25% support intensive activities such as settlement and infrastructure. However, outcrops >20% tend to limit land use, making them more suitable for conservation. This condition is crucial for land use zoning considerations.

10. Flood Risk

Most of Dili is a flood-free zone, including Cristo Rei, making it suitable for food and horticultural agriculture. However, some areas in Cristo Rei and Metinaro are at high flood risk. These flood-prone areas are more suitable for agroforestry and conservation. Forest rehabilitation and water infiltration systems are needed to reduce flood risks.

11. Soil Texture

The average soil composition in Dili consists of 19.5% clay, 33.66% silt, and 46.9% sand. Cristo Rei is dominated by clay, Dom Aleixo and Metinaro by sandy clay, Nain Feto by silty clay, and Vera Cruz by clay. Fine textures are good for water retention, while coarse textures promote aeration. This variation determines the land management strategies for each Sub-District.

12. Soil pH

Soil pH ranges from 5.59 to 6.70, from slightly acidic to neutral. Dom Aleixo has the lowest pH (5.59), while Nain Feto has the most neutral pH (6.70). Neutral pH supports optimal nutrient availability and microbial activity. Acidic soils tend to bind phosphorus, requiring liming.

13. Total Nitrogen

The total nitrogen content in the soil varies from 0.07% to 0.44%, ranging from very low to moderate. The highest value is found in Dom Aleixo (0.44%), while the lowest is in Nain Feto (0.07%). Low nitrogen limits vegetative growth, necessitating the use of organic fertilizers or additional nitrogen. High nitrogen content supports productive agriculture.

14. Available Phosphorus

Available phosphorus content is very low, with the lowest value in Nain Feto (0.68 ppm) and the highest in Dom Aleixo (4.36 ppm). Low phosphorus is often found in acidic soils, as it is fixed by Al and Fe. Phosphorus deficiency limits root growth and crop productivity. Therefore, phosphorus fertilization is crucial.

15. Available Potassium

Available potassium content varies across Sub-Districts, from **3.53 me/100g** (Nain Feto) to **29.30 me/100g** (Metinaro). Potassium supports protein formation, enzyme activity, and the transport of photosynthesis products. Low values indicate agronomic limitations requiring fertilization. However, excessively high levels can cause antagonism with other nutrients.

16. Electrical Conductivity (EC)/Toxicity

The EC values in Dili are generally low to moderate, ranging from 1.07 dS/m (Metinaro) to 2.80 dS/m (Nain Feto). Low values support intensive agriculture due to minimal osmotic stress. Conversely, high EC poses a risk of interfering with nutrient absorption and reducing productivity. Soil leaching strategies and the use of salt-tolerant varieties are needed in areas with higher EC values.

D. SOIL FERTILITY STATUS

Most of Dili District shows low to very low soil fertility. Areas with low fertility account for 99.70 km² (42.27%), while those with very low fertility cover 96.36 km² (40.85%). Lands with moderate fertility are limited to 28.40 km² (12.04%), and soils with high fertility are very limited, covering only 11.43 km² (4.85%). This condition underscores the need for intensive management to improve agricultural land productivity. Cristo Rei Sub-District is dominated by very low fertility soils, covering 49.91 km² (21.16%), making it a priority for rehabilitation. Dom Aleixo also primarily has very low fertility soils, covering 10.32 km² (4.37%). Metinaro is dominated by low fertility soils, covering 47.11 km² (19.97%), while Vera Cruz has 39.68 km² (16.82%) of low fertility soils. Only Nain Feto shows dominance of high fertility soils, covering 3.28 km² (1.39%), providing an opportunity for optimal agricultural development.

E. EROSION AND AGROFORESTRY-BASED CONSERVATION

1. Soil Erosion

Soil erosion analysis is crucial in land suitability evaluation, especially for agricultural commodity development, as erosion affects productivity, the capacity of the soil to retain water and nutrients, and ecosystem sustainability. Using the Universal Soil Loss Equation (USLE) method, factors such as rainfall, soil type, slope gradient, vegetation, and management practices are key determinants of erosion levels. In Timor-Leste, steep topography, unstable soil structure, and low vegetation cover lead to more than 59% of the area experiencing heavy to very severe erosion, requiring serious conservation strategies. In Dili District, Cristo Rei is the area with the highest erosion levels due to steep slopes and poor drainage systems, which accelerate surface runoff and exacerbate the loss of fertile soil layers.

2. Agroforestry-Based Conservation

Agroforestry-based conservation is an effective approach to addressing soil erosion in Dili District. Agroforestry integrates forest trees, food crops, and livestock to provide ecological benefits and sustainable land productivity. This approach focuses on:

- **Increasing vegetation cover:** Reducing surface runoff and maintaining soil moisture.
- **Enhancing soil fertility:** Through organic matter contributions from leaves and roots.
- **Managing water sustainably:** By retaining water in the soil layers through deep-root systems.

The main benefits of agroforestry in soil and water conservation include:

1. **Erosion Mitigation:** Trees and plants serve as natural barriers to prevent soil loss from surface runoff.
2. **Improved Water Infiltration:** Tree root systems increase the soil's capacity to absorb water.
3. **Biodiversity Enhancement:** The combination of food crops and trees creates a more diverse and stable ecosystem.
4. **Increased Agricultural Productivity:** Through the integration of agroforestry components that support diverse crop yields.

3. Agroforestry Implementation in Dili District

The agroforestry systems implemented in Dili District vary according to agroecological zones. Examples of effective agroforestry-based conservation systems include:

- *Alley cropping*: Planting crops between rows of trees on steep slopes to prevent erosion.
- Live fences: Using erosion-resistant plants, such as vetiver, to strengthen slopes.
- Live hedgerows: Using perennial plants like Leucaena to prevent erosion, combined with pepper plants and other climbing species.
- Layered planting: Combining trees, shrubs, and ground cover plants to stabilize soil and reduce runoff.
- Silvopastoral systems: Combining forest vegetation with livestock to manage erosion in grazing areas.

4. Conservation Recommendations

1. Enhance agroforestry practices in erosion-prone zones, such as Cristo Rei, Dom Aleixo, Metinaro, Nain Feto, and Vera Cruz.
2. Implement spatial data-driven management to identify priority areas for conservation interventions.
3. Build farmers' capacity through training and the adoption of modern agroforestry techniques.
4. Strengthen soil conservation policies by integrating agroecological approaches in regional spatial planning.

F. AGRICULTURAL LAND SUITABILITY

1. Land Suitability Evaluation

a. Cristo Rei Sub-District

- The suitable food crops for development include irrigated rice, upland rice, corn, cassava, and others, which have fairly good suitability.
- In addition to food crops, the potential for horticultural fruit crops such as papaya, orange, and durian, as well as vegetable crops such as bell pepper and green beans, is suitable for the area. Flower crops like rose, sunflower, and aster are also considered fairly suitable for the land.

- The development of industrial crops such as robusta coffee and sugarcane, as well as forestry crops like Melaleuca and sandalwood, are fairly suitable for this area.

b. Dom Aleixo Sub-District

- Horticultural crops that can be developed include jackfruit, soursop, and longan. Additionally, flower crops like aster, rose, and sunflower can also be developed in Dom Aleixo Sub-District.
- Medicinal and spice crops like vanilla and nutmeg are moderately suitable for cultivation in Dom Aleixo.
- Industrial crops such as cacao, clove, and melinjo, as well as forestry crops like sandalwood, are considered fairly suitable for development in this area.

c. Nain Feto Sub-District

- Suitable food crops that can be developed in Nain Feto Sub-District include upland rice, corn, and sorghum.
- Horticultural fruit and vegetable crops such as rambutan, guava, green beans, and bell pepper, as well as flower crops like rose, aster, and sunflower, are suitable for development.
- Spice and medicinal plants such as vetiver and nutmeg are moderately suitable for cultivation in Nain Feto.
- Industrial crops such as melinjo and robusta coffee are fairly suitable for development. Forestry crops such as Agathis and Albizia have moderate suitability for development in Nain Feto.

d. Vera Cruz Sub-District

- Suitable food crops for development include cowpea, upland rice, and soybean, which are fairly suitable for the area.
- Horticultural vegetable crops such as cucumber and bitter melon, as well as horticultural fruit crops like snakefruit and grape, have fairly good suitability. Flower crops such as rose, aster, and sunflower also show good suitability for the land.
- Spice and medicinal plants such as turmeric and cardamom are fairly suitable for development. Industrial crops like cotton and kapok, and forestry plants such as teak, mahogany, and Altingia, can also be developed in Vera Cruz.

e. **Metinaro Sub-District**

- Suitable dryland food crops for development in Metinaro Sub-District include sorghum, upland rice, and taro, which have fairly good suitability.
- Horticultural fruit and vegetable crops such as watermelon, custard apple, chili, and mustard greens, as well as flower crops like rose, aster, and sunflower, are suitable for development.
- Spice and medicinal plants such as aromatic ginger and vanilla can be cultivated in this area.
- Forestry crops such as eucalyptus and Melaleuca have moderate suitability in Metinaro.

2. **Zoning of Agricultural Commodity Development in Dili District**

This study aims to evaluate the potential and land suitability for various land-use forms in Dili District, Timor-Leste, as a basis for sustainable land management planning. The analysis considers the biophysical aspects, topography, soil types, as well as the ecological and economic functions inherent in each land-use category.

a) **Dryland Agriculture,** covering 51.26 km² or 22.98% of the area, is spread across elevations of 20–700 meters above sea level (masl) with a dominance of Inceptisol soils. Key commodities include upland rice, corn, sorghum, cassava, and horticultural and industrial crops such as spices and cotton. Dom Aleixo and Vera Cruz Sub-Districts cover the largest areas, while Nain Feto has the smallest. Conservation strategies such as strip cropping and crop rotation are necessary to prevent erosion and maintain soil fertility.

b) **Rainfed Rice,** covering 33.25 km² (14.65%) at elevations of 0–500 masl, with dominant Entisol soils, depends on seasonal rainfall. Metinaro Sub-District has the largest rainfed rice area. Water scarcity is the main challenge, as the dry season lasts up to 8 months. Management is recommended through the use of water retention ponds, drought-resistant rice varieties, and efficient irrigation techniques.

c) **Irrigated Rice,** covering 2.24 km² (0.99%), is located in lowland areas with slopes of 0–8% and a monomodal agro-climate. Development focus is directed towards modernizing tertiary irrigation systems, precision land leveling, and water use efficiency. Flood risk, sedimentation, and saltwater intrusion should be mitigated through drainage channels and mangrove rehabilitation. Locations should be ensured not to overlap with protected or coastal areas to preserve ecosystems.

d) **Grazing Areas,** covering 1.22 km² (0.15%) of Dili District, are scattered across Vera Cruz and Dom Aleixo Sub-Districts. Management should focus on rotational grazing systems to maintain land carrying capacity and forage quality. Integration with agroforestry can increase the economic and ecological value of the area. Recommended forage species include elephant grass, Setaria, and high-nutrient legumes.

G. FOREST POTENTIAL OF DILI DISTRICT

Protected forests in Dili District cover 112.22 km² (49.45% of the area), primarily in mountainous regions with slope gradients of ≥30%. Their main function is as a no-conversion conservation area, playing a key role in preventing erosion, maintaining infiltration, and supporting irrigation systems.

The largest protected forest area is in Metinaro Sub-District (24.41%), followed by Cristo Rei, Vera Cruz, Dom Aleixo, and Nain Feto. Additionally, mangrove forests covering 4.62 km² (2.04%) are scattered across Metinaro and Cristo Rei, functioning as coastal protection zones that support marine ecosystems and are planned for sustainable ecotourism development.

H. LIVESTOCK POTENTIAL IN DILI DISTRICT

This study aims to evaluate land suitability for the development of the livestock sector in Dili District, Timor-Leste, as part of efforts to enhance food security, provide nutrition, and strengthen the local economy. The methodology used involves analyzing land suitability for forage crops (forage feed crops) and evaluating the ecological suitability of various livestock types, considering the region's biophysical, social, and economic conditions.

The potential for livestock development is supported by the availability of grazing land, especially in Metinaro (50.19 ha) and Cristo Rei (20.51 ha), although Vera Cruz has no grazing land at all. Land suitability evaluation results show that the land is generally classified as S2 (moderately suitable) to N (not suitable), with limiting factors such as rainfall, drainage, soil pH, and erosion levels. Therefore, technical improvements are necessary, such as irrigation, strengthening terraces, and balanced fertilization to improve the quality of forage crops. Ecological analysis also indicates that Vera Cruz Sub-District has the most potential, as it is suitable for five main livestock types (beef cattle, dairy cattle, pigs, buffaloes, and sheep), while other Sub-Districts are more limited in their livestock potential.

The future development strategy emphasizes transforming Dili into a center for livestock post-production. With its strategic position as the capital, Dili is envisioned as a hub for the distribution, processing, and consumption of livestock products, while livestock production will be focused in surrounding areas. Priority policies include the development of modern slaughterhouses, cold storage, and logistics facilities meeting international standards. Furthermore, the development of downstream industries such as processed meat, dairy, and value-added products should be encouraged through incentives. With this approach, Dili can play a strategic role in supporting food security and sustainable livestock farming in Timor-Leste.

I. FISHERIES POTENTIAL IN DILI DISTRICT

This study aims to evaluate land suitability for the development of aquaculture in Dili District, Timor-Leste, as an effort to support food security and diversify the local economy. The methodology used involves Geographic Information System (GIS) analysis and field observations to map the existing aquaculture conditions and the obstacles faced by the local community.

Aquaculture activities in Dili District are spread across several locations with different characteristics, such as traditional tilapia and carp farming in Balibar Village, tidal pond systems for milkfish and crab in Metinaro Village, and tilapia and catfish farming under a partnership scheme in Hera Village. Land suitability evaluation is carried out through both actual and potential approaches, considering biophysical factors, water quality, and climate. In Cristo Rei Sub-District, freshwater commodities are considered more suitable for development, despite being limited by steep slopes and dry months, while brackish water commodities face challenges due to low salinity and high improvement costs. Improvement efforts such as using shallow ponds, tiered pond systems, and water quality management can enhance land suitability, although climate factors remain a primary constraint that is difficult to overcome.

J. RECOMMENDATIONS

1. Agricultural Recommendations

Dili District has good land potential for the development of food crops, horticulture, and industrial crops such as coffee and cacao. However, the sector faces challenges such as reliance on rainfall, soil erosion, and low farmer understanding of fertilization. Integrated land improvement, water conservation, as well as training and fertilizer subsidies are needed to increase productivity. Land conversion for industry and tourism also requires the optimization of limited land and appropriate technical interventions.

2. Livestock Recommendations

Dili District is recommended to focus on livestock post-production development by strengthening the supply chain and downstream industries. Infrastructure such as slaughterhouses and cold storage should be prioritized to facilitate distribution. Investment in value-added product processing, such as sausages and cheese, should be encouraged through incentives. This approach will establish Dili as a sustainable livestock distribution and processing center.

3. Fisheries Recommendations

The development of aquaculture in Dili District should be location-based, according to the characteristics of each area. In Balibar, the development of Lake Debu Metan as an ecotourism area and freshwater fish farming is highly promising. In Metinaro and Hera, rehabilitation of the water system and increased production capacity through mechanization and training are needed. The local government is also advised to establish a Fisheries Zoning Plan for structured and sustainable management.

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I. INTRODUCTION

The New Dawn of Timor-Leste on the ASEAN Stage

Timor-Leste has officially become a member of the Association of Southeast Asian Nations (ASEAN). The announcement of Timor-Leste's accession was formalized during the 47th ASEAN Summit held in Kuala Lumpur, Malaysia. This is a historic milestone. This strategic step positions Timor-Leste on a dynamic regional stage, opening up opportunities for collaboration and setting new standards. As the "face" of the nation, Dili District will serve as the main showcase reflecting the country's progress and resilience. On this new ASEAN stage, Dili District will not only be seen as the center of government but also as a barometer of Timor-Leste's readiness to face fundamental challenges. And what greater fundamental challenge could there be for a capital city than ensuring the well-being and food security of its citizens amidst the rapidly accelerating pace of development?

Historical Context: The Role of Dili as the Center of Government

Prior to the arrival of the Portuguese, the Dili area was governed by local traditional authorities. In 1698, the Portuguese began to assert control under Governor António Coelho Guerreiro. Initially, the capital was located in Lifau, Oecusse; however, due to security conditions, it was relocated to Dili on 1 October 1769 and officially designated as the capital of Portuguese Timor on 10 October 1769. Since then, Dili has developed as an administrative center, evolving from a military command in 1908, to a City Council in 1963, and later to an Administrative City during the period of Indonesian administration. Following the occupation period, Dili held the status of a District with six Sub-Districts, which subsequently developed into a District and administrative Sub-Districts within the national governance system.

The Capital at the Crossroads: Development vs. Food Security

As the political, economic, and social heart of Timor-Leste, Dili District faces unique and complex dynamics. Rapid population growth, dense settlements, and office centers have placed significant pressure on land, water, and food resources. This issue aligns with global agendas in the Sustainable Development Goals (SDGs), particularly in ensuring food security (SDG 2) and access to clean water (SDG 6).

Here lies the specific challenge for the capital: limited flat or lowland areas are increasingly encroached upon by the demand for housing and industrial development plans. Therefore, the direction of agricultural development in Dili District must be redefined, shifting from traditional models to more modern and adaptive concepts:

1. **Urban Farming:** Optimizing limited urban space through modern agricultural techniques.
2. **Dryland Optimization:** Utilizing the highland areas on the outskirts of the city, but with one absolute condition: adherence to conservation principles.

Dili District is not just concrete and office buildings. This region comprising Cristo Rei, Dom Aleixo, Metinaro, Nain Feto, and Vera Cruz Sub-Districts forms a complex ecosystem. Here, agricultural land coexists with residential areas and even features extensive mangrove ecosystems, particularly in the Metinaro Sub-District.

Hidden Assets: Geological and Soil Foundations

This vision for modern agriculture is supported by the geological foundation of Dili District. The region is dominated by two main formations: the **Aileu Formation** (77%, consisting of Phyllite, Schist, and Amphibolite) and the **Alluvial Formation** (23%, composed of loose sediment deposits).

To the public, this may sound technical. However, what this means is that these geological conditions greatly support the development of modern irrigation infrastructure. Systems such as piping and pumping, which are vital for urban farming and dryland agriculture, can be implemented here, leading to much more efficient water management.

The primary capital lies not only in the rocks but also in the soil. The great potential is found in the dominant soil types:

- **Inceptisol (84,27%):** This soil type has a sufficiently thick solum and good natural fertility. Traditionally, it is ideal for food crops like upland rice, making it a key asset for optimizing highland areas.

- **Entisol (14,19%):** Although widespread, this soil type faces challenges as it is prone to erosion. This emphasizes the need for strict conservation practices when utilizing highland areas.
- **Alluvial Soil (1,54%):** Though limited in area, alluvial soil is "premium" soil with excellent fertility and physical characteristics. It presents a golden opportunity for diversifying high-value agricultural commodities.

Four Pillars of Potential: From Agroforestry to Brackish Water Fisheries

Given the current conditions, the future of food security in Dili District does not rely on a single sector, but on four integrated pillars:

1. **Agroforestry (Highland Areas):** For the highland areas dominated by Inceptisol and Entisol soils, agroforestry is the solution. This system integrates agriculture, livestock, and forestry. It not only produces food but also enhances environmental quality, reduces land degradation, and increases carbon sequestration, making a direct contribution from the capital to climate change mitigation (SDG 13).
2. **Livestock:** The livestock sector can be integrated, particularly in the surrounding areas of the city.
3. **Freshwater and Brackish Water Fisheries:** This potential is often overlooked. The presence of coastal and mangrove ecosystems (such as in Metinaro) presents significant opportunities for high-value brackish water aquaculture (pond farming), in addition to the potential for freshwater fisheries on land.
4. **Integrated Farming Systems (Urban & Peri-Urban):** Integrating the three pillars above into an integrated farming system will improve land use efficiency, maximize food production, and enhance the economic welfare of communities around the capital.

The Purpose of This Book: A Roadmap for a Resilient Capital

Therefore, the research behind this book aims to comprehensively evaluate the land suitability in Dili District. The focus is on mapping the potential for agricultural sector development, while also considering the integrated potential of the livestock and fisheries sectors (both freshwater and brackish water).

This book is expected to provide strategic and practical recommendations. These recommendations are intended for local governments in spatial planning, for academics, practitioners, and the local community, to collectively manage Dili District's natural resources sustainably. The goal is clear: to create a capital that is not only advanced in infrastructure but also resilient in food security, and ready to showcase Timor-Leste’s best face on the ASEAN stage.

II. GENERAL OVERVIEW OF THE AREA

2.1 DEMOGRAPHY

Dili District consists of five Sub-Districts: Cristo Rei, Dom Aleixo, Metinaro, Nain Feto, and Vera Cruz. Geographically, Dili District is located between approximately 8°34' to 8.567° S latitude and 125°35' to 125.583° E longitude. It borders Ataúro Island to the north, Aileu District to the south, Manatuto District to the east, and Liquiçá District to the west (**Figure 2.1**).

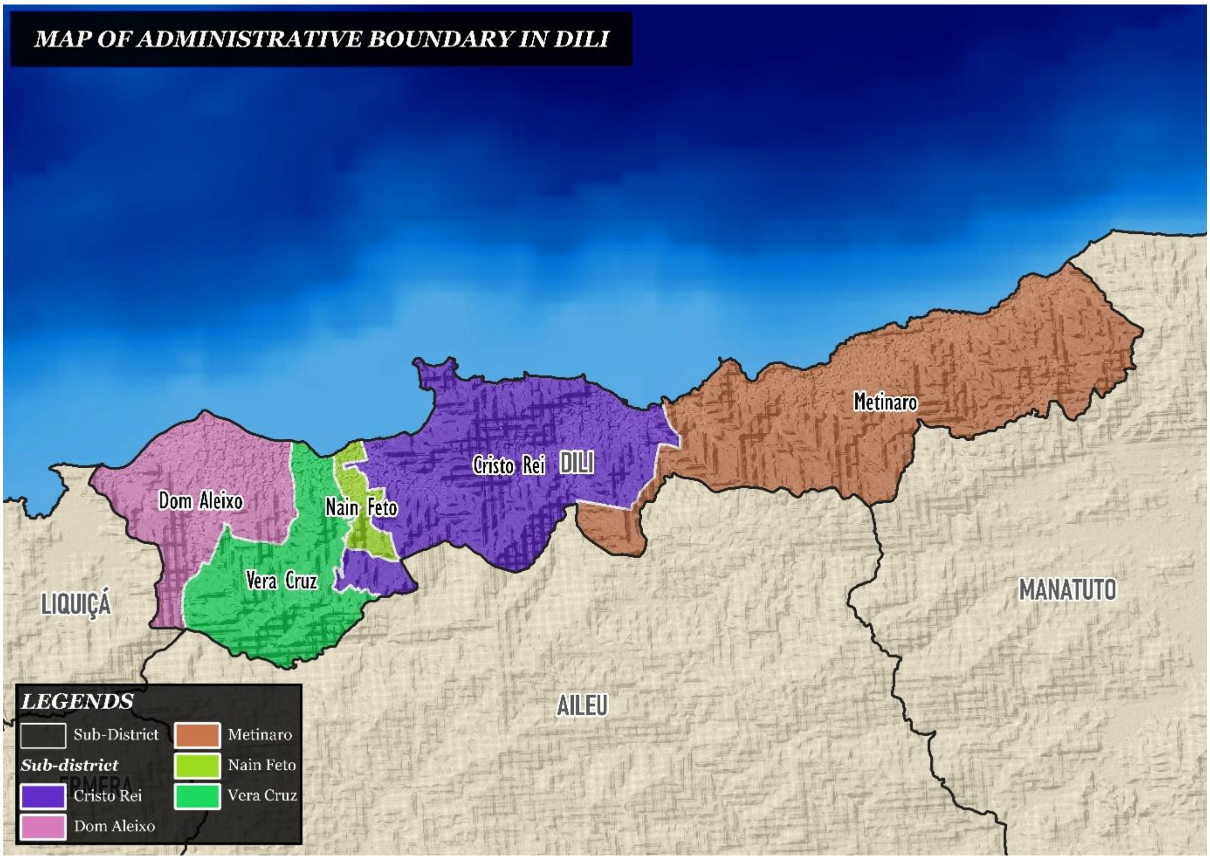


Figure 2.1 Administrative Map of Dili District

The population of Dili District, based on data from the Ministério da Administração Estatal (2025), is recorded at 227,240 people, as presented in **Table 2.1**.

Table 2.1 Demographic Data in Dili District

Sub-District	Area (ha)
Cristo Rei	6.514
Dom Aleixo	3.302
Metinaro	9.100
Nain Feto	514
Vera Cruz	3.267

Before the arrival of the Portuguese, the Dili area was governed by local traditional authorities. In 1698, the Portuguese Government began to assert its power through Governor António Coelho Guerreiro and intervened in traditional governance in Timor, including Dili. Initially, the capital of Portuguese Timor was established in Lifau–Oecusse, but due to unstable security conditions, the capital was moved to Dili on 1 October 1769 and was officially designated as the capital of Portuguese Timor on 10 October 1769.

On 20 April 1859, Governor Afonso de Castro established an administrative division into eleven District, with Dili serving both as the capital and as a District encompassing the areas of Motael, Ulmera, Hera, Caimauc, Dailor, Failacor, and Laclo. Subsequently, Dili's administrative status continued to evolve, from a military command in 1908, to a Municipal Council in 1963, and to an Administrative City during the Indonesian occupation. After the occupation, Dili became a District with six Sub-District, which later developed into a Municipality and Administrative Post.

2.2 SOIL TYPE

Soil types in Timor-Leste were classified using Soil Taxonomy (1992 key). The classification was carried out only to the Great Group level. There are 7 Orders, 16 Suborders, and 22 Great Groups.

Dili District is dominated by the Inceptisols order, covering 191.27 km^2 (84.27 %), as shown in **Figure 2.2**, and distributed across the study area (**Figure 2.3**). The Entisols order covers 32.20 km^2 (14.19 %), and alluvial soils cover 3.50 km^2 (1.54 %). Inceptisols are often used for intensive agriculture; however, inadequate management can reduce their fertility. Entisols are young soils at an early stage of development, with little to no horizon development; they commonly overlie parent material and form from recent deposits. Alluvial soils are formed by depositional processes, typically along rivers, in lowland lakes, or in basins where sediment accumulates. These soils are advantageous for agriculture, including by facilitating irrigation. The soil type map of Dili District is presented in **Figure 2.4.**

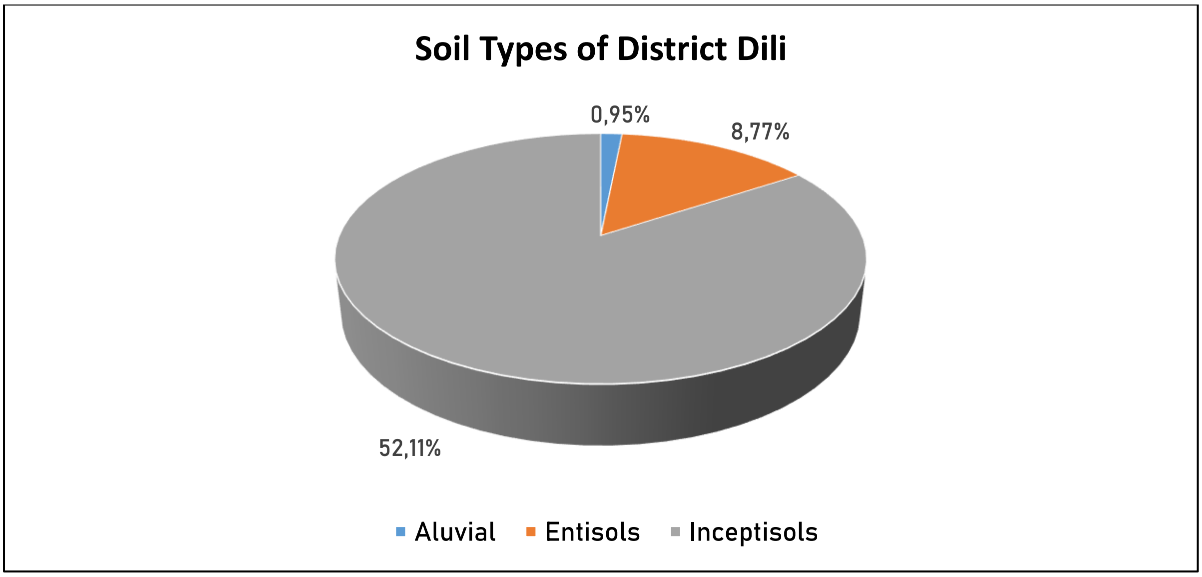
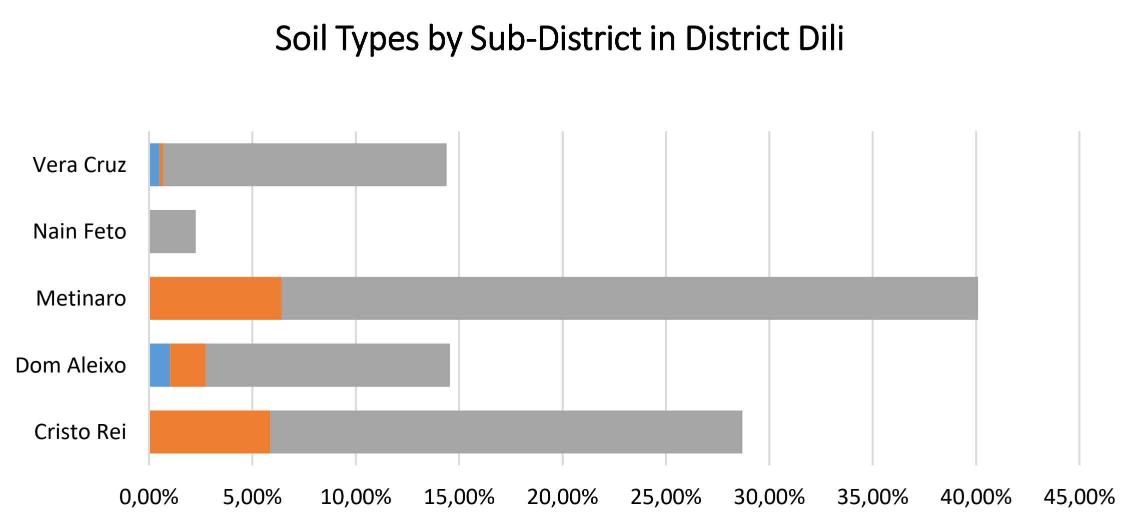


Figure 2.2 Area by Soil Type



	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
Aluvial	0,00%	1,02%	0,00%	0,00%	0,52%
Entisols	5,87%	1,73%	6,41%	0,00%	0,18%
Inceptisols	22,83%	11,80%	33,68%	2,26%	13,70%

Figure 2.3 Distribution of Soil Types by Sub-District in Dili District

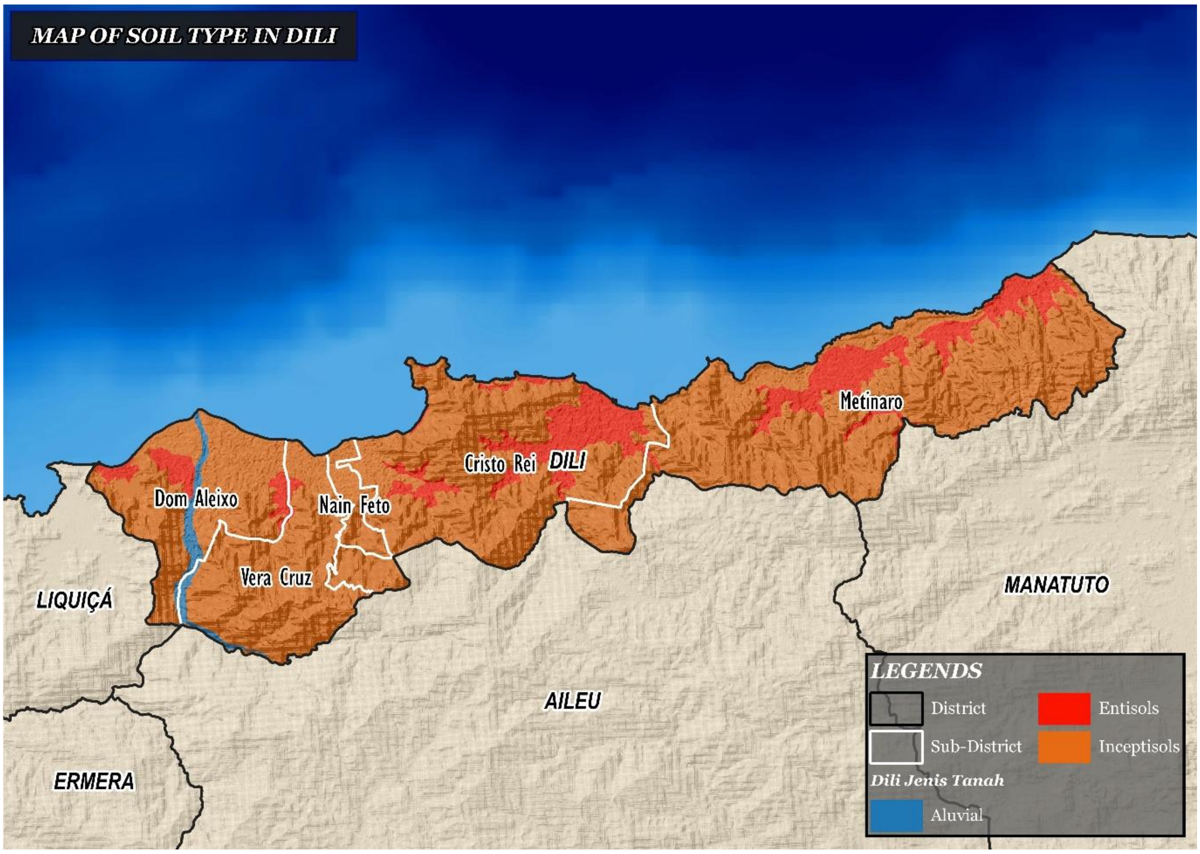


Figure 2.4 Soil Type Map of Dili District

2.3 GEOLOGICAL FORMATIONS

The distribution of geological formations in the study area shows substantial diversity. Each formation contributes uniquely to soil development and influences land potential and limitations for agricultural development. The analysis indicates that the Aileu Formation (77 %) and Alluvial (23 %) dominate Dili District, as presented in **Figures 2.5** and **2.6**, with the spatial distribution of geological formations in Dili District shown in **Figure 2.7.**

The Aileu Formation occurs across most of Dili, covering 77 % with a total area of 17,476 ha, and provides varied soil characteristics relevant to agricultural management under differing environmental conditions. This formation dominates the study area, with the largest extents in the Sub-Districts of Metinaro at 6,819 ha and Cristo Rei at 5,869 ha. The principal rocks in this formation include phyllite, schist, amphibolite, and slate, which are metamorphic rocks. Volcanic rocks are also present, although in smaller amounts. This composition indicates intensive metamorphism and past volcanic activity, which are important indicators for understanding tectonic conditions and soil stability in the area.

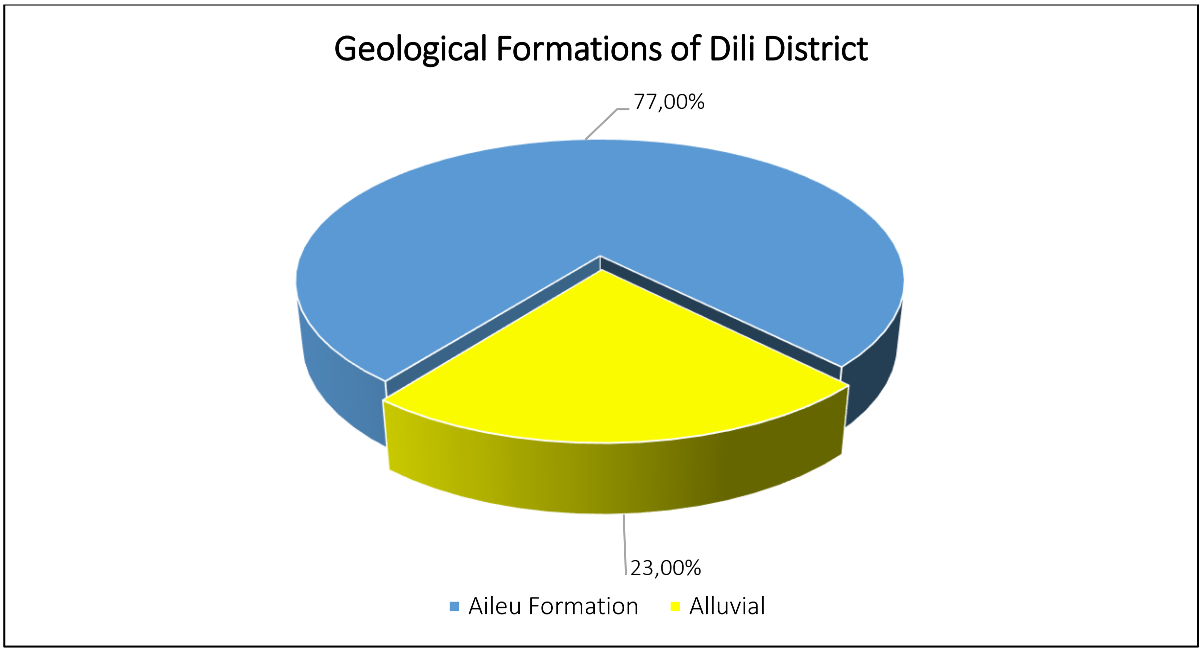
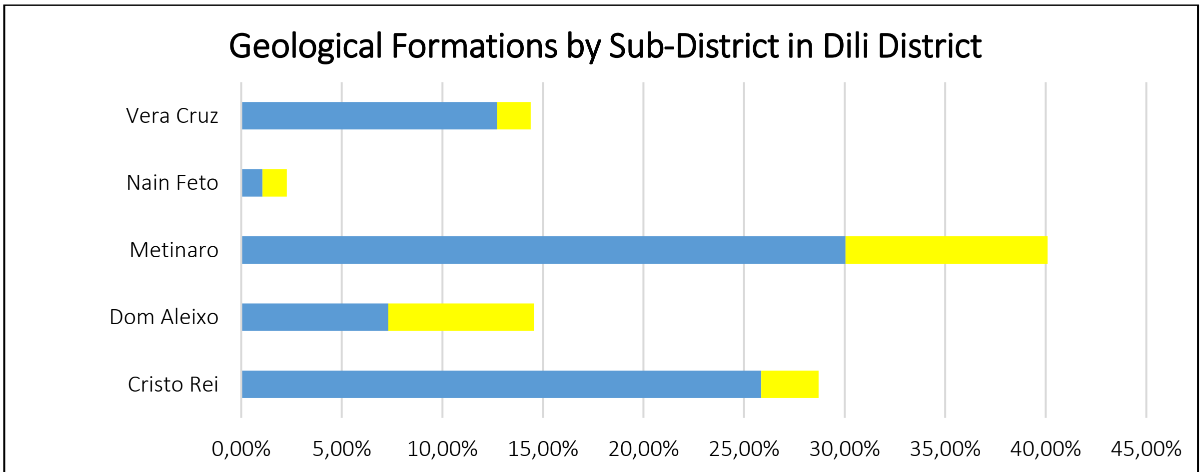


Figure 2.5 Geological Formations of Dili District



	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
Aileu Formation	25,86%	7,32%	30,04%	1,06%	12,72%
Alluvial	2,84%	7,23%	10,05%	1,21%	1,67%

Figure 2.6 Area of Dili District by Geological Formation

The Alluvial Formation comprises 23 % (5,221 ha) of the total area and is found in lowlands that receive sediment deposition from flowing water. The lithology consists of unconsolidated sediments ranging from clay to boulder-sized fragments. These conditions contribute to the formation of fertile alluvial soils suitable for irrigation-based land management (Brady and Weil, 2017). The presence of Alluvial in several Sub-Districts, with the largest areas in Metinaro at 2,281 ha and Dom Aleixo at 1,641 ha, creates opportunities to utilize land with efficient irrigation systems.

This diversity of geological formations provides an important basis for land suitability evaluation. Each formation directly affects soil physical and chemical properties, such as texture, structure, water-holding capacity, and susceptibility to erosion (Brady and Weil, 2017; Lal, 2019). As stated by Brady and Weil (2017), geological formations directly influence soil characteristics, which ultimately determine land-use potential.

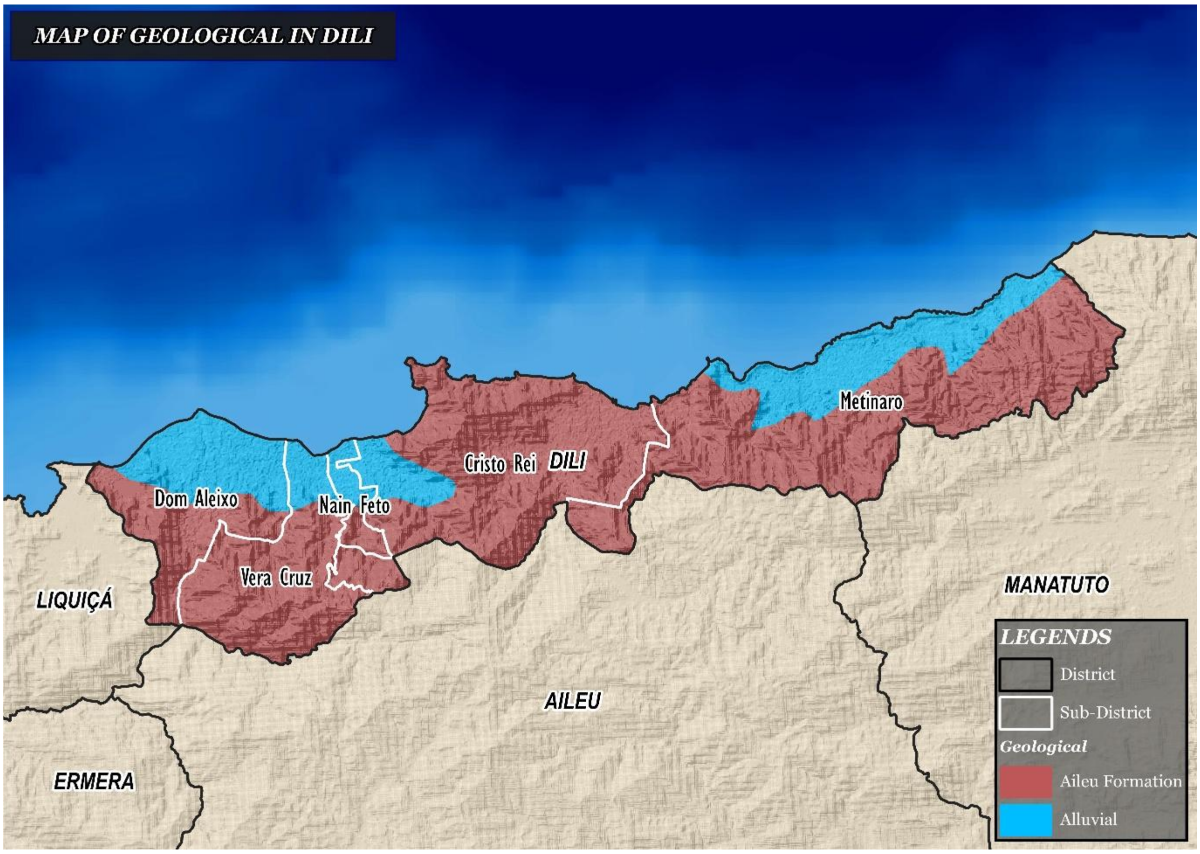


Figure 2.7 Geological Formations Map District Dili

2.4 LAND USE

The development of agricultural commodities was a primary priority for strengthening food security in Dili District. To achieve optimal productivity, management of these commodities needed to be aligned with appropriate land-use patterns. Dili District exhibited diverse land uses distributed across its Sub-Districts.

Dryland Arable-Food Crops accounted for 0.15 % and occurred only in the Sub-District of Dom Aleixo. Rice Fields covered 1.58 % and were also found only in Dom Aleixo.

Commercial Agriculture comprised two categories, namely Estate Crops and Smallholder Estate Crops. Estate Crops covered 2.97 %, distributed in the

Sub-Districts of Vera Cruz (2.90 %) and Cristo Rei (0.07 %). Smallholder Estate Crops covered 1.26 %, all in the Sub-District of Metinaro, as shown in **Figure 2.8.**

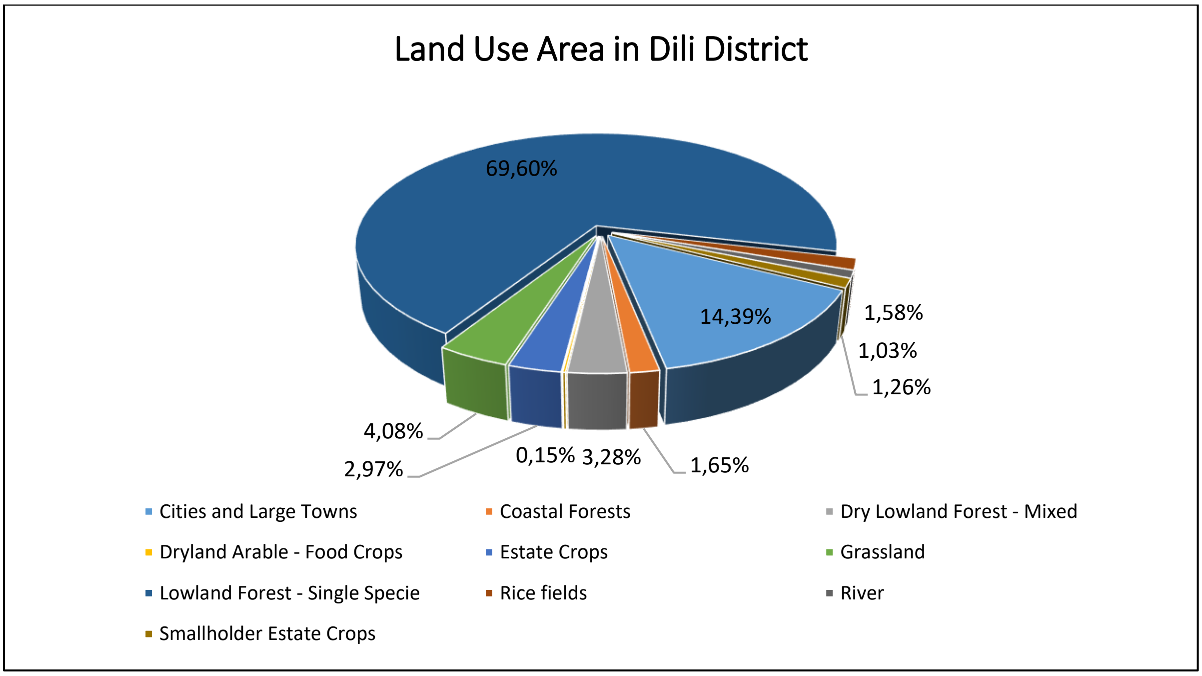
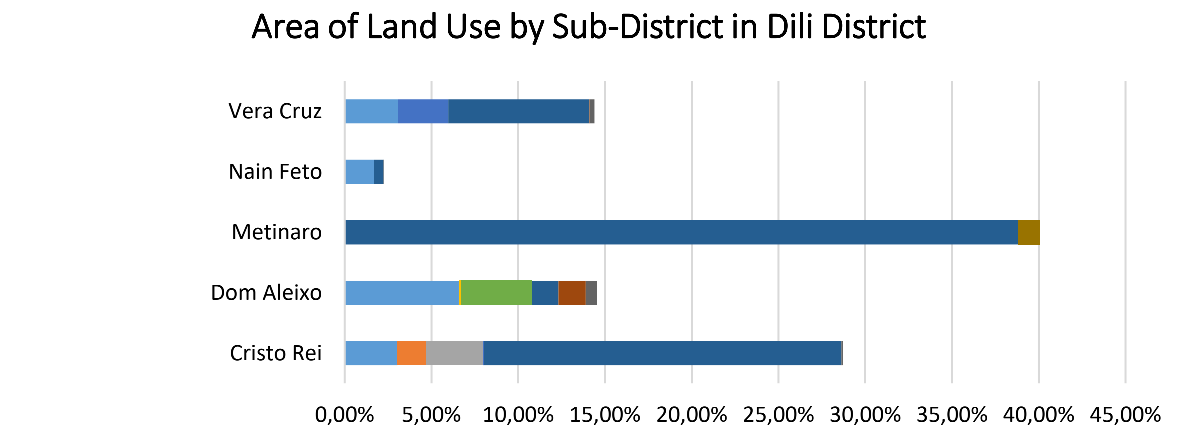


Figure 2.8 Land Use Area Chart in Dili District

Forest land use had the largest proportion in Dili District, reflecting the important role of forests in the regional ecosystem. The principal component in this category was Lowland Forest-Single Species, which covered 69.60 %. The largest distribution of forest land use was in the Sub-District of Metinaro (38.83 %).

Grassland covered 4.08 % in Dili District. This condition indicates potential land optimization that can be developed for sustainable agriculture, conservation, and ecosystem-based management. This condition indicates potential land optimization that can be developed for sustainable agriculture, conservation, and ecosystem-based management.

River land use occurred in nearly all Sub-Districts except Metinaro, with the largest distributions in Dom Aleixo (0.66 %), Vera Cruz (0.27 %), Cristo Rei (0.08 %), and Nain Feto (0.02 %). Rivers play an important role in meeting water needs for communities and ecosystems. Human-made land use, such as Cities and Large Towns, accounted for 14.39 % of the total land use in Dili District, with the largest proportions in Dom Aleixo (6.57 %), Vera Cruz (3.80 %), Cristo Rei (3.04 %), and Nain Feto (1.70 %). The land-use graph by Sub-District is presented in **Figure 2.9**, and the distribution map is presented in **Figure 2.10.**



	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
Cities and Large Towns	3,04%	6,57%	0,00%	1,70%	3,08%
Coastal Forests	1,65%	0,00%	0,00%	0,00%	0,00%
Dry Lowland Forest - Mixed	3,28%	0,00%	0,00%	0,00%	0,00%
Dryland Arable - Food Crops	0,00%	0,15%	0,00%	0,00%	0,00%
Estate Crops	0,07%	0,00%	0,00%	0,00%	2,90%
Grassland	0,00%	4,08%	0,00%	0,00%	0,00%
Lowland Forest - Single Specie	20,58%	1,51%	38,83%	0,54%	8,14%
Rice fields	0,00%	1,57%	0,00%	0,00%	0,01%
River	0,08%	0,66%	0,00%	0,02%	0,27%
Smallholder Estate Crops	0,00%	0,00%	1,26%	0,00%	0,00%

Figure 2.9 Graph of Land Use Area by Sub-District in Dili District

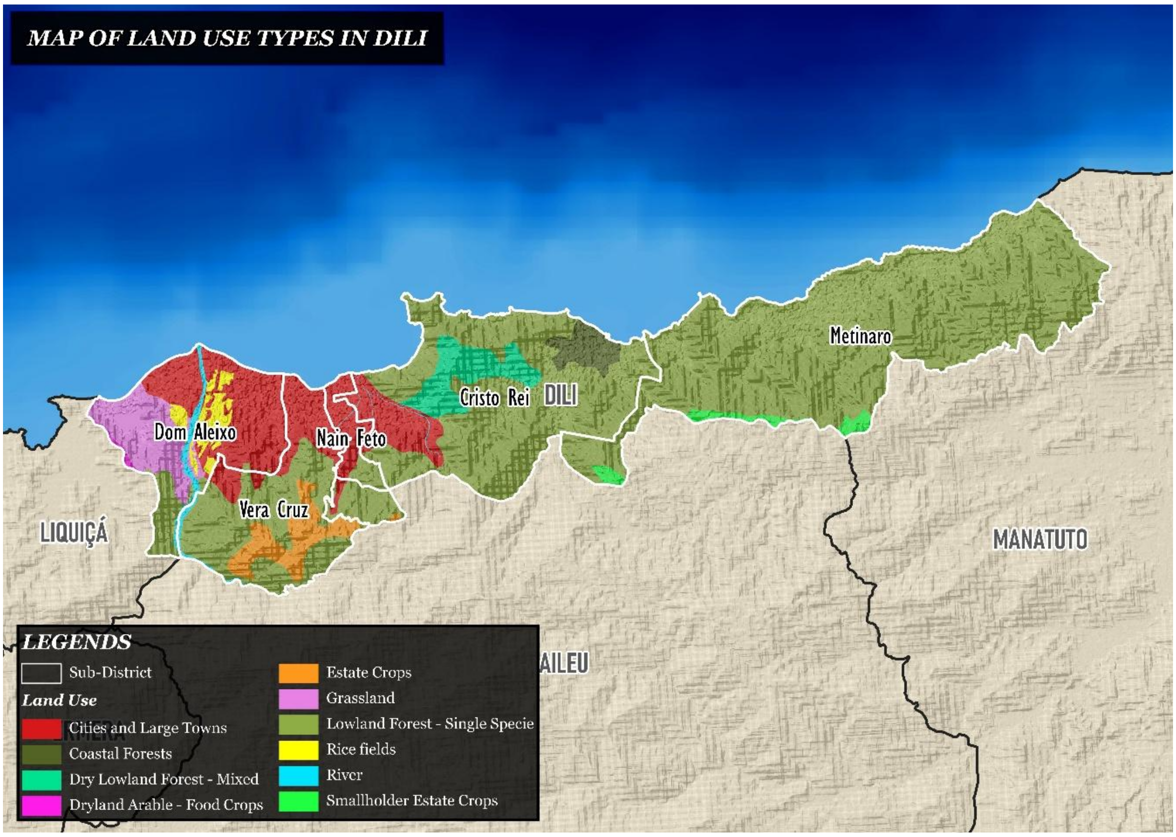


Figure 2.10 Land Use Map of Dili District

2.5 SLOPE GRADIENT

The distribution of slope gradient classes across the five Sub-Districts of Dili District provides significant topographic information with direct implications for land management strategies, soil erosion risk, and natural resource conservation. Slope gradients were grouped into five classes: flat (0 to 8 %), gentle (8 to 15 %), moderately steep (15 to 25 %), steep (25 to 45 %), and very steep (> 45 %) (Arsyad, 2010). These differences in slope gradient reflect the area's complexity and determine both the potential and the challenges for implementing land management practices, particularly in the agricultural sector. See **Figure 2.11.**

The flat class (0 to 8 %) covered substantial proportions in several Sub-Districts. Metinaro had the largest flat area at 10.03 km^2 or 8.73 % of its total area. Such flat terrain is well suited to intensive agriculture, including irrigated rice fields, due to minimal erosion risk and better accessibility. Other Sub-Districts with notable flat areas were Dom Aleixo (7.87 %) and Cristo Rei (6.64 %), as shown in **Figure 2.12.**

The gentle class (8-15 %) was fairly evenly distributed across the Sub-Districts. These conditions allow more flexible land management for both agriculture and settlement. Other Sub-Districts such as Metinaro (4.43 %) and Cristo Rei (2.65 %) also had sizeable gentle areas, supporting mixed activities that combine agriculture and conservation.

The moderately steep class (15-25 %) dominated large portions of several Sub-Districts. These slopes remain usable for agriculture with the application of soil conservation techniques such as terracing. In addition, Metinaro (4.43 %) and Cristo Rei (2.65 %) also had significant areas in this category, indicating potential for intensive land management but requiring attention to erosion risk. The slope gradient map of Dili District is presented in **Figure 2.13.**

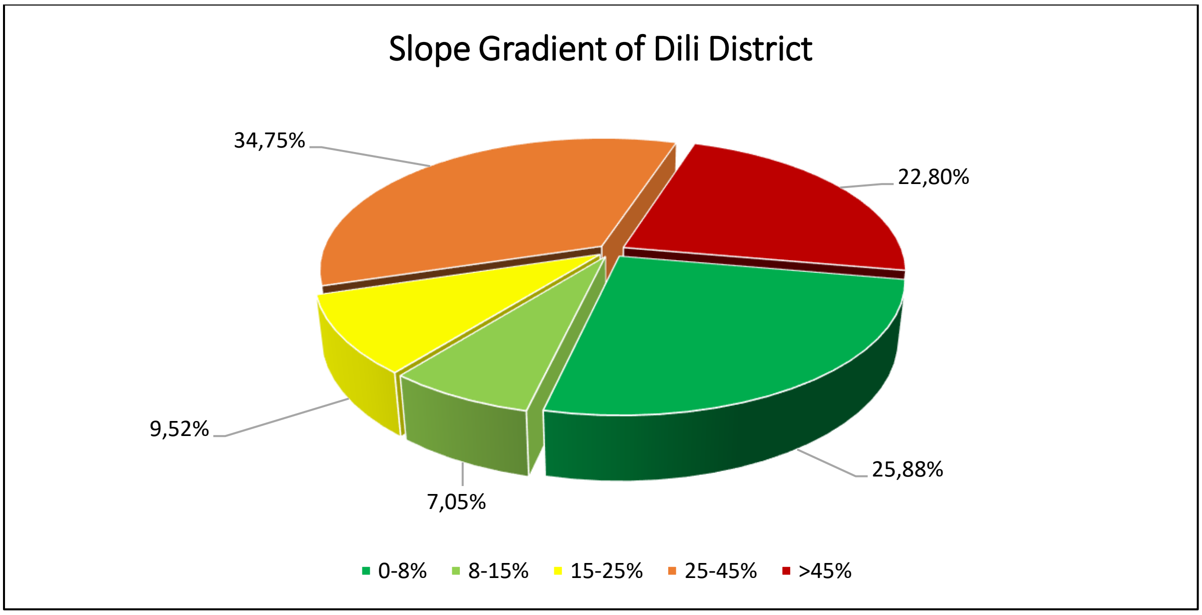
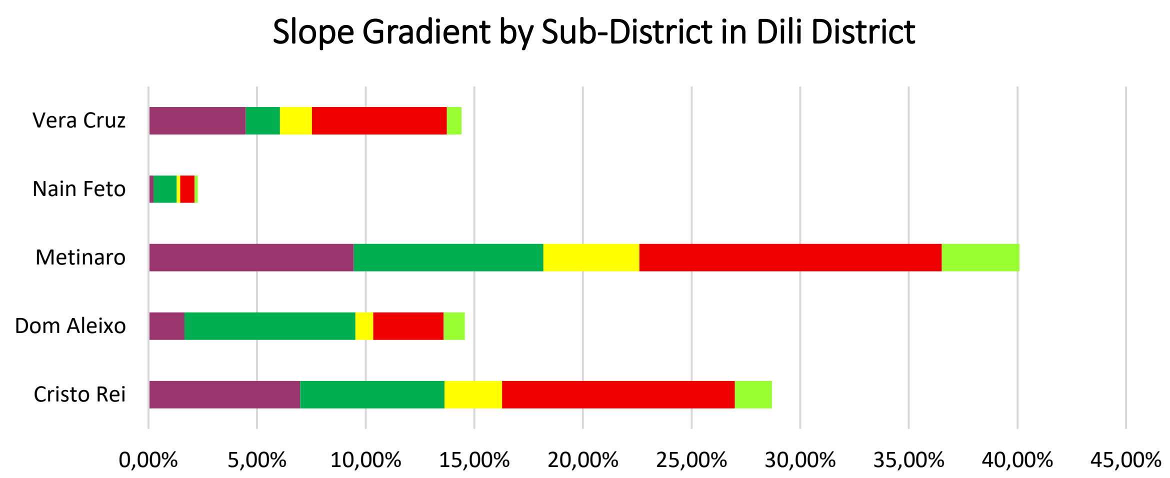


Figure 2.11 Graph of Slope Gradient in Dili District

The steep class (25-45 %) indicates topography suitable for conservation-oriented activities such as agroforestry and reforestation to reduce erosion risk and prevent further land degradation. Metinaro had a steep-slope proportion of 13.92 %, followed by Cristo Rei at 10.71 %. These conditions underscore the need for strategic and sustainable conservation-based land management to support soil stability and ensure ecosystem sustainability.

The very steep class (> 45 %) occurred in several Sub-Districts, including Metinaro (9.44 %) and Cristo Rei (6.99 %). Areas with very steep slopes are highly limited for intensive agricultural activities and are more suitable for environmental conservation and water resource protection.



	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
>45%	6,99%	1,65%	9,44%	0,23%	4,48%
0-8%	6,64%	7,87%	8,73%	1,06%	1,58%
15-25%	2,65%	0,82%	4,43%	0,16%	1,46%
25-45%	10,71%	3,24%	13,92%	0,67%	6,21%
8-15%	1,70%	0,96%	3,57%	0,14%	0,68%

Figure 2.12 Graph of Slope Gradient by Sub-District in Dili District

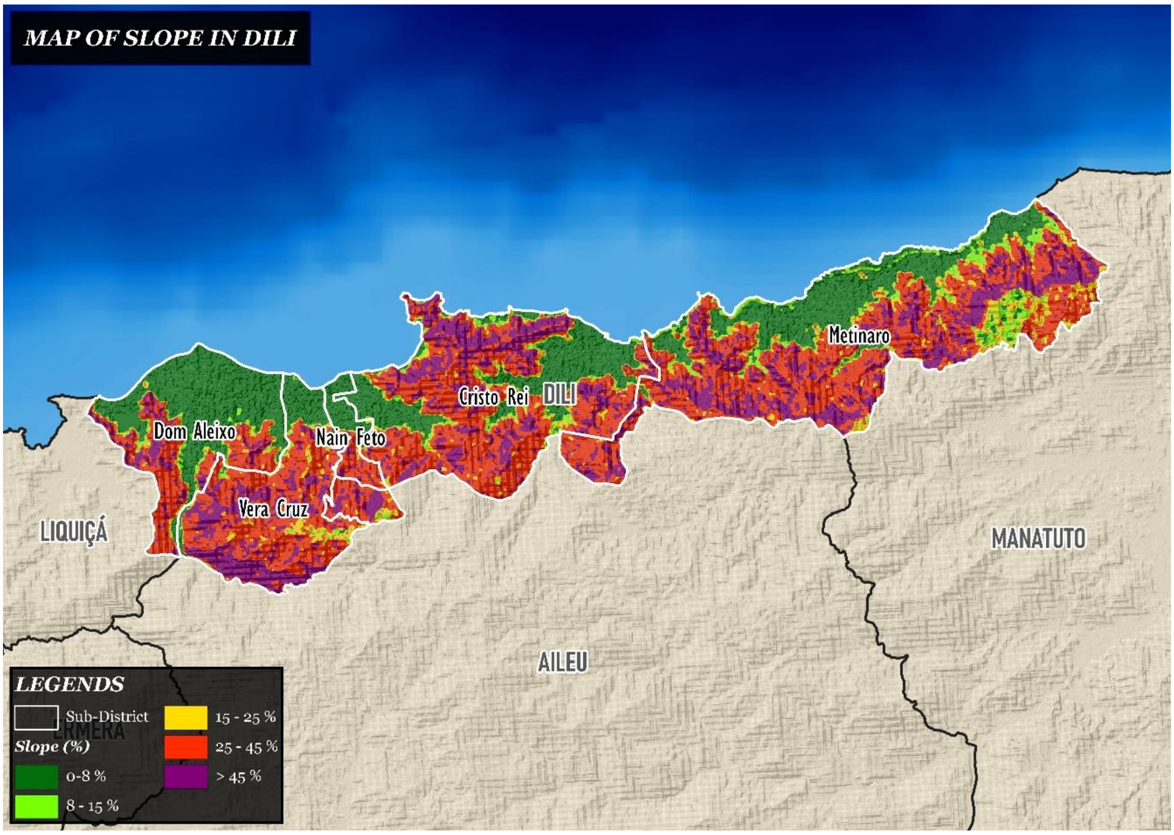


Figure 2.13 Slope Gradient Map of Dili District

2.6 AGROCLIMATIC ZONES

Dili District, as an administrative area and the national capital, functions not only as the center of government and economic activity but also exhibits significant agroclimatic diversity. With a monomodal rainfall pattern concentrated in a single main season from November to March, the area is divided into three principal agroclimatic zones: Zone A, Zone B, and Zone C. These zones are defined by the combination of rainfall pattern and elevation above sea level, each with distinct characteristics and land-use potential. The graph of agroclimatic zones in Dili District is presented in **Figure 2.14.**

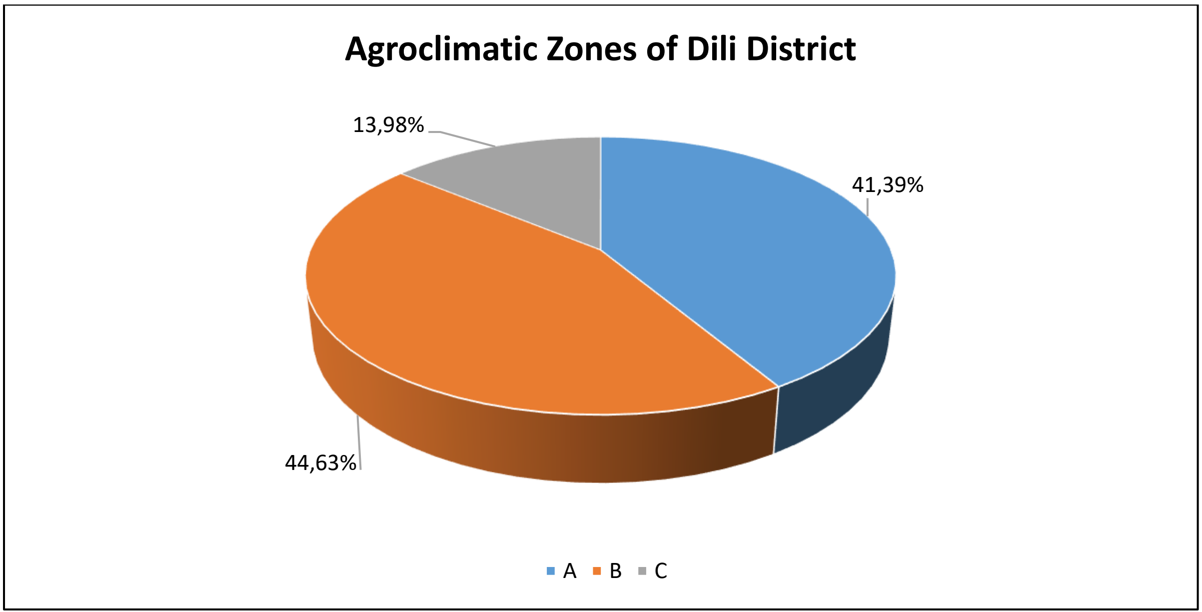
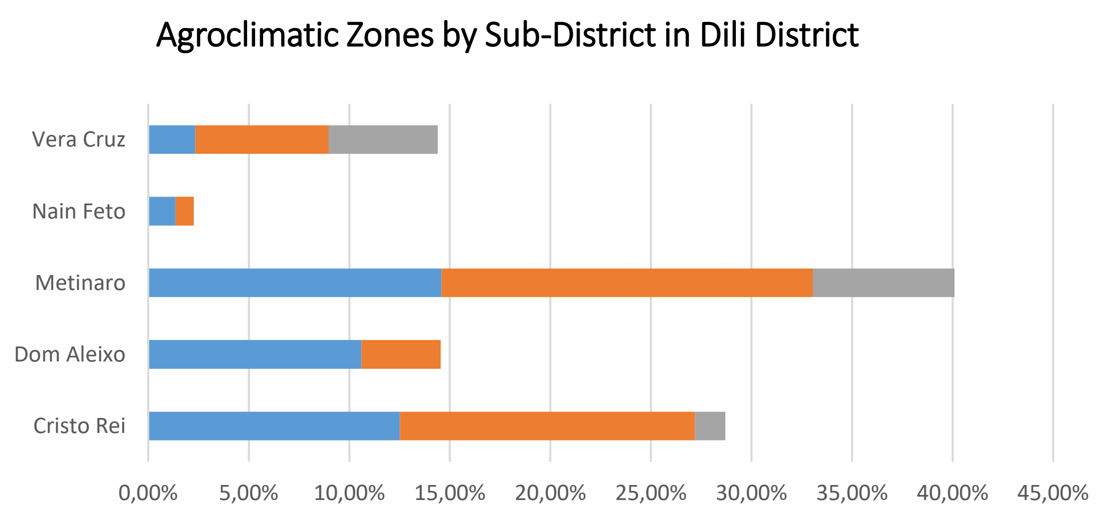


Figure 2.14 Agroclimatic zones of Dili District

Zone A comprises lowlands (< 100 masl) characterized by moderate rainfall and relatively flat topography. This zone is well suited to annual-cropping systems with food crops such as maize, cassava, and pulses. It is distributed across several Sub-Districts, predominantly in Metinaro at 33.10 km^2 (14.58 %), followed by Cristo Rei at 28.41 km^2 (12.52 %), Dom Aleixo at 24.07 km^2 (10.60 %), Nain Feto at 3.07 km^2 (1.35 %), and Vera Cruz at 5.30 km^2 (2.33 %). The total area of Zone A in Dili District is approximately 93.95 km^2 or 41.39 % of the district's agroclimatic zones. The dominance of Zone A in Sub-Districts such as Metinaro and Cristo Rei indicates strong potential for intensive lowland agriculture. In the urban Sub-Districts of Nain Feto and Vera Cruz, the limited extent of Zone A still allows opportunities for small-scale or urban farming.

Zone B represents mid-elevation areas, generally 100 to 500 m asl. It has undulating topography and agroclimatic conditions that enable mixed systems combining food crops and livestock. With a total area of 209.21 km^2 or 44.63 % of Dili's agroclimatic extent, this is the dominant zone and is distributed across the Sub-Districts of Metinaro at 41.92 km^2 (18.47 %), Cristo Rei at 33.30 km^2 (14.67 %), Vera Cruz at 15.05 km^2 (6.63 %), Dom Aleixo at 8.95 km^2 (3.95 %), and Nain Feto at 2.06 km^2 (0.91 %). Its broad coverage makes Zone B highly suitable for integrated farming systems, including perennial crops such as cashew and coconut, as well as cattle and goat husbandry adapted to local agroclimatic conditions. In Cristo Rei and Metinaro, the combination of relatively extensive terrain and the presence of Zone B also offers substantial opportunities for both food-crop development and smallholder livestock management, as shown in **Figure 2.15.**



	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
A	12,52%	10,60%	14,58%	1,35%	2,33%
B	14,67%	3,95%	18,47%	0,91%	6,63%
C	1,51%	0,00%	7,04%	0,00%	5,43%

Figure 2.15 Agroclimatic Zones by Sub-District in Dili District

Zone C, which comprises areas at elevations greater than 500 m above sea level with mountainous topography, has environmental characteristics more suitable for conservation, agroforestry, and deep-rooted perennial crops. This zone occupies approximately 31.73 km^2 or 13.98 % of the total agroclimatic extent in Dili. The areas covered by Zone C are Metinaro at 15.98 km^2 (7.04 %) and Vera Cruz at 12.33 km^2 (5.43 %). In contrast, Zone C in Cristo Rei covers only

3.42 km^2 (1.51 %), and in Nain Feto it occurs in a relatively small extent of 0.01 km^2. The agroclimatic map is presented in **Figure 2.16.**

Overall, the distribution pattern of agroclimatic zones in Dili District shows highly diverse land resource potential. Dominant Zone B provides broad scope for agricultural development adapted to mid-elevation conditions, while Zones A and C complement the district's characteristics to support food security, livestock, and ecosystem conservation. The presence of all three zones, even in highly urbanized Sub-Districts such as Nain Feto and Vera Cruz, indicates that opportunities remain for sustainable development through agricultural practices and environmental conservation.

With an approach based on agroclimatic zonation mapping, land-use planning in Dili can be guided more precisely and grounded in local potential. This is important for supporting food security, sustainable natural resource management, and adaptation to future climate change.

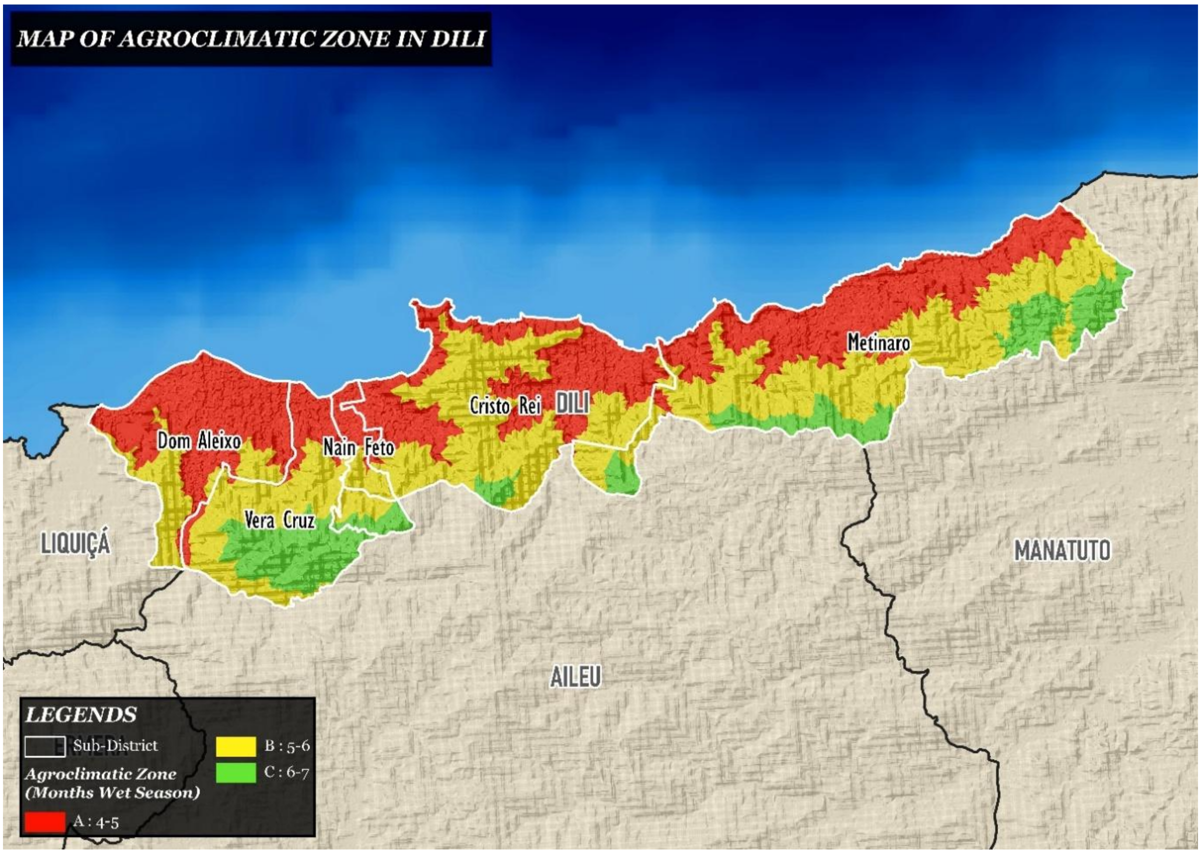


Figure 2.16 Agroclimatic Zones Map District Dili

2.7 EXISTING CONDITIONS

The City of Dili, as the capital of Timor-Leste, functions not only as the center of government and urban activity but also includes upland areas with strategic potential to support development of the agriculture, livestock, and fisheries sectors. These areas were intended to optimize the sustainable use of natural resources to enhance food security and community welfare.

Figure 2.17 Upland Land Conditions in the City of Dili

Observations focused on two administrative areas, namely the Villages of Balibar and Lahane Oriental. The main commodities commonly found in these areas included banana, cassava, mango, and taro, as presented in **Figure 2.18**, which were generally cultivated by local communities as sources of food and income. In addition, an agroforestry system was identified in Lahane Oriental, integrating forestry and agricultural crops within a single area. In practice, the land was planted with a combination of Eucalyptus, cassava, and acacia, each with distinct ecological functions and economic value. However, the use of organic fertilizers remained limited. Most farmers relied on crop residues as organic matter to support soil fertility, while the use of farmyard manure was not yet optimized. This condition indicates opportunities for strengthening capacity and agricultural extension, particularly in applying environmentally friendly technologies and managing local resources more efficiently.

Figure 2.18 Banana and Cassava Cultivated in Dili

A visit to the residence of Xanana Gusmão revealed a diversity of species cultivated in the home garden, including fruit trees such as citrus, mango, soursop, and guava, as well as timber species such as teak and candlenut. Land in the Villages of Hera and Sabuli showed relatively intensive use for the development of horticultural gardens. These two areas served as production sites for various fresh vegetable commodities, including water spinach, spinach, chili pepper, eggplant, and caisim (**Figure 2.19**). With appropriate management and support through policy and infrastructure, these areas have strong potential to be transformed into a competitive and sustainable horticultural production center.

Figure 2.19 Productive Areas for Vegetable Crop Development

Figure 2.20 Rice Fields in Hera

In the Village of Hera, irrigated rice fields were identified as an important component of the local agricultural system. The irrigated rice fields in Hera also provide opportunities for agricultural diversification through intercropping and integration with horticultural commodities (**Figure 2.20**).

In addition to productive irrigated rice fields in the Village of Hera, several marginal lands were identified with physical characteristics less favorable for intensive agriculture. These lands generally had low soil fertility, suboptimal topography, or limited access to water. Nevertheless, such marginal areas retain development potential that can be optimized through innovative approaches, including selecting crop species tolerant of suboptimal conditions and applying soil and water conservation techniques, as shown in **Figure 2.21.**

Figure 2.21 Marginal Land in Hera

Furthermore, the Village of Bairro Pite in the Sub-District of Dom Aleixo also had promising potential for developing dryland agriculture with commodities such as jackfruit, avocado, and corn. With an integrated approach and appropriate technical support, dryland agriculture in Dili had the potential to become an important component in increasing local agricultural productivity, diversifying food sources, and strengthening community economic resilience in the area **(Figure 2.22).**

Figure 2.22 Dryland Agriculture in Bairro Pite

The Villages of Dare and Bairro Pite have community forests as part of spatial planning based on conservation and sustainable natural resource use. The presence of community forests functions not only as a source of timber and non-timber products but also plays an important role in environmental balance through spring protection, erosion control, and carbon sequestration **(Figure 2.23).**

Figure 2.23 Community Forests in the Villages of Darre and Bairro Pite

In addition to the land-use forms identified earlier, extensive and diverse mixed-garden practices were also found in several administrative areas (Villages) such as Sabuli, Meti Aut, Duyung (Sereia), Bidau Santana, Becora, Balibar, and Dare. These systems offer multiple functions, ranging from meeting household consumption needs and environmental conservation to increasing household income **(Figure 2.24).**

Figure 2.24 Mixed Gardens in Dili

The presence of idle land in the Village of Hera is an important aspect in the context of regional development and optimizing land resource use. This area should be considered for use as grazing land. The potential can be optimized to support the smallholder livestock sector. Integration of idle land in Hera as grazing areas can be further enhanced through planned planting of forage crops. This approach not only addresses the need for high-quality feed for livestock but also serves as an environmentally friendly land rehabilitation strategy **(Figure 2.25).**

Figure 2.25 Idle Land in the Village of Hera

The Director of Agriculture of the City of Dili stated that future agricultural development policy would focus on urban farming, such as aquaculture and hydroponics. Accordingly, it is necessary to optimize upland functions through adaptive approaches, including development of agroforestry systems, dryland agriculture, and forage-based grazing lands, given that lowlands are planned for settlement and industrial development. In addition, the presence of cajeput in upland areas offers a significant opportunity to implement agroforestry systems integrated with various agricultural crops. This approach enables optimal land use by combining economic, ecological, and social functions within a landscape-based management system (**Figure 2.26**). Through this system, upland areas function not only as environmental buffers but also as sustainable sources of agricultural production. The researchers recommended implementing an agroforestry system with a proportion of 60 % forest trees and 40 % agricultural commodities, together with conservation vegetation, as a form of landscape-based sustainable agriculture.

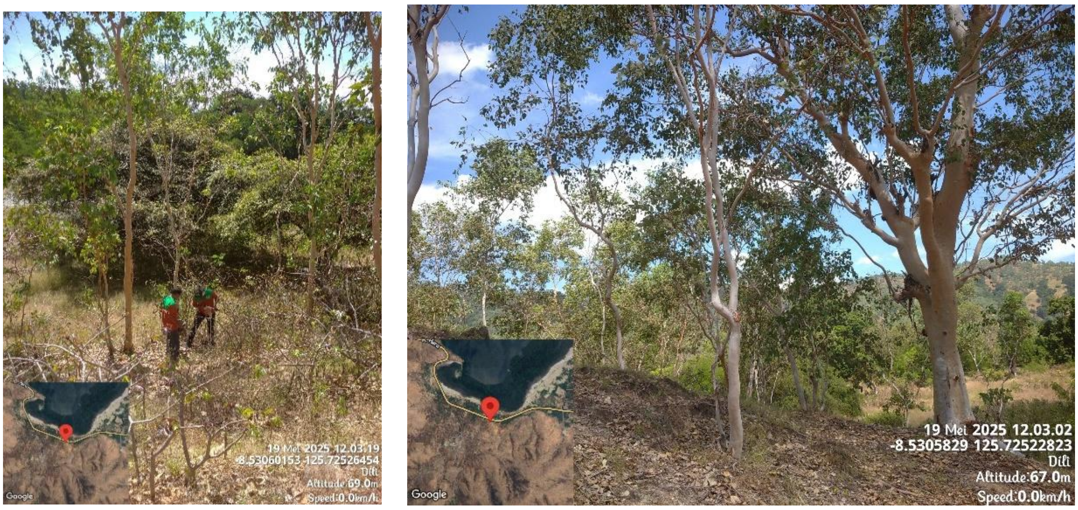


Figure 2.26 Agroforestry in Dili

The City of Dili represents a landscape rich in potential, spanning agriculture, community forestry, and sustainable urban development, with integration of upland uses for agroforestry, dryland farming, and grazing, and lowland uses for settlement and industry.

2.8 *Chromolaena odorata*

Chromolaena odorata (**Figures 2.27** and **2.28**) is a flowering weed in the family Asteraceae that grows in tropical and subtropical regions. The species is native to North America, Mexico, and the Caribbean, and subsequently spread widely to Asia, Africa, and Australia through human activities and natural phenomena (Day *et al*., 2013). It occurs in developing countries such as Timor-Leste, with significant impacts on the environment and local economies.

In tropical Asia, *C. odorata* is commonly found from lowlands up to 500 m asl, especially in open areas such as coconut and rubber plantations, home gardens, and grazing lands (Peniwiratri and Arbiwati, 2021). Its morphological characteristics include a cylindrical hairy stem, simple leaves with serrated margins, and compound inflorescences that are bluish when young and turn brown with age **(Figure 2.28)**. Chemically, *C. odorata* contains active compounds such as flavonoids, tannins, alkaloids, saponins, and essential oils (Jamatia *et al*., 2024). These constituents have been used as raw materials in traditional medicine to treat diabetes, burns, hypertension, and skin infections (Jamatia *et al*., 2024).

Figure 2.27 *Chromolaena odorata* plant
(Source: Researcher Documentation, 2025)

In Timor-Leste, *Chromolaena odorata* was first recorded in the 1980s and spread rapidly due to slash-and-burn practices and a dry tropical climate that favors its growth (Day *et al*., 2013). *C. odorata* can grow on various soil types, including nutrient-poor land, and is typically found at elevations of 500 to 2,000 m asl (Westaway *et al*., 2018). Its rapid spread indicates strong adaptability but also poses a serious threat to productive agricultural land.

Chromolaena odorata is an invasive weed that threatens agriculture, livestock, and the environment in Timor-Leste. It forms dense, fast-growing stands that inhibit the growth of crops such as corn, coffee, and other horticultural species. It frequently invades newly cleared agricultural land that serves as a primary livelihood for rural communities (Day *et al*., 2013). Its deep root system and extensive branching allow faster uptake of soil nutrients than cultivated crops, causing yield declines and weakening food security. In the livestock sector, the leaves of *C. odorata* contain toxic compounds that can cause liver damage in cattle and goats if consumed in large quantities (Day *et al*., 2013; Jamatia *et al*., 2024).

Figure 2.28 Flower Structure and Leaves of *Chromolaena odorata*
(Source: Researcher Documentation, 2025)

Weed dominance in grazing lands reduces forage availability, lowers grazing capacity, and decreases farmers' income (Westaway *et al*., 2018). Ecologically, it dominates native vegetation and disrupts the regeneration of local species important for biodiversity (Mugwedi, 2020). Its biomass dries readily and increases fire risk during the dry season (Day *et al*., 2013), accelerating land degradation, reducing environmental quality, and diminishing soil microbial communities that help maintain soil fertility.

Despite being considered harmful, *Chromolaena odorata* has several potential uses. It has been used as an indicator of soil fertility; mixing *C. odorata* biomass with farmyard manure has been reported to increase phosphorus content in sandy soils and to support the growth of cultivated crops such as shallot. Its high organic matter content also makes it a potential feedstock for environmentally friendly organic fertilizer. In Vietnam, the leaves of *C. odorata* are used to treat soft-tissue wounds and leech bites, while in Africa the plant is used as a natural antiseptic. *C. odorata* biomass can also be processed into high-quality vermicompost through biodegradation with the earthworm *Eisenia fetida*. The resulting compost contains essential nutrients such as nitrogen, phosphorus, and potassium, making it a potential alternative for sustainable organic fertilizer.

III. RESEARCH METHODS

The study was conducted in Dili District, Timor-Leste, with the primary objective of assessing land suitability for agricultural development. Data were collected through field surveys, laboratory analyses, and the use of geospatial information systems. The research took place from May to June 2025 with a focus on direct field observations, soil sampling, interviews with local farmers, and geographic information system-based mapping. Each research stage was organized systematically to obtain accurate information to support sustainable land management planning.

3.1 RESEARCH DESIGN

A. Methodological Approach

This study employed both quantitative and qualitative approaches. The quantitative approach aimed to obtain numerical data for statistical analysis, whereas the qualitative approach was used to explore farmers' understanding and experiences in managing agricultural land (Trigunasih, 2016). The methods included field observation and laboratory analysis, including soil sampling and interviews with local communities.

B. Sampling Point Determination

Sampling points were selected using a Village-based approach that considered factors such as land-use practices, agricultural traditions, and community dynamics. This approach was designed to represent the homogeneous land units in the area and to yield results that accurately reflect field conditions. Soil sampling was carried out randomly and compositely using soil augering. Each land unit was represented by one composite soil sample, collected at a depth of 0 to 30 cm for annual crops and 30 to 60 cm for perennial crops. Approximately 1 kg of soil was collected per sample for laboratory analysis.

C. Observation of Soil Morphology

During soil sampling, environmental conditions were observed and recorded using a soil observation form. Parameters included soil color, texture, structure, consistency, and drainage conditions. For more detailed analysis, ring samples of undisturbed soil were taken to measure bulk density (BD) and soil porosity, which inform land fertility and water-holding capacity (Sukarman et al., 2017).

D. Interviews and Questionnaires

In parallel with the field survey, structured interviews and questionnaires were administered to farmers using purposive or judgmental sampling, considering respondents' experience and expertise in agriculture (Sekaran and Bougie, 2013). Data collected included cropping patterns, agricultural constraints, and prevailing land-use systems in the study area.

E. Land Suitability Evaluation

Field survey results, climate data, and laboratory analyses were compiled and evaluated using the agroecosystem land suitability assessment system based on the criteria of Ritung et al. (2011). The classification method referred to the FAO (1976) framework with a matching approach, namely aligning land characteristics with the growth requirements of the evaluated crops. The agricultural commodities assessed included food crops, horticultural crops, and industrial crops.

3.2 RESEARCH PROCEDURES

A. Literature Review

The literature review stage aimed to compile secondary data to support this study. The data collected included administrative maps of the study area, geographic conditions, agricultural land area, and agricultural commodity production data. Climate data analyzed included temperature, rainfall, dry months, and relative humidity. In addition, previous studies relevant to land suitability evaluation were reviewed to strengthen the theoretical foundation of this research.

B. Land Unit Analysis

Land Unit analysis aimed to delineate land units as a basis for planning field observations. The resulting homogeneous land units were used as references for soil sampling and for preparing the land suitability map. Land Unit analysis comprised:

a. Interpretation of the Digital Elevation Model (DEM) to analyze landforms and slope gradient.
b. Satellite imagery analysis to verify actual land-use patterns, particularly in areas that had undergone land conversion such as rice fields, settlements, and other infrastructure.
c. Use of supporting data, including slope gradient maps, geological maps, and soil type maps, to strengthen land-unit delineation.
d. Overlay of thematic maps to generate homogeneous land units that would serve as the basis for soil sampling.

C. Field Survey

Field surveys were conducted to verify the conformity of sampling points with actual field conditions. If discrepancies were found between land-use analysis results from satellite imagery and on-the-ground conditions, adjustments were made by establishing new sampling points. Sampling points were determined based on satellite imagery analysis and the latest field conditions.

In addition, interviews were conducted with local farmers to obtain supplementary information on farming practices and constraints in land management. Observations focused on environmental factors affecting agricultural productivity, such as soil drainage, effective soil depth, erosion risk, flood risk, and the presence of surface rock outcrops (Ritung et al., 2011).

Soil sampling was carried out using the soil augering method at depths of 0 to 30 cm for annual crops and 30 to 60 cm for perennial crops. The collected soil samples were then analyzed in the laboratory to identify soil physical and chemical properties that influence land fertility. Climate data, including temperature, rainfall, and relative humidity, were obtained from local climate observation stations and presented in tabulated form. The results of the land suitability evaluation and the characteristics of each land unit are presented in **Table 3.1**, while the distribution map of land suitability is shown in **Figure 3.1.**

Table 3.1 Relationship among Parameters, Data Acquisition, and Data Sources

No	Parameter	Data Acquisition		Data Source
		Primary	Secondary	
1	Temperature		√	Remote Sensing/ Climatology of Timor-Leste
2	Rainfall		√	Remote Sensing/ Climatology of Timor-Leste
3	Dry Months		√	Remote Sensing/ Climatology of Timor-Leste
4	Humidity		√	Remote Sensing/ Climatology of Timor-Leste
5	Drainage	√		Field Survey
6	Soil Texture	√		Laboratory Results
7	Coarse fragments	√		Field Survey
8	Effective Soil Depth	√		Field Survey
9	Cation exchange capacity (CEC)	√		Laboratory Results
10	Base saturation (BS)	√		Laboratory Results
11	Soil pH	√		Laboratory Results
12	Soil organic Carbon (SOC)	√		Laboratory Results
13	Total N	√		Laboratory Results
14	P_2O_5	√		Laboratory Results
15	K_2O	√		Laboratory Results
16	Salinity	√		Laboratory Results
17	Alkalinity	√		Laboratory Results
18	Slope gradient	√		Field Survey
19	Erosion hazard	√		Field Survey
20	Flood hazard	√		Field Survey
21	Surface rock cover	√		Field Survey
22	Rock outcrops	√		Field Survey

D. Laboratory Soil Analysis

The following parameters were measured to determine soil properties and characteristics of the laboratory samples:

a. Soil organic carbon (SOC) by the Walkley and Black method (%).

b. Total N by the Kjeldahl method (%).

c. Soil texture by the pipette method.

d. Soil pH by potentiometer in H2O (1:2.5).

e. Available P (ppm) and available K (ppm) by Bray-1 when soil pH < 7 and by Olsen when soil pH > 7, reported as (mg/100 g).
f. Salinity (dS/m) using the potentiometer method (H2O 1:2.5).
g. Cation Exchange Capacity (CEC) (cmol) and Base Saturation (BS) (%) using NH4OAc 1N pH 7 as the extraction.
h. Total Phosphorus (mg/100 g) and Total Potassium (mg/100 g) determined using the 25 % HCl method.
i. Total Zinc (ppm) determined using the DTPA extraction method and Available Zinc (ppm) determined using the HNO3-: $HClO_4$ digestion method.
j. Total Sulfur (ppm) and Available Sulfur (ppm) determined using the spectrophotometric method.
k. Soil fertility status determined according to PPT (1995).
l. Erosion hazard assessed using the Universal Soil Loss Equation (USLE).

E. Land Suitability Analysis

Field observations and laboratory results were tabulated as agroecosystem land characteristics and qualities. Agroecosystem land suitability was then analyzed by matching land characteristics and qualities with crop growth requirements to obtain land suitability classes according to Ritung et al. (2011). Classification of land suitability was carried out to the land-unit level.

Land suitability classes were defined as actual suitability and potential suitability. Actual suitability for each homogeneous land unit (SLH) was determined by matching land characteristics and qualities with crop requirements without improvements to limiting factors. Potential suitability was determined by considering inputs and management measures applied to each SLH, assuming improvements to the limiting factors.

F. Planning for Agricultural Commodity Development

Commodity planning was based on potential land suitability for the commodities to be developed, with the highest land suitability class for each crop used as the primary parameter. Additional parameters included the dominant land use in each Land Unit and farm feasibility.

G. Land-Use Guidance

Land-use guidance was prepared at the land-unit level, based on the highest land suitability class followed by lower classes, along with measures to manage and improve limiting factors. Preparation of digital maps using geographic information systems facilitated information interpretation. The information included agroecosystem land suitability, land-use guidance, and agricultural commodity zoning. Land suitability maps were prepared based on SLHs and the results of agroecosystem land suitability classification.

The classification results were mapped for each evaluated commodity group. Crop-specific land suitability was presented in an agricultural commodity zoning map, while land-use planning was presented in a land-use guidance map. The research flowchart is presented in **Figure 3.1.**

H. Data Analysis Using Geographic Information System Technology

The land suitability information system comprised spatial data (the SLH map) and attribute data (land suitability classes). Integration of these components using QGIS 3.10 produced information on land suitability classes for food crops, horticultural crops, and plantation crops based on the evaluation results. The land suitability maps, database, and land-resource information were compiled using land suitability data and criteria, taking into account developments in use such as varieties, cultivation technology, and land management.

The land-use planning map was derived from land suitability classification and commodity zoning. This planning map is a thematic digital map that provides land-use guidance for various food, horticultural, and plantation crops. Digital maps were created by converting primary and secondary data and information in raster and analog formats into digital data. Advantages of digital maps include ease of error correction, ease of copying, long-term storage, and the ability to measure distance and area on screen without time-consuming and costly field measurements (Nugroho and Yarianto SBS, 2010). The resulting outputs comprise printable analog or hard-copy maps in *.jpeg format, and integrated digital maps in *.dbf or shapefile *.shp formats that are easy to copy and informative. The map marginalia display the map title followed by, in order, the author’s name, scale bar, and legend box (homogeneous land units, study area, soil type, slope, and land use), sources, latitude and longitude coordinates, and the datum used.

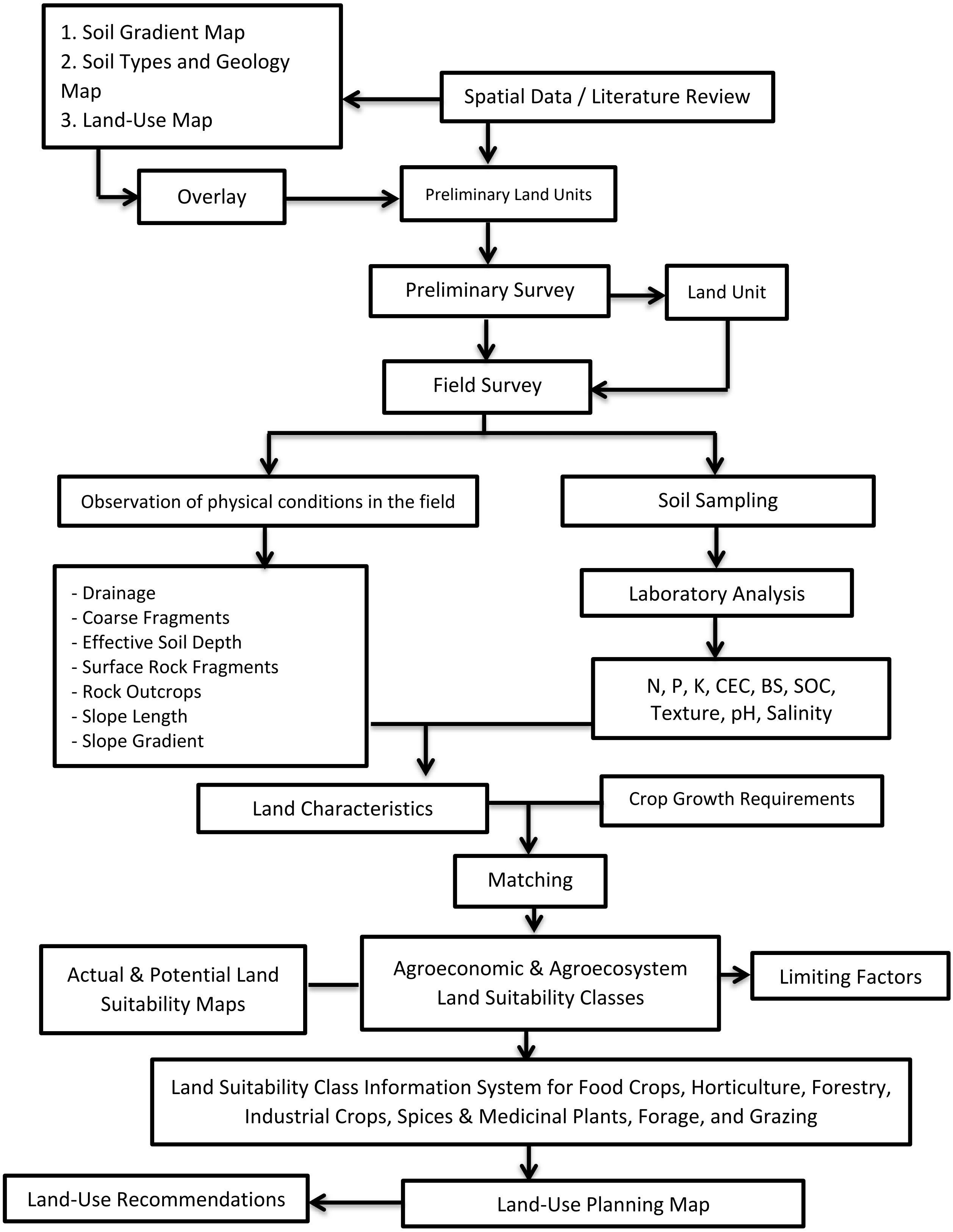


Figure 3.1 Research Process Flowchart

3.3 GEOGRAPHIC INFORMATION SYSTEMS TECHNOLOGY

A Geographic Information System (GIS) is a system containing spatially referenced data that can be analyzed and transformed into information for specific purposes. A GIS can:

1. Collect, store, and retrieve information based on spatial location.
2. Identify locations within a given area that meet predefined criteria.
3. Explore relationships among multiple datasets within a given area.
4. Facilitate the selection and distribution of data for particular analytical application models that can estimate the impacts of alternatives on conditions in a specific area.
5. Present a given area graphically and numerically, both before and after analysis (Murai, 2006).

Across various definitions of GIS, several common keywords recur: geographically referenced data, analysis of data (spatial and attribute) to produce information, and specific objectives. Therefore, compared with other systems, GIS has distinct capabilities for handling data and information from a geographic perspective. This is particularly relevant to development planning, which is carried out in the context of specific regions.

The term “geographic” is a subset of “spatial.” These terms are often used interchangeably, leading to a third term, “geospatial.” All three terms convey the same meaning in the context of GIS. Use of the term “geographic” refers to matters concerning the Earth: its two- or three-dimensional surface (Prahasta, 2005).

The term “geographic information” refers to information about places located on the Earth’s surface, knowledge of the position where an object is situated on the Earth’s surface, and information on attributes present on the Earth’s surface for which the position is given or known (Prahasta, 2005).

GIS is a formal entity comprising various physical resources related to objects on the Earth’s surface. Thus, GIS is also a type of software that can be used for input, storage, manipulation, display, and output of geographic information together with its attributes (Prahasta, 2005). **Figure 3.2** shows the components that constitute a GIS.

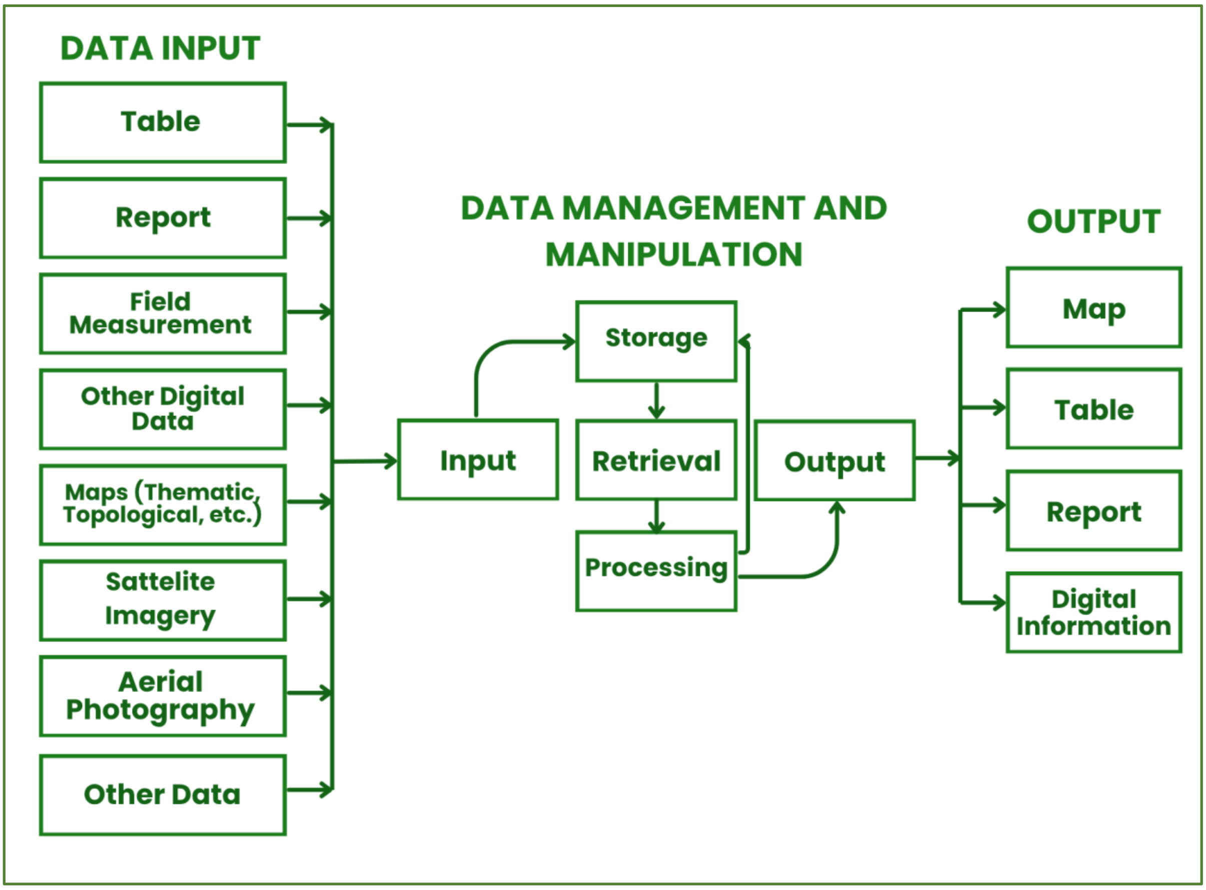


Figure 3.2 Components of a Geographic Information System (GIS)
(Source: Prahasta, 2005)

Geographic Information Systems (GIS) can be applied across many fields. Several capabilities of this system are (Prahasta, 2005):

1. Cartographic Capabilities

   With these capabilities, GIS users can produce maps and technical drawings effectively and efficiently. Cartographic capabilities include digitizing, graphic visualization, interactive line manipulation, and plotting.

2. Data Management Capabilities

   GIS can store, process, and manipulate geographically referenced data. These management capabilities also include attribute processing, namely storing and displaying specific attribute data associated with particular geographic features.

3. Analytical Capabilities

   Analytical capability refers to interpreting and studying collected data and information for specific purposes. This includes engineering-function analysis, prediction or forecasting, computational operations, demographic analysis, sociocultural analysis, analysis of various regions and Districts, presentation of graphs and tabulations, overlay analysis, logical analysis, and selection analysis.

4. Integration of GIS and Multimedia

   Integrating GIS with multimedia enhances the presentation of GIS analysis results, making them more engaging and easier to read and understand.

A. GIS Processes and Components

GIS essentially performs six processes (Prahasta, 2005):

1. Data Input

   Before geographic data can be used in GIS, they must be converted into digital format, a process called digitizing. In this study, on-screen digitizing was used, whereby data conversion can be performed with scanning technology.

2. Data Transformation

   GIS data types may need to be transformed or manipulated to conform to the system, for example when scales differ. Prior to integration, data must be transformed to a common scale. Transformations may be temporary for display purposes or permanent for analysis.

3. Editing

   Editing is the stage of digital correction. Corrections may involve adding or removing arcs or features by editing excess arcs (overshoot) or adding missing arcs (undershoot). Editing is also used to manually add arcs when creating polygons, lines, or points.

4. Data Management

   After spatial data are entered, processing of descriptive data follows, including annotation (adding text to coverages), labeling (providing information on the relevant map), and attributing, in which each label ID produced during labeling is assigned attributes that provide information about the polygon or arc it represents.

5. Query and Analysis

   In GIS, queries are essentially analyses performed in tabular form. Fundamentally, GIS analysis employs spatial analysis. Two key strengths are:

   a) Proximity Analysis

      A distance-based geographic analysis among layers. Questions include, for example, how many houses are in a given watershed. Proximity analysis uses buffering, that is, building supporting zones around a layer at a specified distance to assess the closeness of relationships among features.

   b) Overlay Analysis

      The process of integrating data from different layers is called overlay. While conceptually a visual operation, analytically it requires combining more than one layer. An example is overlay or spatial join, such as integrating soil, slope, and vegetation data or land ownership with assessed land tax values.

6. Visualization

   For some types of geographic operations, the most effective final outputs are maps or graphics. Maps are highly effective for storing and conveying geographic information.

B. GIS Components

In general, a GIS operates through the integration of five components, namely hardware, software, data, people, and methods, described as follows (Budianto, 2010).

1. Hardware

   This is the computer on which the geographic information system operates. At present, GIS can run on a wide range of hardware, from centralized server computers to desktop computers used as stand-alone systems or in network configurations.

2. Perangkat Lunak (*Software*)

   GIS software provides the functions and tools needed to create, process, analyze, and display geographic information, for example:

   a. Tools for data input and manipulation.

   b. A database management system (DBMS).

   c. that support geographic query, analysis, and visualization.

d. A graphical user interface (GUI) for accessing the tools.

3. Data

   Data are a crucial component of GIS. Fundamentally, GIS works with two geographic data models: vector and raster. The vector model represents and stores spatial data using points, lines or curves, or polygons along with their attributes. The raster model represents and stores spatial data using a matrix or pixels that form a grid. Each pixel or cell has its own attributes, including its unique coordinates located at a grid corner, at the grid center, or elsewhere. The accuracy of this data model depends strongly on the resolution or pixel size of the grid on the Earth's surface.

4. Human

   GIS technology is not beneficial without people to manage the system and develop plans applicable to real-world conditions. As with other information systems, GIS users range from technical specialists who design and maintain the system to users who employ GIS to support their day-to-day work.

5. Methods

   An effective GIS aligns a sound design plan with real-world rules. The modeling methods and implementation will differ for each problem.

C. Data Processing in GIS

GIS data processing includes the following activities (Budianto, 2010):

1. Base Map Digitizing

   Digitizing was performed on the Rupabumi Indonesia map at a scale of 1:25,000, which served as the basis for conducting the survey and for map digitizing, including data updating. Data were converted to digital format layer by layer with topology.

2. Data Import

   Data import was carried out for satellite imagery whose formats differed from the processing software. This format conversion is an initial step commonly performed in image processing.

3. Geometric Correction of Imagery

   Geometric correction is required to assign a map reference or coordinate system to satellite imagery. This can be done by three methods: image-to-image (using previously corrected imagery), image-to-ground (map coordinates measured directly in the field using a GPS, Global Positioning System), and image-to-map.

4. Digital Image Processing

   Satellite imagery was processed digitally to enhance the standard 25 m spatial resolution of multispectral bands to 15 m color. This was conducted using image data fusion with the Brovey transform. The process supported visual interpretation of planimetric features such as transportation networks, rivers, and other planimetric objects.

5. Satellite Image Classification

   Digital classification was also performed, supported by a knowledge-base approach to extract spatial land-use information. Supervised classification and filtering were applied. This digital classification model, which provides grouping accuracy superior to unaided visual interpretation, was complemented by visual interpretation of Brovey-transformed imagery. Digital classification grouped recognizable feature sets as samples (sampling areas). The image-processing software then automatically searched for pixel arrays similar to the sample areas to form classes. The classified imagery was subsequently field-tested to identify discrepancies and uncertain pixels. Deviations identified during field testing were required to be less than 3 % of the test area. The classification results were used to update the digitized Rupabumi Indonesia map using the digital light table effect and raster–vector overlay.

6. Updating Spatial Information

   Spatial information on maps was updated using raster–vector overlay complemented by the light table effect to interpret and analyze spatial land-use information. Planimetric spatial information was updated via raster–vector overlay. This approach combined digital image classification and visual image interpretation to obtain accurate updated spatial data. Features deemed important to map but not clearly visible on imagery were mapped using GPS during field surveys. The final output of the updating process was digital land-use spatial data in GIS.

7. Field Survey

   Field surveys were conducted to correct laboratory image-interpretation errors, investigate uncertain spatial features on imagery, and plot positions of important objects that could not be extracted directly from the imagery.

8. Reinterpretation and Editing

   This step improved inaccurate image-interpretation results based on fieldwork findings. It was performed digitally in the laboratory to obtain final, up-to-date spatial information.

9. Edge Matching

   Edge matching was carried out to ensure continuity across adjacent map sheets. This process was performed digitally on all adjacent layers.

10. Digital Cartography and Map Production

    Cartographic processing was conducted fully in digital form to obtain map layouts that meet established cartographic standards. The cartographic design followed the thematic cartography model issued by Badan Informasi Geospasial.

11. Database Development and Modeling

    A database was developed for all GIS spatial data produced, comprising digital spatial land-use data, attribute data, and the thematic maps generated.

IV. LAND CHARACTERISTICS

4.1 TEMPERATURE

Temperature is a critical agroclimatic parameter because it directly affects plant physiological processes such as photosynthesis, respiration, and transpiration (Mujiyo *et al*., 2020). Temperature also determines soil moisture capacity and water requirements in cropping systems, making it an essential element in planning sustainable natural resource management. This assessment integrated field temperature measurements with geospatial data derived from the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM), applying the Braak formula to estimate temperature as a function of elevation using a thermal lapse-rate approach (Hidayat and Farihah, 2020). The mapping shows interactions among topography, elevation, and microclimate that influence the spatial distribution of temperature.

In Dili District, high temperatures greater than 26 °C predominated. High-temperature areas occurred in Cristo Rei Sub-District, as shown in **Figure 4.1.** This area lies along the northern coast of Timor-Leste. These conditions support tropical crops such as corn, peanut, cassava, watermelon, coconut, and robusta coffee (Mujiyo *et al*., 2020). However, elevated temperature increases evapotranspiration and reduces soil moisture, requiring technical interventions such as efficient irrigation systems, soil and water conservation techniques, and the use of heat-tolerant varieties. Areas with temperatures of 24 to 26 °C are classified as warm to hot and are suitable for horticultural commodities such as tomato, red chili pepper, papaya, banana, and eggplant. Although supportive, the risks of drought and uneven temperature distribution remain agronomic challenges that must be managed with locally adapted agroclimatic practices (Hidayat and Farihah, 2020).

Meanwhile, zones with moderate temperatures of 21 to 24 °C were limited in extent but were dominant in the Vera Cruz Sub-District. These conditions have optimal potential for developing highland crops such as potato, cabbage, carrot, and strawberry, particularly when supported by appropriate humidity and elevation. Therefore, land management strategies should be specific and adaptive based on the thermal zonation identified through geospatial modeling and climate data to support sustainable agricultural development (Mujiyo *et al*., 2020; Hidayat and Farihah, 2020).

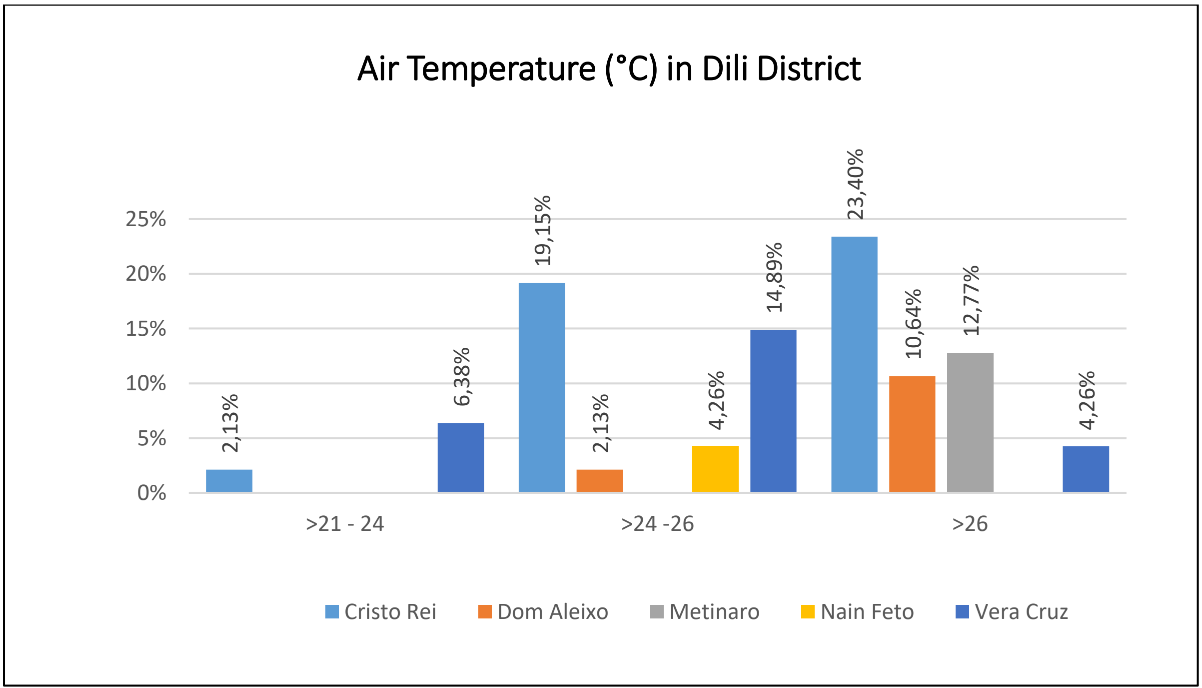


Figure 4.1 Air Temperature Data (°C) in Dili District

4.2 RAINFALL

Identification of land characteristics in Dili District through direct field observation was a relevant approach for evaluating land suitability for sustainable agriculture. Key parameters such as rainfall, number of dry months, drainage conditions, soil texture, slope gradient, and potential erosion hazard were important indicators for determining land capacity to support efficient cropping systems adapted to local agroclimatic conditions. Rainfall was a crucial aspect of this evaluation because it directly affects groundwater availability, soil moisture, and micro-ecosystem dynamics. Annual rainfall, defined as the total precipitation received by an area within one year, is a primary indicator for determining agroclimatic zones and land suitability classes. The level and distribution of rainfall determine the types of commodities that can be cultivated, the efficiency of irrigation systems, and the potential risks of drought or waterlogging (Mujiyo *et al*., 2020).

Based on field observations, Dili District showed variation in rainfall intensity among Sub-Districts. Cristo Rei and Vera Cruz, which receive annual rainfall of 1,000 to 1,500 mm/year, fall within a climatic category that agronomically supports naturally irrigated farming systems. In contrast, Dom

Aleixo exhibited lower dominant rainfall, in the range of 500 to 1,000 mm/year. This condition is influenced by the geographic position of Dom Aleixo on the northern coast of Timor Island and the presence of mountains to its south. Moist winds originating from the south tend to lose much of their moisture when crossing the mountains, thereby reducing the rainfall reaching Dom Aleixo. These conditions indicate the need for technical interventions such as artificial irrigation, the use of drought-tolerant varieties, and the application of water-conservation techniques (Farizi *et al.*, 2024).

This variation in rainfall distribution reflects differing capacities of each area to provide water for cultivation needs. Areas with higher rainfall have greater potential for developing tropical commodities such as rice, corn, and horticultural crops, whereas areas with lower rainfall require more intensive, technology-based water management approaches. Therefore, optimization of water resources through climate- and area-based planning is an important strategy to support sustainable agricultural productivity in Dili District (Aditya *et al.*, 2021).

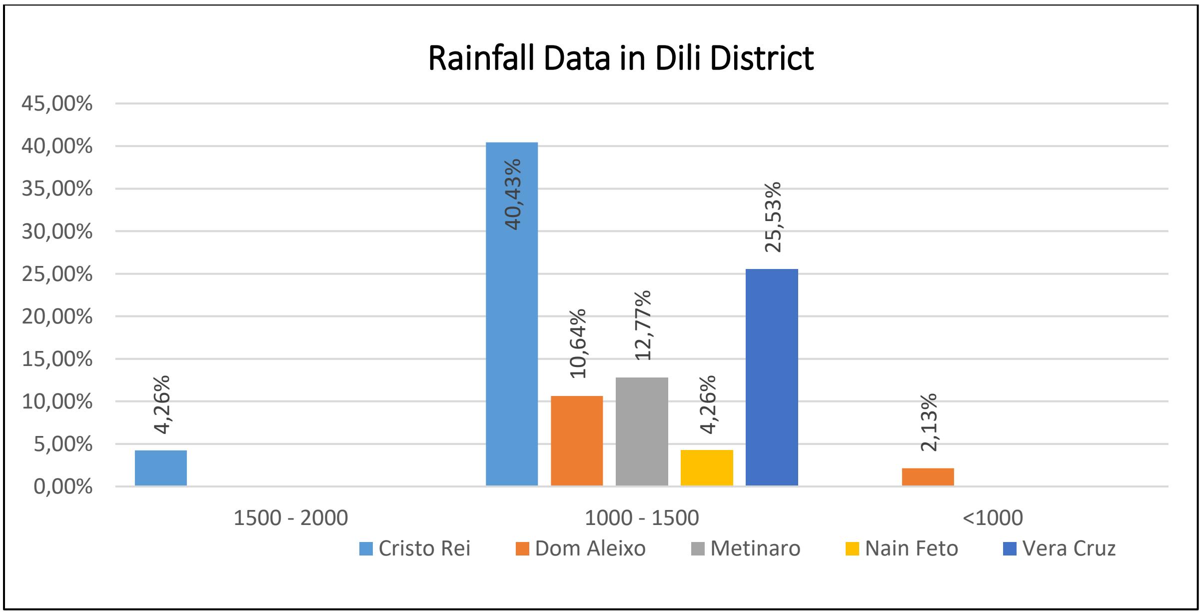


Figure 4.2 Rainfall Data in Dili District

4.3 DRY MONTHS

Variation in the number of dry months across Dili District reflects inter-Sub-District climatic heterogeneity, with direct implications for land suitability and water-management strategies for agriculture. Sub-Districts such as Cristo Rei, Metinaro, Vera Cruz, and Nain Feto predominantly experience more than six dry months per year. Areas with > 6 dry months were identified in Cristo Rei, as shown in **Figure 4.3.** This condition is influenced by Cristo Rei's location on the northern coast and direct exposure to dry east–southeasterly winds. Moist air masses originating from the south tend to release most of their moisture on the southern mountain slopes, leaving northern areas, including Cristo Rei, with much lower rainfall (UNDP, 2013). In addition, the area's relatively flat topography does not favor strong uplift for condensation, limiting rain-cloud formation. The number of dry months is a key parameter for determining a land's capacity to support sustainable cropping systems. According to Gunawan *et al*. (2023), land with > 6 dry months requires more intensive technical approaches and water-conservation measures. That study indicates that, in areas with similar climatic characteristics, water-use efficiency can be improved through approaches based on the economic value of irrigation water and community-based management. Rusmayadi *et al*. (2023) emphasize that traditional flood irrigation commonly used in dry regions causes substantial water losses; in contrast, drip and sprinkler technologies exhibit higher water-use efficiency and can be applied adaptively where dry months predominate. Efficiency- and conservation-oriented water-management strategies are therefore crucial to sustaining agricultural systems in Dili District, particularly in the face of climate change and degradation of water resources.

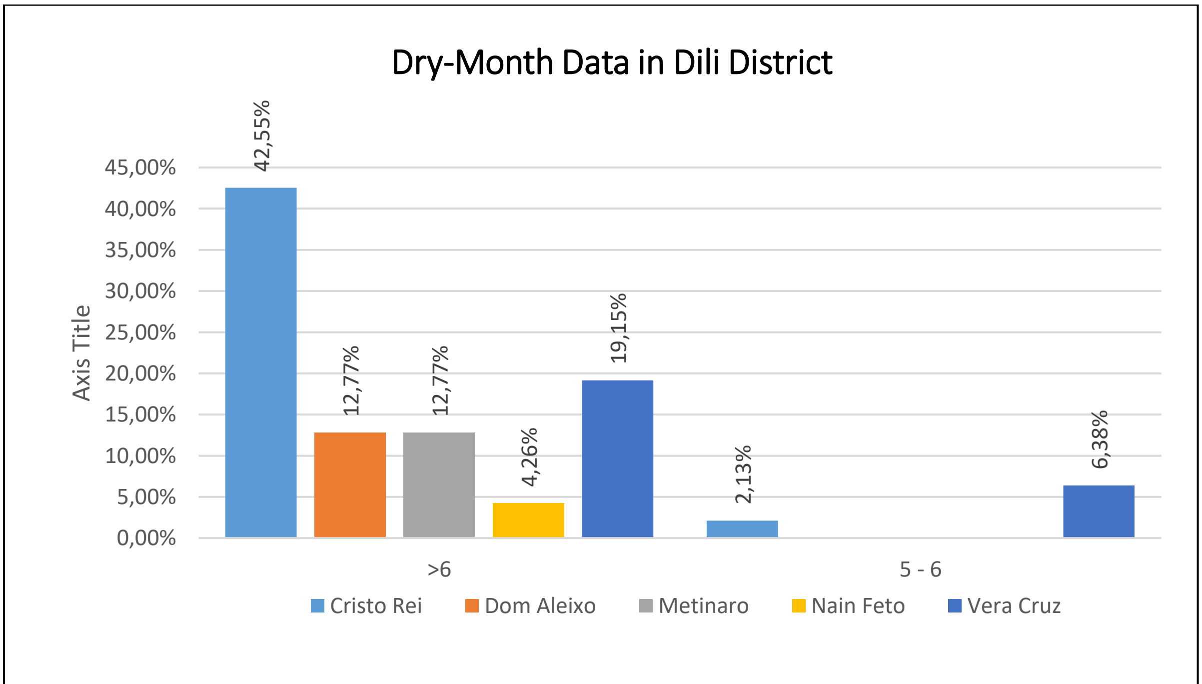


Figure 4.3 Graph of Dry Months in Dili District

4.4 ELEVATION

The distribution of elevation in Dili District shows that most of the area falls within the low elevation category **(Figure 4.4)**. The Sub-District of Cristo Rei occupies the largest portion of this elevation range, followed by Dom Aleixo, Metinaro, and Vera Cruz. The low elevation characteristic indicates that Dili is predominantly composed of coastal plains with relatively flat topography. This condition makes Dili highly suitable for government centers, residential areas, infrastructure development, and economic activities. However, the dominance of lowland areas also results in vulnerability to flooding, waterlogging, and saltwater intrusion.

In addition to low elevations, some areas of Dili District fall within the medium elevation category. Cristo Rei and Vera Cruz contain regions at this elevation, reflecting the presence of hills with moderate heights. Medium elevations play a crucial role in maintaining environmental balance, particularly as water catchment areas and green buffer zones. These areas can also be used for dryland agriculture and plantations, though with some limitations due to slope gradients.

Overall, the topographic characteristics of Dili show a dominance of lowlands that support intensive human activity, complemented by medium-elevation areas that serve strategic ecological functions. This emphasizes that land-use planning and spatial development in Dili should carefully balance the use of lowland areas for urbanization and infrastructure with the protection of medium-elevation hill areas as ecological buffers (FAO, 2007; Department of Statistics Timor-Leste, 2023).

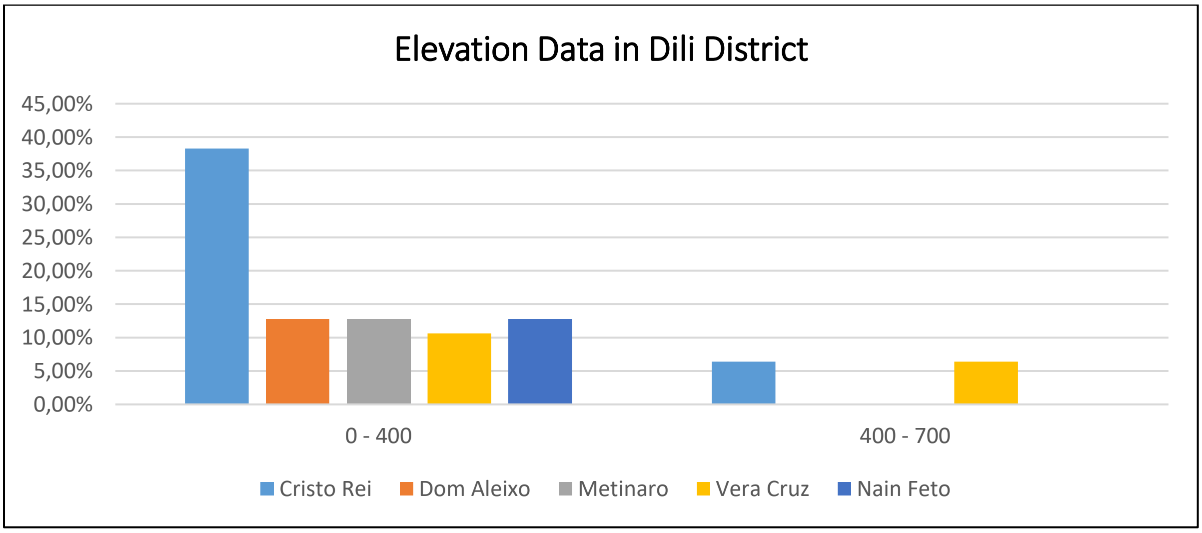


Figure 4.4 Graph of Elevation in Dili District

4.5 DRAINAGE

Drainage conditions in Dili District indicate that most areas have well-functioning drainage, as shown in **Figure 4.5**, particularly in Sub-Districts of Cristo Rei, Vera Cruz, and Metinaro. An optimal drainage system plays a crucial role in maintaining soil hydrological balance, improving aeration, and supporting efficient water distribution for plant needs. Well drainage allows oxygen to enter the root zone, reducing the risk of anaerobic conditions and promoting optimal vegetation growth (Sururi & Fadlurrohman, 2024).

In contrast, areas with poorly drained were identified in several Sub-Districts, such as Dom Aleixo, Nain Feto, and parts of Vera Cruz. This condition can lead to waterlogging, decreased land quality, and impaired plant growth due to poor aeration and high soil moisture. Prolonged waterlogging can cause the accumulation of toxic compounds, significantly reducing land productivity. Therefore, inadequate drainage is an important indicator in planning water management systems and sustainable environmental governance. The concept of eco-drainage becomes relevant, particularly in areas with impaired drainage. Kamila *et al*. (2016) demonstrated that eco-drainage applications can reduce stormwater runoff by up to 51% and improve infiltration capacity through infiltration wells and retention ponds designed according to local conditions.

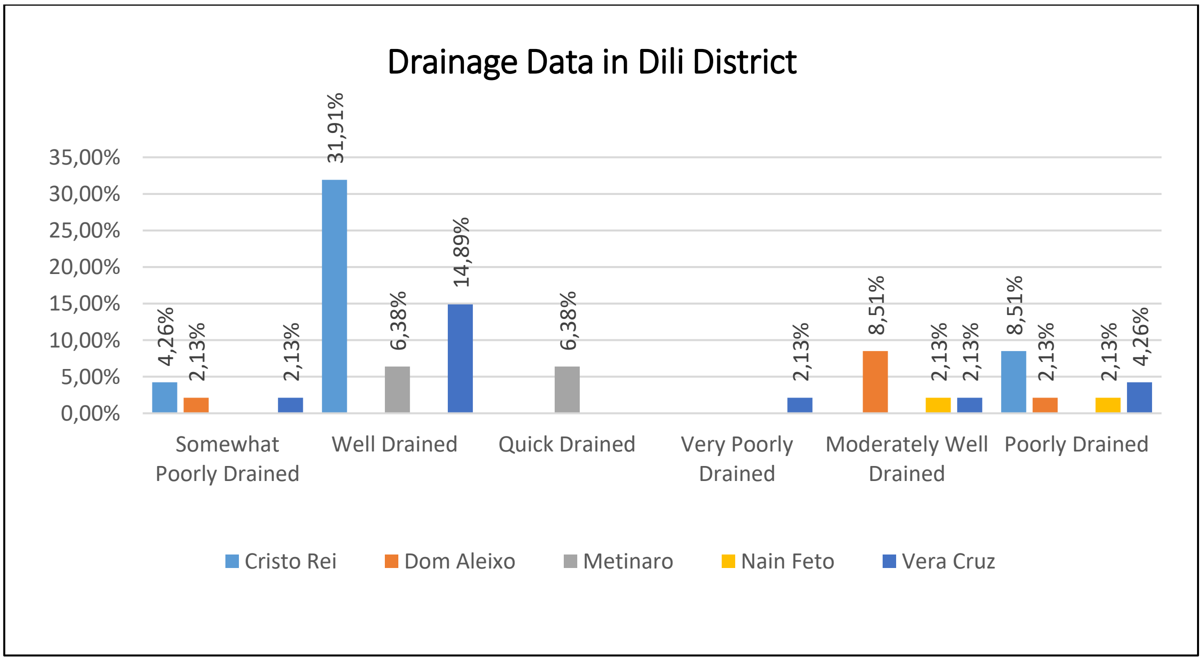


Figure 4.5 Drainage Data (%) in Dili District

4.6 COARSE FRAGMENTS

The characteristics of coarse fragments in the soil are a critical indicator in land suitability evaluation because they directly affect the soil's capacity to retain water, manage infiltration, and support plant root growth. Based on the analysis in Dili District, most areas have a coarse material content of <3%, as shown in Figure 4.6, indicating that the soil in these regions is relatively fertile and suitable for cultivating crops such as sorghum, corn, or tomatoes, which are adaptable to semi-arid climates and fine-textured soils (Mahfut *et al.*, 2015). Areas with a coarse fragments content of 3–15% can still be utilized productively with conservative approaches such as crop rotation and organic nutrient management. Areas with higher coarse fragments content, ranging from 15–35% to 35–60%, have low water retention and are more prone to erosion, making them more suitable for cultivating deep-rooted plants that are tolerant of shallow soils, such as peanuts and cassava, with the support of soil conservation techniques such as terracing and drip irrigation (Ndun *et al.*, 2021; Conceicao, 2013).

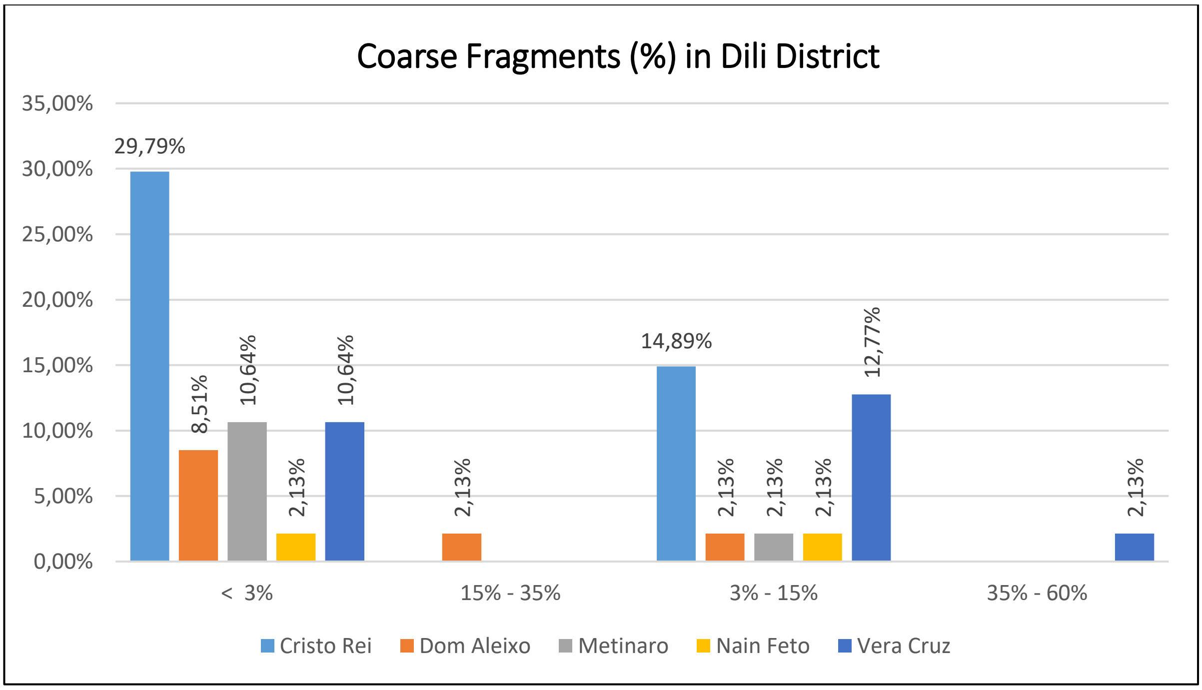


Figure 4.6 Coarse Fragments Data (%) in Dili District

4.7 EFFECTIVE SOIL DEPTH

Effective soil depth is a key biophysical parameter in land suitability evaluation, particularly for agricultural cultivation. This depth refers to the soil layer that can be penetrated by plant roots without physical barriers such as hard rock, plinthite, or massive clay layers. Soils with an effective depth of 90–120 cm allow optimal root development, enhance water retention capacity, and improve nutrient absorption efficiency, thus classified as very suitable land for intensive agriculture (Aditiyas *et al*., 2014).

Based on field observations in Dili District, the distribution of effective soil depth, categorized as deep (90–120 cm) as shown in **Figure 4.7**, is most extensively found in the Sub-District of Cristo Rei. This phenomenon can be explained through a morphogenetic approach, where soil formation processes are stable and not disrupted by geomorphological limiting factors such as severe erosion, shallow sedimentation, or tectonic activity. The relatively flat topography and soil texture that supports water infiltration further enhance the formation of deep and uniform soil profiles. This aligns with findings by Vong (2017), who studied the characteristics of Bobonaro clay soils in Maliana, Timor-Leste, and demonstrated that soils with high effective depth have good agronomic potential, although attention is needed regarding their expansive properties.

The uniform soil depth in Dili District offers significant opportunities for developing intensive farming systems based on mechanization. Deep soils free from limiting layers facilitate land suitability zoning planning and the application of modern agricultural technologies such as precision irrigation and mechanical tillage. A study by Suharto (2006) in Bengkulu also showed that optimal soil depth contributes to groundwater storage capacity and supports the efficiency of conservation-based land use systems.

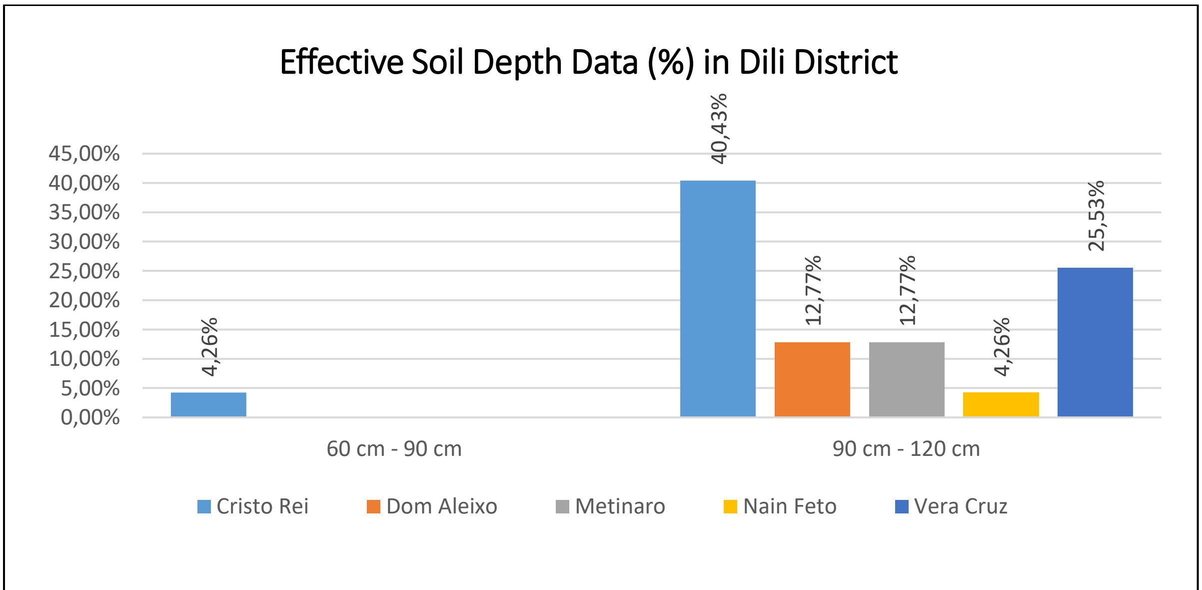


Figure 4.7 Effective Soil Depth Data (%) in Dili District

4.8 SURFACE ROCKS

The characteristics of surface rocks are an important parameter in land suitability evaluation for agriculture, as they directly affect the ease of soil tillage, water absorption efficiency, and land productivity potential. The presence of surface rocks can reduce the effective volume of soil, decrease water retention capacity, and impede root penetration and agricultural machinery. Therefore, analyzing the distribution of surface rocks is essential in determining the physical suitability of land for agricultural activities and other agronomic uses.

The spatial distribution of surface rocks in Dili District has strategic implications for land management and utilization. Dili has diverse categories of surface rocks as presented in **Figure 4.8**. Areas with low rock content (20%) are more suitable for plantation development or require the application of soil conservation techniques to control erosion rates and maintain land productivity. Therefore, adaptive and sustainable land management strategies are needed to optimize land functions based on their physical characteristics in Dili District.

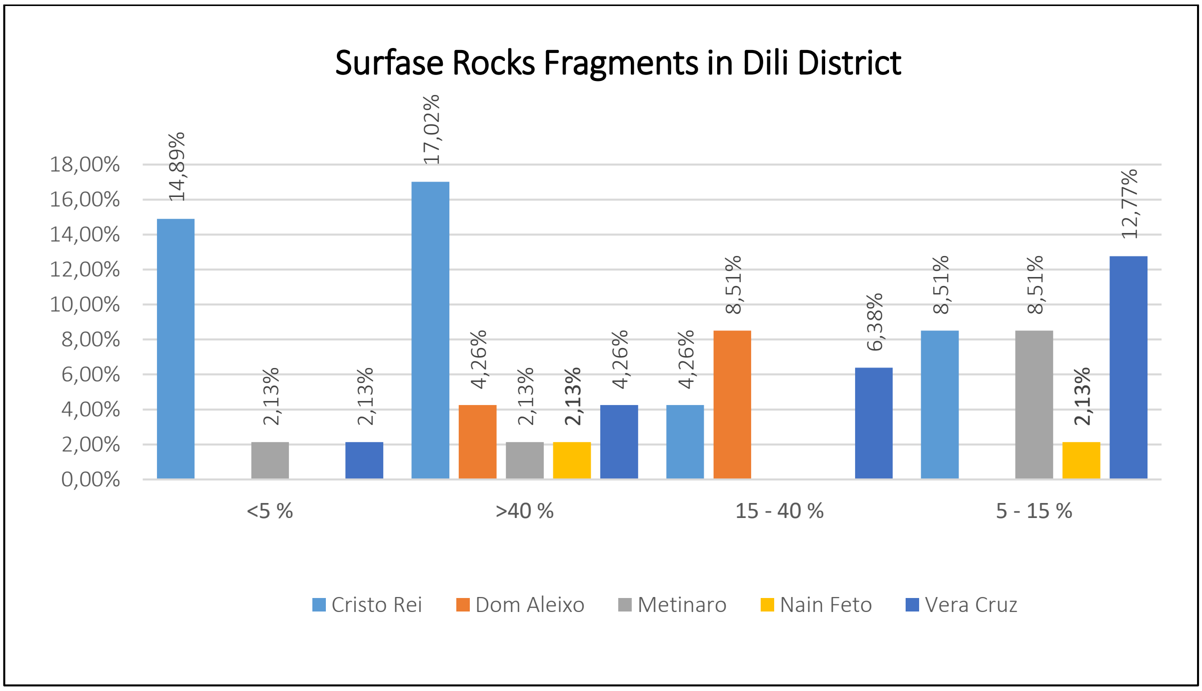


Figure 4.8 Surfase Rocks Fragments Data (%) in District Dili

4.9 ROCK OUTCROPS

Rock outcrops are geomorphological features that play a significant role in the biophysical evaluation of land, especially in regional geology and land use planning. The presence of rock outcrops directly affects physical soil properties such as texture, effective depth, infiltration capacity, and erosion potential. In land suitability studies, this parameter is used to assess the land's limitations for agricultural, forestry, and infrastructure development activities (Ritung *et al*., 2011). In Dili District, Timor-Leste, the distribution of rock outcrops shows a dominance of moderate categories (5–25%), as presented in Figure 4.9. This category indicates that most areas have surface rocks that are not overly dominant, allowing productive land management. Land with rock outcrops >25% typically shows relatively clear conditions for intensive activities such as dryland farming, settlement development, and basic infrastructure. In contrast, land with rock outcrops >20% tends to have significant physical limitations, making it more suitable for conservative functions such as vegetation rehabilitation, landscape-based ecotourism, and protected forest management (Bachri, 2008; Susilawati *et al*., 2017).

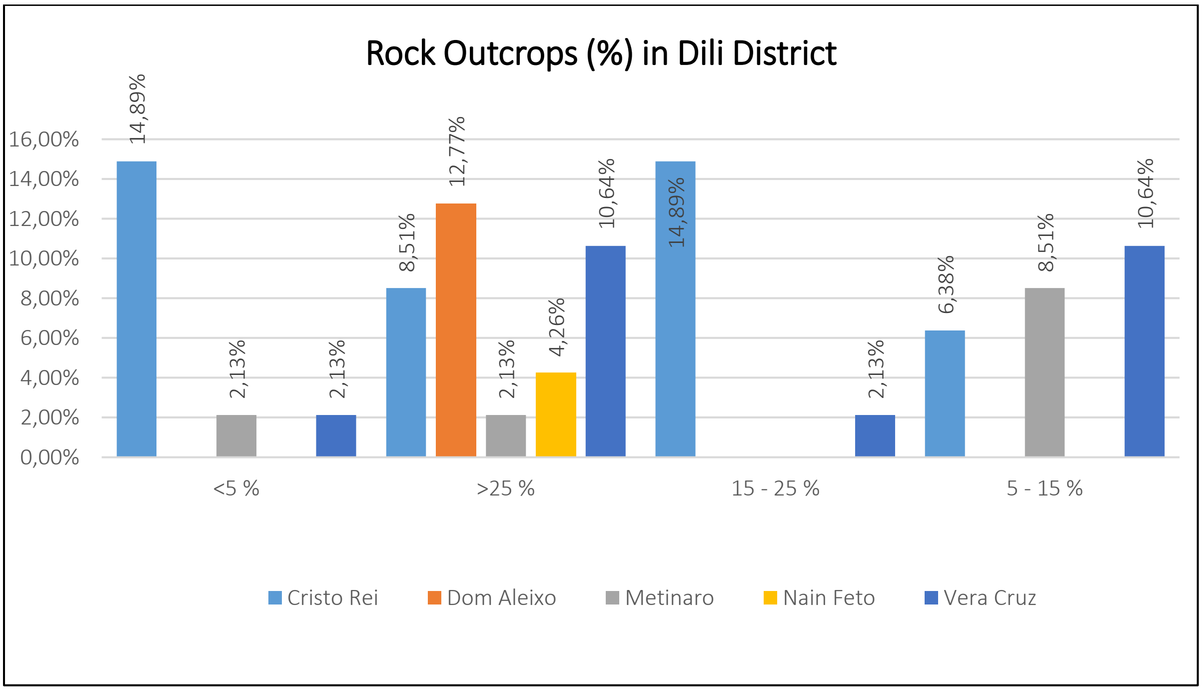


Figure 4.9 Rock Outcrops Data (%) di District Dili

4.10 FLOOD HAZARD

Based on geological and hydrological studies by de Jesus *et al*. (2023), most of Dili is categorized as a flood-free zone, as shown in **Figure 4.10**. One of the areas with no flood hazard potential is Cristo Rei Sub-District, which has a well-functioning drainage system, as illustrated in **Figure 4.5**. This flood-free zone has great potential for developing agricultural land for food crops and horticulture. Strategies for agricultural intensification can be directed through organic farming approaches and the use of superior varieties (Kurniyati *et al*., 2021), supported by agro-climatic suitability, irrigation water availability, and strengthening farmer institutions to ensure sustainable production.

On the other hand, areas with high flood risks, such as parts of Cristo Rei and Metinaro, should be directed toward conservative functions. Agroforestry approaches and flood-tolerant farming systems become relevant adaptive solutions. Comprehensive conservation efforts, such as forest rehabilitation and the development of water absorption systems, are crucial for reducing flood hazard levels sustainably. This approach not only strengthens ecosystem resilience but also supports optimal land utilization.

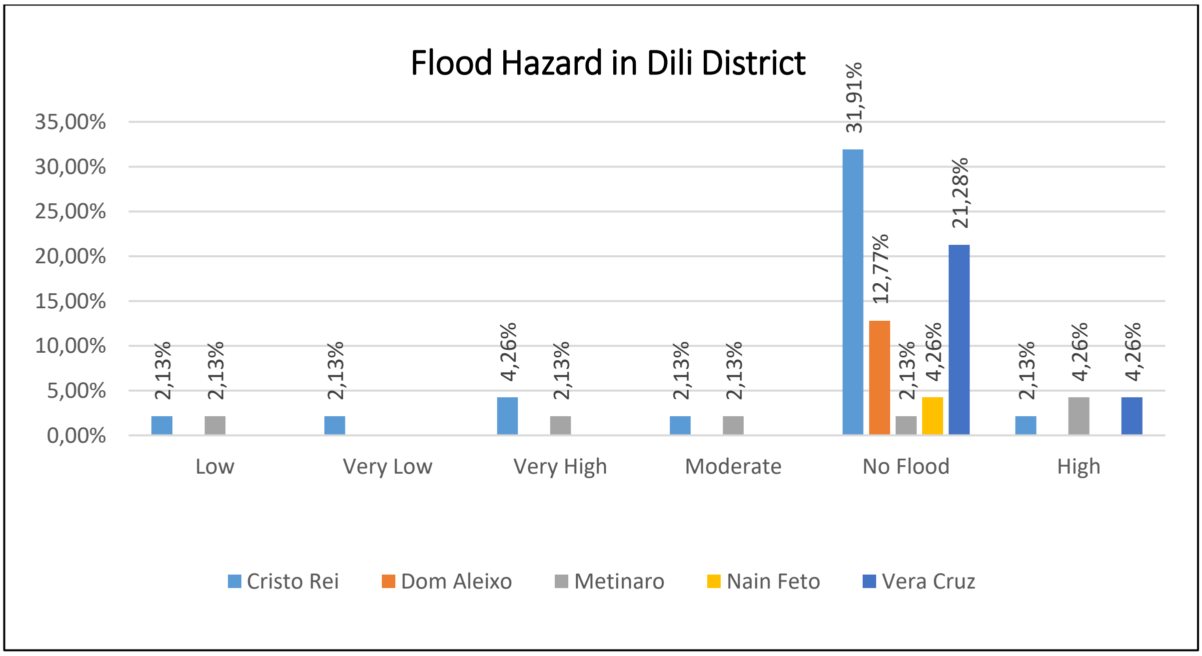
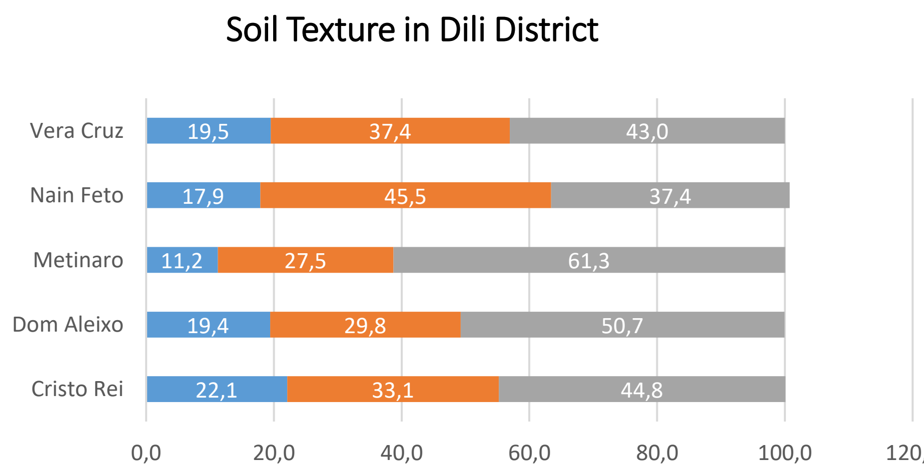


Figure 4.10 Flood Hazard Graph in District Dili

4.11 SOIL TEXTURE

Soil texture characteristics in each area of Dili District show variations in soil texture classes with clay fraction (19.5%), silt (33.66%), and sand (46.9%), with clay being the dominant class. Soil texture in each Sub-District in Dili shows quite diverse variations. Cristo Rei Sub-District is dominated by clay texture with 22.1% clay, 33.1% silt, and 44.8% sand. Dom Aleixo Sub-District has a sandy clay texture with 19.4% clay, 29.8% silt, and 50.7% sand. Metinaro Sub-District also shows a dominant sandy clay texture with 11.2% clay, 27.5% silt, and 61.3% sand. Nain Feto Sub-District is dominated by silty clay texture with 17.9% clay, 45.5% silt, and 37.4% sand. Meanwhile, Vera Cruz Sub-District has a dominant clay texture with 19.5% clay, 37.4% silt, and 43.0% sand (**Figure 4.11**). Finer soil textures affect the availability of organic matter and the soil's ability to retain water, while coarser textures improve soil aeration.



	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
Clay (%)	22,1	19,4	11,2	17,9	19,5
Silt (%)	33,1	29,8	27,5	45,5	37,4
Sand (%)	44,8	50,7	61,3	37,4	43,0

Figure 4.11 Soil Texture Graph in District Dili

4.12 pH

Acidic soils tend to have high concentrations of H^+ and Al^{3+} ions, which can inhibit the absorption of essential nutrients such as phosphorus, calcium, and magnesium. This condition is commonly found in humid tropical regions with high rainfall, including parts of Indonesia and Timor-Leste. According to Camila *et al*. (2023), soil pH ranges from 5.8 to 6.6, classified as moderately acidic to slightly acidic, yet still within the optimal range for the growth of food crops and horticulture.

In District Dili, the soil acidity generally falls within the slightly acidic to neutral pH range **(Figure 5.1)**. The lowest pH value recorded was in Dom Aleixo Sub-District at 5.59, which is considered slightly acidic. Similar conditions were also observed in several other Sub-Districts, namely Cristo Rei (6.07), Metinaro (6.38), and Vera Cruz (6.27). Meanwhile, Nain Feto Sub-District exhibited neutral pH, at 6.70.

Soils with a neutral pH (approximately 6.5–7.5) are considered ideal because most nutrients are available in soil solution at this pH. At this level, soil microorganism activity is also optimal, making organic matter mineralization an effective process. Putri *et al*. (2019) indicated that forest soils tend to have a near-neutral pH (±6.59), contributing to high soil fertility. Soils with slightly alkaline pH (>7.5) are typically found in dry regions or calcareous soils. In these conditions, phosphorus tends to be bound by calcium and magnesium, reducing its availability to plants. Additionally, microelements such as molybdenum (Mo) can reach toxic concentrations, potentially harmful to plants (Febrianti, 2025).

4.13 TOTAL NITROGEN

Total nitrogen (N-total) in soil is a crucial chemical indicator as it directly supports vegetative growth, protein formation, and soil microorganism activity. Nitrogen is an essential macronutrient required in large quantities, and its presence in soil is greatly influenced by organic matter content, mineralization processes, and land management practices (Maro'ah *et al*., 2021).

Laboratory analysis **(Figure 4.12)** shows that the N-total content in soils in District Dili ranges from very low to moderate, with values between 0.07% and 0.44%. The lowest values were recorded in Nain Feto Sub-District, while the highest were found in Dom Aleixo Sub-District. N-total content in Metinaro Sub-District is 0.08%, Cristo Rei 0.10%, and Vera Cruz 0.24%.

Soils with high N-total generally exhibit good agronomic productivity, as they are able to provide nitrogen in the forms of ammonium (NH_4^+) and nitrate (NO_3^-), which are readily absorbed by plants. In contrast, soils with low N-total (<0.2%) have limited ability to support plant growth and thus require interventions such as the addition of organic material or nitrogen fertilizer.

4.14 AVAILABLE PHOSPHORUS

Available phosphorus (P-available) is a key soil parameter determining both actual and potential fertility. Available phosphorus refers to the fraction of phosphate that plants can directly absorb, primarily in the forms of ortho-phosphate ions $H_2PO_4^-$ and HPO_4^{2-}, which play an essential role in plant metabolism, such as ATP formation, nucleic acid synthesis, and root system development. Phosphorus availability is significantly influenced by soil reaction (pH), organic matter content, and the presence of ions like Al^{3+} and Ca^{2+}, which can cause phosphorus to be fixed into insoluble forms (Sari *et al*., 2018).

According to laboratory results **(Figure 4.12)**, the available phosphorus content in soils in District Dili is categorized as very low. The lowest value recorded was in Nain Feto Sub-District at 0.68 ppm, followed by Metinaro Sub-

District at 0.80 ppm, Cristo Rei at 1.02 ppm, and Vera Cruz at 2.38 ppm. The highest P-available content was found in Dom Aleixo Sub-District, reaching 4.36 ppm.

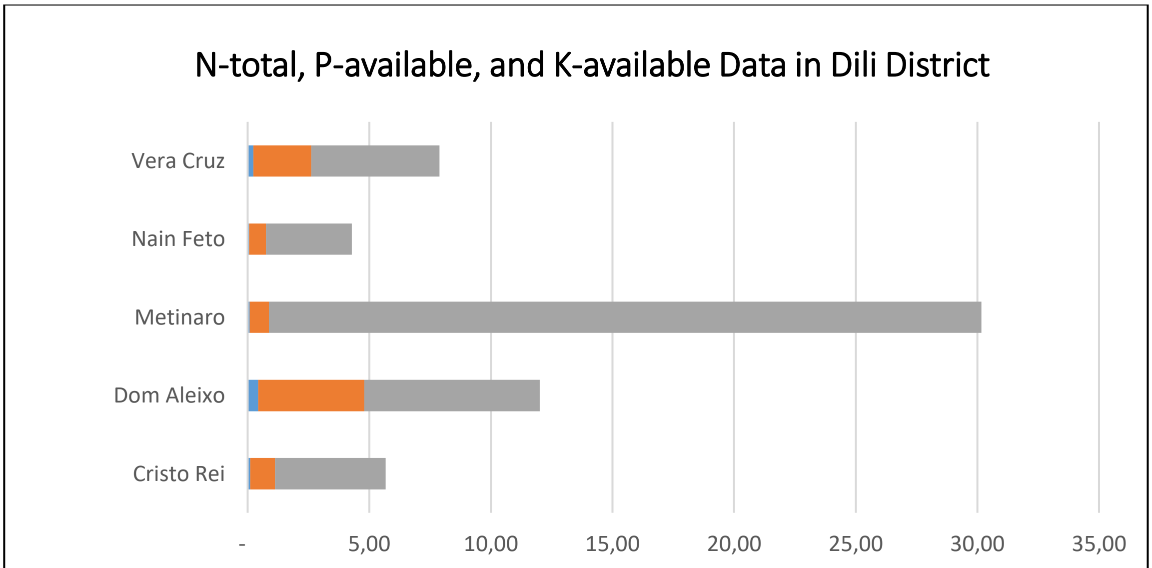
Soils with low P-available are generally found in acidic soils (pH < 6.0) or calcareous soils with high calcium content. In acidic soils, phosphorus is fixed by Al^{3+} and Fe^{3+}, while in alkaline soils, it is bound by Ca^{2+}, making it unavailable to plants. Conversely, soils with high P-available have good agronomic potential, as they support optimal plant growth without the need for additional phosphate fertilization. However, excessively high phosphorus levels can cause nutrient imbalances, particularly with microelements such as Zn and Fe, and increase the risk of environmental pollution through surface runoff, particularly in poorly drained soils (Sharma *et al*., 2007; Astuti *et al*., 2020; Silva *et al*., 2023).

4.15 AVAILABLE POTASSIUM

Available potassium (K-available) is an essential soil chemical indicator as it directly supports various physiological processes in plants, such as protein formation, enzyme activation, osmotic pressure regulation, and the transport of photosynthesis products. Available potassium is usually expressed as exchangeable K (K-dd), which is readily absorbed by plant roots. Optimal K-available values indicate a soil's good capacity to support sustainable plant growth, whereas low values indicate agronomic limitations and the need for fertilization interventions (Nursyamsi *et al*., 2013).

The available potassium content in District Dili shows variation across Sub-Districts **(Figure 4.12)**. The lowest value was found in Nain Feto Sub-District at 3.53 me/100g, followed by Cristo Rei Sub-District at 4.55 me/100g, Vera Cruz Sub-District at 5.28 me/100g, and Dom Aleixo Sub-District at 7.21 me/100g. The highest K-available content was recorded in Metinaro Sub-District, at 29.30 me/100g.

Potassium availability in soils is influenced by sorption and desorption processes. Potassium is available in various forms, including soluble K (K^+), exchangeable K, and non-exchangeable K (Nursyamsi *et al*., 2007). However, excessively high potassium levels can cause antagonism with the uptake of other nutrients, such as magnesium (Mg^{2+}) and calcium (Ca^{2+}), and increase the risk of environmental pollution through leaching, particularly in coarse-textured soils with rapid drainage systems (Mahbub *et al*., 2023).



	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
N-total	0,10	0,44	0,08	0,07	0,24
Available phosphorus	1,02	4,36	0,80	0,68	2,38
Available Potassium	4,55	7,21	29,30	3,53	5,28

Figure 4.12 N-total, P-available, and K-available Data Dili District

4.16 ELECTRICAL CONDUCTIVITY (EC)

Electrical conductivity (EC), also known as soil electrical conductivity (DHL), is an essential chemical parameter that reflects the salinity level of the soil, which directly affects the root environment and the physiological efficiency of plants. Low EC indicates minimal osmotic stress in the soil, which supports optimal nutrient uptake and is suitable for intensive cultivation systems such as horticulture and food crops. Conversely, high EC indicates the accumulation of salts, which can cause osmotic stress, cell membrane damage, and a decrease in enzymatic activity, thus inhibiting plant growth and productivity. According to Da Costa *et al*. (2015), EC is a key indicator in land suitability evaluation for annual crops in Timor-Leste. High salinity has been shown to disrupt ion balance in the soil solution and hinder root growth, requiring conservative strategies such as leaching, the use of tolerant varieties, and the application of soil amendments to mitigate its negative effects.

Laboratory analysis results show that the electrical conductivity (EC) content in the soil of Dili District ranges from low to moderate **(Figure 5.1)**. The lowest value is recorded in Metinaro Sub-District at 1.07 dS/m, followed by Vera Cruz Sub-District at 1.39 dS/m, Dom Aleixo Sub-District at 1.97 dS/m, and Cristo Rei Sub-District at 1.99 dS/m. Meanwhile, the highest EC content is found in Nain Feto Sub-District, reaching 2.80 dS/m.

V. SOIL FERTILITY

Soil fertility refers to the soil's capacity to supply nutrients and water, as well as to provide chemical conditions that support optimal plant growth. The level of soil fertility is evaluated using several key chemical parameters, including cation exchange capacity (CEC), base saturation, soil organic carbon (SOC), Total Phosphorus, and Total Potassium.

5.1 CATION EXCHANGE CAPACITY (CEC)

Laboratory test results indicate that the Cation Exchange Capacity (CEC) in the Dili District region ranges from low to very high (**Figure 5.1**). Nain Feto Sub-District exhibits the highest CEC, with a value of 48.59 me/100g, indicating that the soil in this area has an excellent ability to retain nutrients, thus supporting optimal soil fertility. Dom Aleixo Sub-District also recorded a high CEC, although not as high as in Nain Feto. In contrast, Metinaro and Cristo Rei Sub-Districts have relatively low CEC values, indicating that the soil's ability to retain nutrients in these areas is more limited. This condition requires more careful land management to maintain productivity.

Cation Exchange Capacity (CEC) refers to the ability of the soil to hold and exchange positively charged ions, such as calcium, magnesium, potassium, and ammonium, which are essential for soil fertility. CEC is influenced by the clay content and organic matter, as both have negative charges that serve as sites for ion exchange. Soils with a 2:1 clay type or high organic matter, such as peat and natural forest soils, typically exhibit high CEC. Research by Asfaw and Mamo (2021) indicates that land management practices without the addition of organic matter can reduce CEC, even in deeper soil layers. To enhance CEC in areas like Dili, organic matter such as compost or manure can be added, and lime or dolomite can be used to raise the pH of acidic soils, thereby improving soil charge and increasing CEC.

5.2 BASE SATURATION (BS)

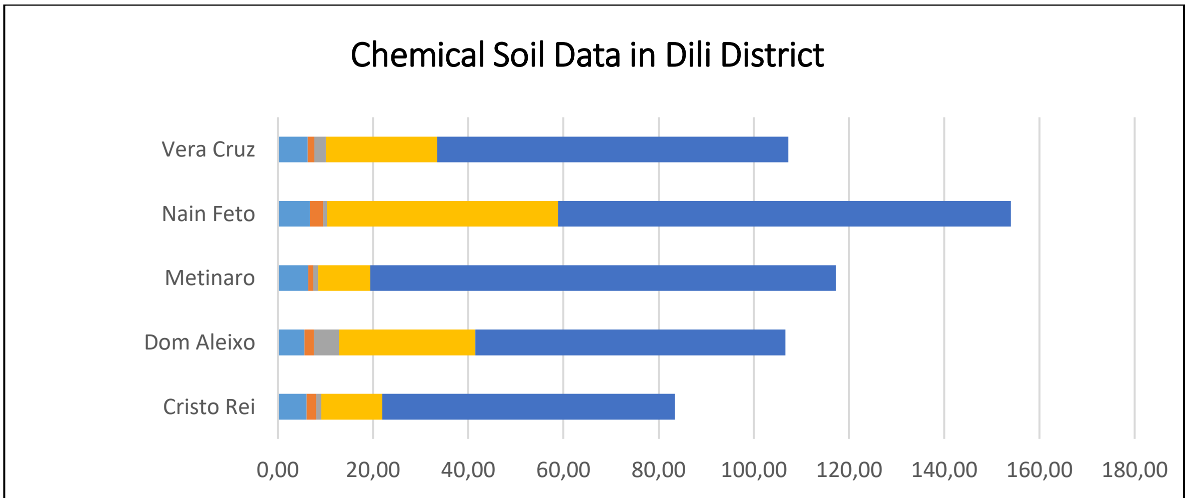
Laboratory test results indicate that the base saturation (BS) in the Dili District region ranges from high to very high (**Figure 5.1**), reflecting a soil chemistry that is predominantly rich in base cations. Metinaro Sub-District has the highest base saturation value at 97.86%, indicating soils that are very rich in bases and have high fertility potential. Nain Feto Sub-District also shows very high base saturation, supporting similar favorable conditions. Additionally, Vera Cruz Sub-District has a relatively high base saturation value of 73.75%, followed by Sub-Districts Dom Aleixo and Cristo Rei, which also display high base saturation values. The base saturation value reflects the level of soil fertility and the availability of essential nutrients for plants. In Dili District, varying soil conditions affect base saturation, which can range from low to high depending on factors such as soil texture, organic matter content, and pH.

Soils with high base saturation generally have a neutral to slightly alkaline pH, good organic matter content, and soil textures that facilitate ion exchange. Conversely, soils with low base saturation often have acidic pH, low organic matter content, and soil textures that do not support efficient ion exchange. Research in tropical regions has shown that soils with high base saturation tend to have better fertility and support optimal plant growth. To enhance base saturation in Dili District, several steps can be taken. Adding organic matter such as compost or manure can increase the soil's organic matter content, which in turn improves cation exchange capacity and base saturation. Additionally, applying agricultural lime can raise the pH of acidic soils, reduce the dominance of H^+ or Al^{3+} ions, and increase the availability of base cations.

5.3 ORGANIC CARBON (SOC)

Laboratory analysis reveals significant variation in organic carbon (SOC) content across the Dili District region, ranging from very low to very high levels. Dom Aleixo Sub-District has the highest SOC content, recorded at 5.29%, indicating that the soil in this area is rich in organic matter, which is essential for soil fertility and structure. In contrast, Nain Feto Sub-District shows very low SOC content at only 0.82%, indicating minimal organic matter and low soil fertility potential. Sub-Districts Cristo Rei and Metinaro have relatively low SOC levels, suggesting that the soils in these areas require special attention to improve organic matter content. Meanwhile, Vera Cruz Sub-District exhibits moderate SOC content, implying that the soil in this area has medium fertility potential. The differences in SOC content reflect the varied soil conditions across Dili District, which should be considered in land management strategies and efforts to improve soil fertility to support optimal agricultural productivity.

SOC content reflects the amount of carbon available from organic matter in the soil and is a key indicator of soil quality. To increase SOC content in Dili District, recommended practices include the implementation of simple agroforestry systems, the use of mulching or crop residues, and the application of compost, manure, or biochar. Minimal tillage is also highly effective in maintaining organic carbon accumulation and slowing down microbial decomposition. This approach has been shown to improve soil structure, reduce erosion, and enhance long-term fertility under tropical conditions.



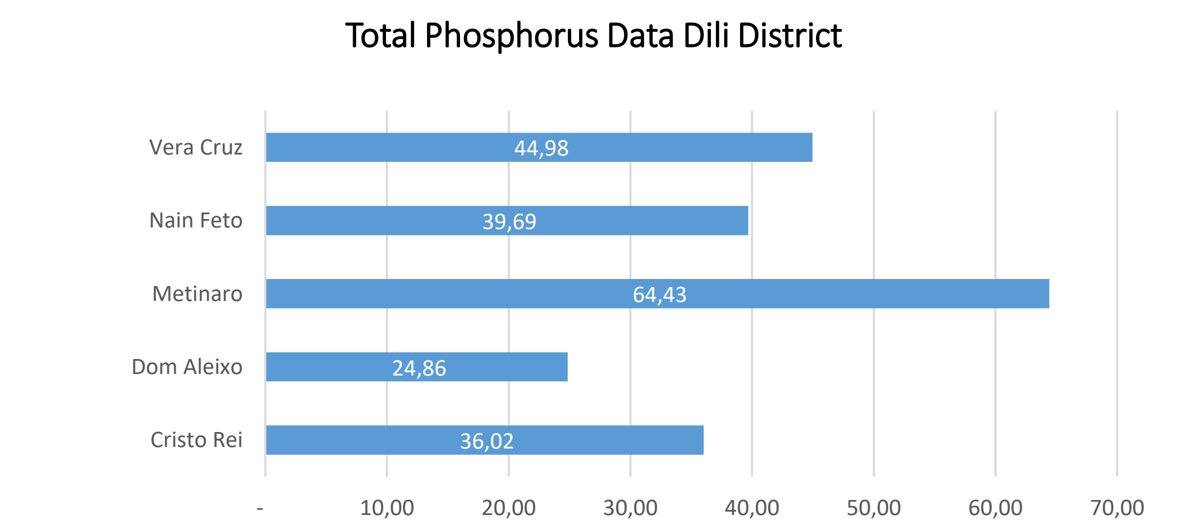
	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
pH	6,07	5,59	6,38	6,70	6,27
Electrical conductivity	1,99	1,97	1,07	2,80	1,39
Organic Carbon (%)	1,09	5,29	1,04	0,82	2,43
Cation Exchange Capacity	12,83	28,65	10,96	48,59	23,43
Base Saturation	61,42	65,10	97,86	95,06	73,75

Figure 5.1 Chemical Soil Graph Data in Dili District

5.4 TOTAL PHOSPHORUS (P-TOTAL)

Based on laboratory analysis, the total phosphorus (P-total) content in the Dili District ranges from moderate to very high **(Figure 5.2)**. The Sub-district of Metinaro has the highest P-total level, recorded at 64.43 mg/100g, categorized as very high. This indicates that the soil in this area has an abundant supply of phosphorus, which plays a vital role in supporting plant growth and development. Vera Cruz Sub-District shows a high level of P-total, reflecting good soil fertility in terms of phosphorus availability. Meanwhile Nain Feto, Cristo Rei, and Dom Aleixo Sub Ditrsicts have P-total levels in the moderate range, with the lowest value recorded at 24.86 mg/100g.

Total phosphorus (P-total) represents the entire phosphorus content in the soil, both organic and inorganic, including both available and unavailable forms for plants. In areas like Dili, where limestone-based soils and traditional farming systems prevail, P-total levels are generally high. However, high P-total does not always correlate with agricultural yields, as much of the phosphorus may be fixed and insoluble, especially if pH and base saturation are not managed effectively (Oliveira *et al*., 2025). To optimize P-total's role in supporting plant growth, proper management is required. The addition of natural phosphates can serve as a long-term reserve, while enhancing soil biological activity through the application of compost, biochar, or cropping systems that stimulate microbial activity can help mobilize bound phosphorus. Research in Timor-Leste indicates that the use of rice husk biochar increases phosphorus availability and plant productivity, especially in soils with high P-total (Reis *et al*., 2023).



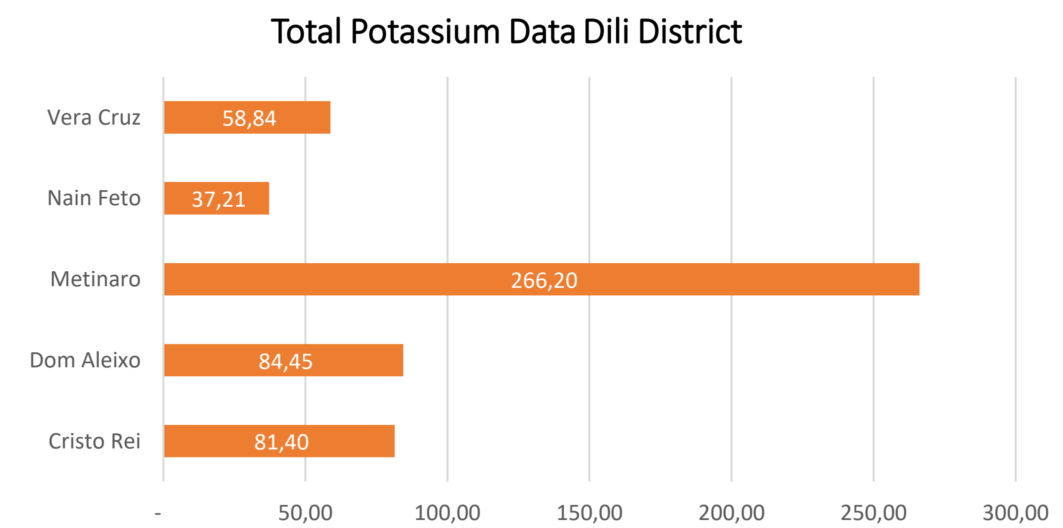
	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
Total	36,02	24,86	64,43	39,69	44,98

Figure 5.2 Phosphorus Graph Data of Dili District

5.5 TOTAL POTASSIUM (K-TOTAL)

Laboratory analysis results show that the total potassium (K-total) content in the Dili District ranges from moderate to very high **(Figure 5.3)**, with Metinaro Sub-District having the highest value of 266.20 mg/100g, classified as very high. Cristo Rei Sub-District and Dom Aleixo also have very high K-total levels, indicating good soil fertility potential. Meanwhile, Vera Cruz Sub-District has a high K-total level, which is still adequate to meet plant nutrient requirements. On the other hand, the District of Nain Feto has the lowest K-total value, at 37.21 mg/100g, classified as moderate, which suggests the need for more optimal nutrient management.

K-total capacity represents the total potassium content in the soil, both chemically and physically available, either in solution or bound to soil particles like clay minerals and organic matter. The potassium content in Timor-Leste soils is highly influenced by the degree of weathering of the parent material, land use, and biological activity. Generally, potassium levels in Timor-Leste soils are moderate due to a combination of tropical dry climate conditions and traditional farming practices that do not routinely apply potassium fertilizers (Soares *et al.*, 2019). Low values are often found in intensively used lands without nutrient replacement, especially on sloping lands and areas affected by erosion. Conversely, soils with moderate to high K-total are typically found in areas still rich in organic matter. To enhance K-total in Dili soils, the practice of fertilizing with natural potassium sources such as organic fertilizers (compost and manure) is highly recommended. Furthermore, the proper use of mineral potassium fertilizers helps restore soil potassium reserves. The application of soil conservation techniques, such as planting cover crops and mulching, can reduce erosion and potassium loss. Improving organic matter content also enhances the soil's ability to retain potassium, as potassium binds to organic matter and soil colloids (Lima *et al.*, 2020).



	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
Total	81,40	84,45	266,20	37,21	58,84

Figure 5.3 Total Potassium Graph Data Dili District

5.6 TOTAL ZINC (ZN-TOTAL)

Laboratory analysis results **(Figure 5.4)** show that Vera Cruz Sub-District has the highest total zinc (Zn-total) level, at 100.95 ppm, indicating that the soil in this area has adequate zinc availability to support optimal plant growth. In contrast, the Nain Feto Sub-District shows the lowest Zn-total content at 59.35 ppm, which requires attention in the management of this micronutrient.

Total zinc (Zn-total) refers to the entire zinc content in the soil, both available and unavailable to plants. In the Dili District, soils formed from the weathering of limestone and clay typically have low organic matter content and high weathering rates, so most zinc is bound to clay minerals or iron and aluminum oxides, making it less available for plant absorption. Research in tropical regions has shown that 65–80% of zinc remains in an insoluble form (Ferreira *et al*., 2023), particularly in sloping lands affected by degradation due to shifting cultivation systems (Costa *et al*., 2022). To increase zinc availability for plants, integrated management is required, including the addition of organic materials like compost, manure, or biochar, and the use of zinc fertilizers ($ZnSO_4$) and mycorrhizal inoculation. Additionally, soil pH should be managed to remain neutral to slightly acidic to prevent the precipitation of zinc into insoluble forms, ensuring optimal zinc availability for plant growth.

5.7 AVAILABLE ZINC (ZN-AVAILABLE)

Laboratory analysis results show that available zinc (Zn-available) levels **(Figure 5.4)** in Vera Cruz Sub-District are the highest, at 1.85 ppm, which is sufficient to meet plant requirements for this micronutrient. Conversely, Cristo Rei, Dom Aleixo, Nain Feto, and Metinaro Sub Districts show the lowest available zinc levels, with the lowest value recorded at 0.42 ppm in Metinaro Sub-District. This indicates that although the total zinc content in some locations is quite high, the availability of zinc for plant absorption is still limited.

Zn-available refers to the zinc that is water-soluble or easily exchangeable in the soil, making it readily available for plant absorption. This micronutrient plays a crucial role in plant metabolism, including growth hormone formation, protein synthesis, and enzyme activity. Although Zn-total levels in the soil may be high, available zinc levels are often low due to zinc being strongly bound to clay minerals or organic matter, which is insoluble. Furthermore, high levels of zinc can reduce phosphorus availability in the soil through the formation of zinc-phosphorus complexes, especially under high soil pH, excess phosphorus, and light-textured soils (Barber, 1995). Available zinc levels may increase with excessive long-term zinc fertilization, heavy metal pollution, or highly acidic soils that enhance zinc solubility.

5.8 TOTAL SULFUR (S-TOTAL)

Sulfur is a secondary macronutrient that is critical for plant growth because it plays a role in amino acid synthesis. In the soil, sulfur is present in two main forms: organic and inorganic, with most of it contained in the organic form. Total sulfur content includes all sulfur in these forms (Brady & Weil, 2008).

Laboratory analysis results show that the total sulfur (S-total) content in the Dili District varies, with the highest value found in Cristo Rei Sub-District at 199.11 ppm. This indicates that the soil in this area has a relatively good potential to provide the sulfur needed for physiological plant processes, such as amino acid synthesis and chlorophyll formation. The lowest S-total value is recorded in the Nain Feto Sub-District, at 113.85 ppm. Although still within a range that can support plant growth, the lower sulfur content indicates the need for special attention to nutrient management, especially for plants that are sensitive to sulfur deficiencies. The variation in sulfur content reflects the differences in soil characteristics across regions, so fertilization strategies and land management should be tailored to support optimal agricultural yields across the Dili District.

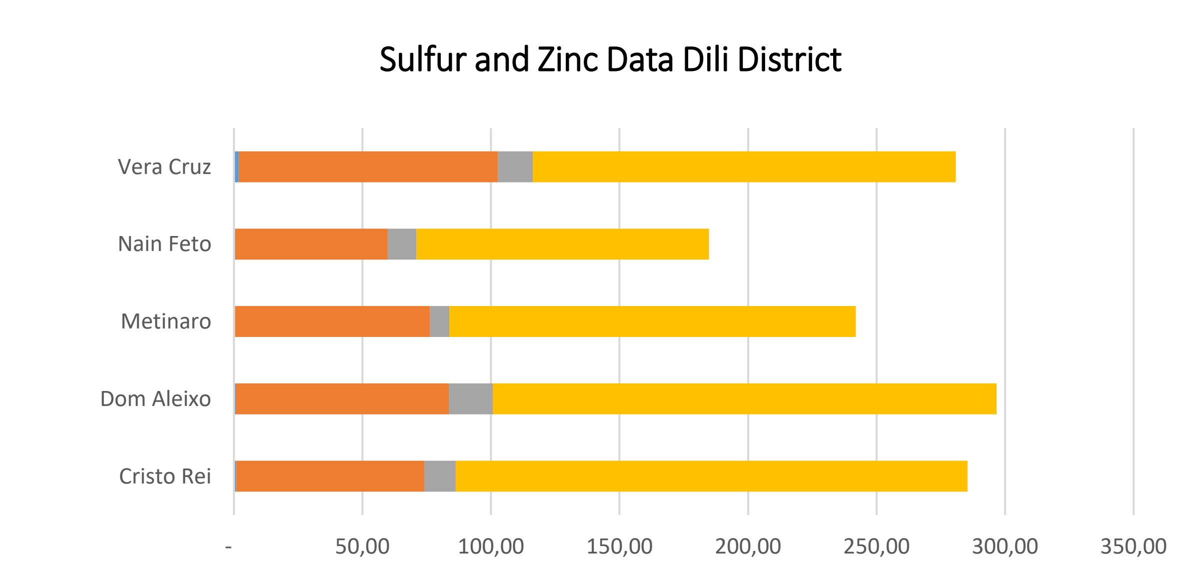
Low total sulfur levels in the soil can be caused by low organic matter content and repeated use of chemical fertilizers without the addition of organic materials, which can lead to a decline in nutrient levels, including sulfur. Conversely, high total sulfur levels are typically found in soils with high organic matter accumulation, such as peat soils or soils with poor drainage systems. However, excessively high sulfur levels can pose problems for plants, such as interfering with the absorption of other nutrients or causing increased soil acidity if sulfur is present in excess as sulfate.

5.9 AVAILABLE SULFUR (S-AVAILABLE)

Available sulfur (S-available) in the soil is part of the total sulfur that has undergone mineralization from organic materials and is ready for plant absorption. This content is a direct indicator of soil fertility related to sulfur. High S-available levels are influenced by high organic matter content, which, through decomposition, produces organic sulfur compounds that are then converted into inorganic forms (SO_4^{2-}) usable by plants (Widijanto *et al.*, 2011).

Based on laboratory analysis, the available sulfur (S-available) content in the Dili District shows significant variation between districts. Vera Cruz Sub-District has the highest S-available content, at 13.43 ppm, indicating that the soil in this area has adequate sulfur availability to support plant metabolic processes, such as protein synthesis and chlorophyll formation. In contrast, Metinaro Sub-District has the lowest S-available content, at 7.40 ppm. This value indicates potential sulfur limitations in the area, which could affect plant growth if not balanced with proper nutrient management. This variation emphasizes the importance of site-specific management strategies for fertilization to maintain nutrient balance and enhance agricultural productivity across the Dili District.

High S-available levels are often the result of excessive and continuous sulfur fertilization without soil testing. On the other hand, low S-available levels are often caused by low organic matter, which limits the supply of sulfur from organic sources. Additionally, the lack of sulfur fertilization and the presence of steep lands also contribute to the limited sulfur availability for plants.



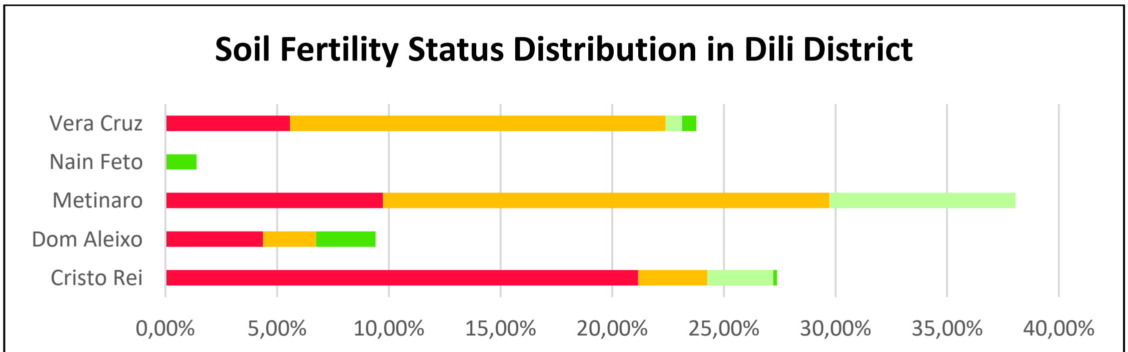
	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
Zn-Available	0,88	0,75	0,42	0,50	1,85
Zn-total	73,21	82,85	75,93	59,35	100,95
S-Available	12,22	17,14	7,40	11,14	13,43
S-total	199,11	195,95	158,15	113,85	164,58

Figure 5.4 Sulfur and Zinc Graph Data Dili District

5.10 SOIL FERTILITY STATUS

Based on the soil fertility status analysis in the Dili District, most areas show low to high soil fertility levels **(Figure 5.5)**. The area with low fertility status covers 99.70 km², or 42.27% of the total area, while the area with very low fertility accounts for 96.36 km², or 40.85%. The area with moderate fertility status is 28.40 km² (12.04%), and only a small portion of the area, 11.43 km² (4.85%), has high soil fertility. This condition indicates that most of the land in the Dili District requires management and improvement of fertility to optimize plant productivity.

The spatial distribution of soil fertility status across each District shows varying patterns **(Figure 5.6)**. Cristo Rei Sub-District is dominated by land with very low fertility status, covering 49.91 km², or 21.16% of its total area, highlighting the need for fertility restoration efforts in this area. The Sub-district of Dom Aleixo predominantly has very low fertility status, with an area of 10.32 km² (4.37%). Metinaro Sub-District is mainly composed of land with low fertility, covering 47.11 km², or 19.97%, while Vera Cruz Sub-District has an area of 39.68 km² (16.82%) categorized as low fertility. In contrast to the other districts, the Nain Feto Sub-District shows a dominance of high soil fertility, with an area of 3.28 km² (1.39%) of its total land area, offering greater potential to support optimal agricultural productivity. The variation in fertility status necessitates location-specific management strategies to achieve maximum results.



	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
Very Low	21,16%	4,37%	9,75%	0,00%	5,57%
Low	3,10%	2,37%	19,97%	0,00%	16,82%
Moderate	2,96%	0,00%	8,34%	0,00%	0,74%
High	0,16%	2,65%	0,00%	1,39%	0,63%

Figure 5.5 Graph of Soil Fertility Status Distribution in Dili District

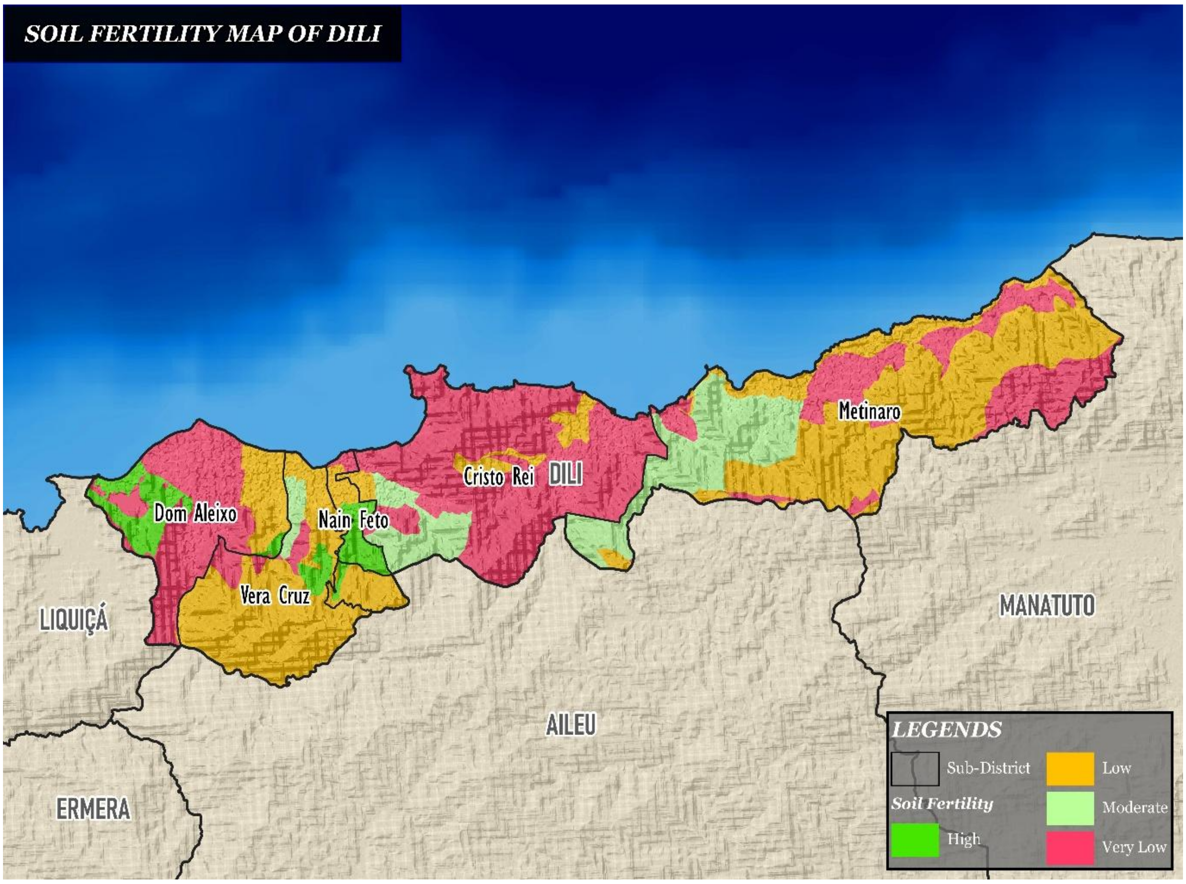


Figure 5.6 Map of Soil Fertility Status

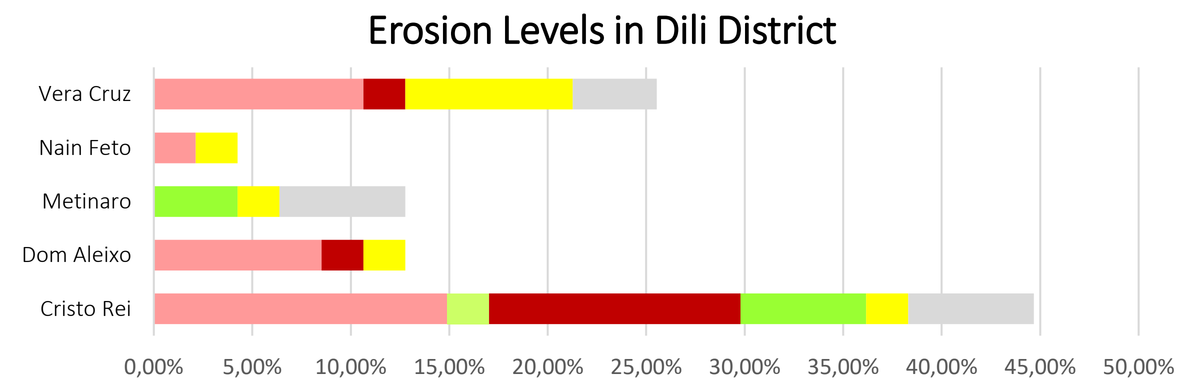
VI. EROSION AND CONSERVATION

6.1 SOIL EROSION

Soil erosion analysis plays a crucial role in land suitability evaluation, particularly for agricultural commodity development. Soil erosion not only affects land productivity but also impacts ecosystem sustainability, environmental degradation, and the loss of the land’s ability to retain nutrients and water. In the context of agricultural land management, erosion analysis serves as the foundation for designing appropriate soil conservation strategies to mitigate negative impacts and ensure sustainable land use.

According to the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978), soil erosion is influenced by several key factors, including rainfall erosivity, soil erodibility, slope length and steepness, vegetation cover, and land management practices. In Timor-Leste, most of these factors have characteristics that contribute to high erosion rates. The topography dominated by steep slopes, low levels of land conservation, unstable soil structure due to geological influences, and limited vegetation cover are the main factors accelerating the rate of erosion. As stated by Morgan (2005), uncontrolled soil erosion can lead to the loss of the topsoil layer, which is the most fertile component of the soil, thus limiting its productivity capacity.

Dili District has an erosion range from no erosion to severe erosion. Areas with very heavy to heavy erosion are found in Cristo Rei, as shown in **Figure 6.1**. This is because the region has very steep slopes, as presented in **Chapter 2** of this book. Steep slopes accelerate surface runoff, which in turn accelerates soil erosion and transport (Akbar, 2024; Siswanto *et al*., 2019; Andrian *et al*., 2014; Martono, 2004). Furthermore, the region has somewhat hindered drainage, as presented in **Chapter 4** of this book, with poor drainage systems in residential and open land areas. Uncontrolled water flow will accelerate surface runoff, which then erodes the fertile topsoil (Arifin, 2023). The map of erosion distribution in Dili District is presented in **Figure 6.2**.



	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
Heavy	14,89%	8,51%	0,00%	2,13%	10,64%
Light	2,13%	0,00%	0,00%	0,00%	0,00%
Very Heavy	12,77%	2,13%	0,00%	0,00%	2,13%
Very Light	6,38%	0,00%	4,26%	0,00%	0,00%
Moderate	2,13%	2,13%	2,13%	2,13%	8,51%
No Erosion	6,38%	0,00%	6,38%	0,00%	4,26%

Figure 6.1 Erosion Levels in Dili District

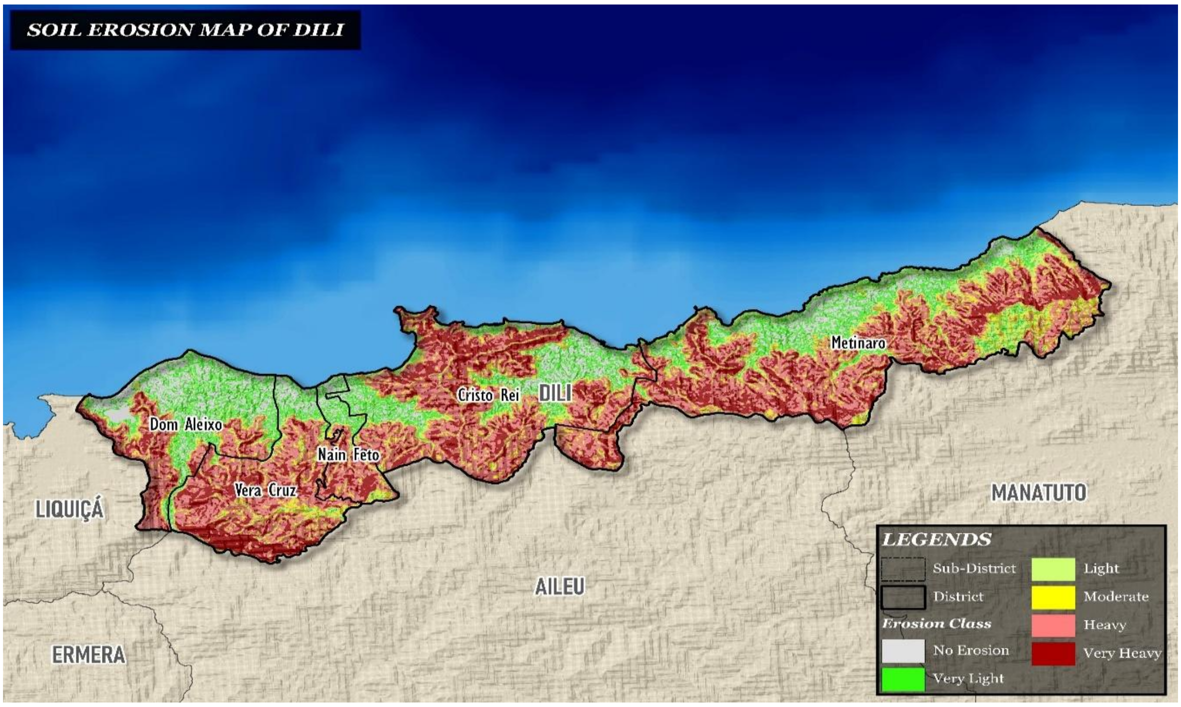


Figure 6.2 Soil Erosion Distribution Map of Dili District

6.2 SOIL AND WATER CONSERVATION

Conservation is an effort in the long-term management of natural resources aimed at maintaining the quality and productivity of land. Conservation plays a crucial role in protecting soil from degradation, rehabilitating degraded soil, enhancing infiltration, and maintaining soil fertility.

In Dili District, conservation is based on slope gradient levels (**Figure 6.3**), ranging from flat to very steep (0-45%). On flat to gentle slopes (0-8%), it is recommended for growing food crops, secondary crops, and horticulture. These commodities can also be cultivated on land with slopes up to 40%, but terracing should be implemented to allow more rainwater to infiltrate the soil, thereby reducing erosion and surface runoff. Such conditions are found in all five Sub-Districts of Dili District (Sub-Districts Cristo Rei, Dom Aleixo, Metinaro, Nain Feto, and Vera Cruz). For land with slopes greater than 45%, it is recommended to cultivate perennial crops (woody plants such as banyan, eucalyptus, acacia, lenggung, teak, *gamal*, *Leucaena*, *Nimba*, and others). The goal is to create terraces in areas where planting space is very narrow. In these areas, the soil is more susceptible to erosion and landslides, especially during heavy rainfall.

Table 6.1 Slope Gradient Data of Dili District

Sub-Districts	Slope (%)	Potential Class	Area (ha)	Area (%)
Cristo Rei	15-25%	Moderately Potential	630,5	2,79
Cristo Rei	25-45%	Agroforestry	2379,43	10,52
Cristo Rei	>45%	Agroforestry	1590,92	7,03
Cristo Rei	0-8%	Highly Potential	1492,82	6,6
Cristo Rei	8-15%	Potential	400,16	1,77
Dom Aleixo	15-25%	Moderately Potential	195,06	0,86
Dom Aleixo	25-45%	Agroforestry	716,58	3,17
Dom Aleixo	>45%	Agroforestry	381,48	1,69
Dom Aleixo	0-8%	Highly Potential	1763,43	7,8
Dom Aleixo	8-15%	Potential	235,06	1,04
Metinaro	15-25%	Moderately Potential	1039,83	4,6
Metinaro	25-45%	Agroforestry	3089,21	13,66
Metinaro	>45%	Agroforestry	2147,18	9,49
Metinaro	0-8%	Highly Potential	1961,26	8,67
Metinaro	8-15%	Potential	824,78	3,65
Nain Feto	0-8%	Highly Potential	238,51	1,06
Nain Feto	8-15%	Potential	33,91	0,15
Nain Feto	15-25%	Moderately Potential	38,55	0,17
Nain Feto	25-45%	Agroforestry	147,6	0,65
Nain Feto	>45%	Agroforestry	54,17	0,24
Vera Cruz	15-25%	Moderately Potential	352,55	1,56
Vera Cruz	25-45%	Agroforestry	1375,32	6,08
Vera Cruz	>45%	Agroforestry	1018,92	4,51
Vera Cruz	0-8%	Highly Potential	354,98	1,57
Vera Cruz	8-15%	Potential	156,92	0,69

Dili District, consisting of Sub-Districts Cristo Rei, Dom Aleixo, Metinaro, Nain Feto, and Vera Cruz, has slopes ranging from 25% to over 45%. The area with the largest proportion of these steep slopes is Metinaro, covering an area of 7,708.14 ha (34.08%). This means that land with very steep slopes can only be used for perennial crops. In Dili District, land with gentle slopes (0-8%) covers 5,811 ha (25.69%), slopes of 8-15% cover 1,650.83 ha (7.30%), and slopes of 15-25% cover 2,256.49 ha (9.98%) **(Table 6.1)**. This indicates that the land in Dili District that is highly suitable for cultivation is less extensive than land available for agroforestry.

Agroforestry is a conservation effort in the form of a planting system that integrates forestry, agriculture, fisheries, and livestock into a comprehensive farming business to optimize land use. This system promotes efficient and optimal land use (Sanudin & Priambodo, 2013). In other sub-districts of Dili District, where the slope conditions are similar (0-8%), rice fields are also found due to excellent irrigation water. Therefore, proper crop rotation management is necessary to ensure the land can produce sustainably.

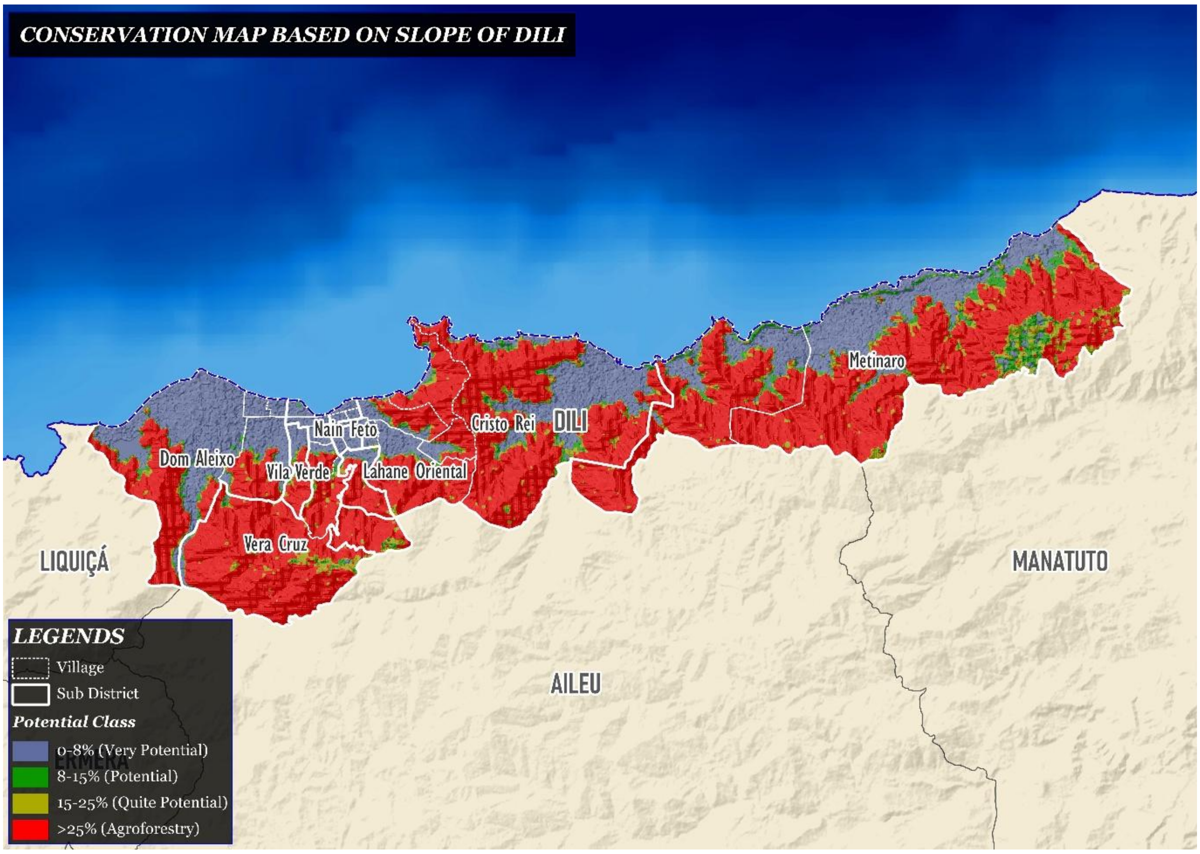


Figure 6.3 Conservation Map Based on Slope Gradient of Dili District

On land with steep slopes, agroforestry is applied. Agroforestry is a land management system that integrates trees, agricultural crops, and/or livestock on the same land to provide ecological interactions and diverse ecosystems. The integration of agroforestry components (trees, agricultural crops, and livestock) can enhance soil fertility and improve physical, biological, and chemical properties of the soil. It also provides specific habitats, increases biodiversity, reduces runoff, retains the kinetic energy of rainfall, binds soil particles, improves groundwater retention, and controls erosion.

Based on its components, agroforestry is classified into several systems:

1. **Agrosilvicultural System**: The integration of trees and certain food crops on the same land.
2. **Silvopastoral System**: A combination of tree cultivation and livestock grazing, aimed at supporting livestock farming.
3. **Agrosilvopastoral System**: The planting of trees, food crops, pasture, and livestock on the same land. This system aims to optimize land production functions but requires intensive management at the subsystem level.
4. **Home Gardens**: This system is characterized by intensive cultivation of annual and seasonal crops, generally consisting of vegetables, cereals, fruit trees, grasses, and livestock management.

1. **Other Systems**: These include the cultivation of multipurpose trees, beekeeping, aquaculture, and forestry, all of which can be utilized for various agricultural and non-agricultural purposes. The agroforestry conservation model is presented in **Figure 6.4.**

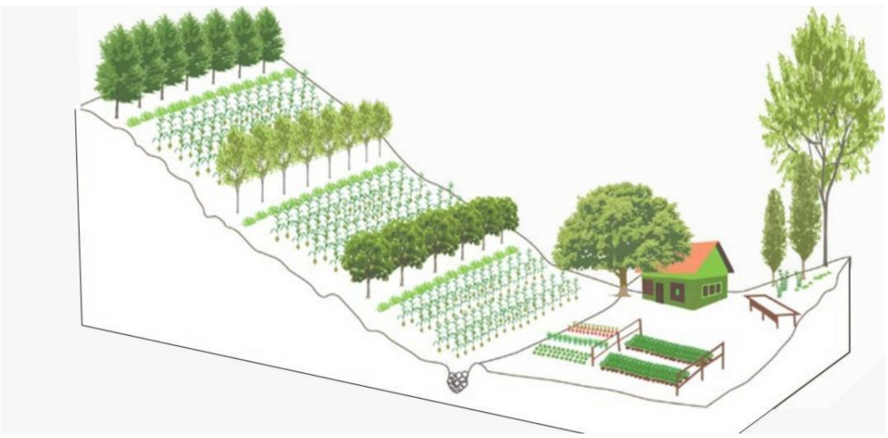


Figure 6.4 Agroforestry Conservation Model
(Source: La *et al*., 2016)

A. The Importance Of The Agroforestry Concept

Agroforestry plays an important role in the production of local commodities (firewood, timber, fruit, and animal feed) as well as global commodities (coffee, tea, cocoa, rubber, and latex). Agroforestry also has a strategic role in helping countries through poverty alleviation, food security, and environmental sustainability. It helps improve farmers' resilience and increases household income by providing diverse harvests at different times throughout the year. The combination of trees, food crops, and livestock helps reduce environmental risks, creates permanent ground cover that combats erosion, minimizes flood damage, and enhances water retention, which benefits crops and pastures.

Agroforestry offers several benefits, including:

1. Improved Food Security and Nutritional Enrichment

Agroforestry provides a diversity of plant species that generate various types of food, contributing to improved food security. The integration of different agroforestry components can enhance agricultural productivity and increase nutritional diversity for consumers.

2. Resilient Livelihoods

The integration of trees, food crops, and livestock can reduce production vulnerability to climate disasters and market shocks. Additionally, agroforestry can help mitigate pest attacks in monoculture systems by creating a better microclimate. Agroforestry also influences climate impacts that hinder agricultural systems, creating more resilient livelihoods.

3. Climate Change Mitigation and Adaptation

The integration of various agricultural plants helps mitigate the effects of climate change on the agricultural sector. The use of trees in agroforestry plays a role in carbon sequestration, regulating the microclimate, reducing the rate of climate change, and influencing plant growth.

4. Environmental Protection

Agroforestry systems help regulate climate and environmental services. Perennial plants help improve air and water quality. Tree litter can be used as organic material to reduce the need for chemical fertilizers. Deep-rooted systems play a role in supporting the nutrient cycle. Agroforestry components also support biodiversity by creating environments suitable for flora and fauna habitats in agricultural landscapes.

5. **Poverty Alleviation**

Agroforestry can increase income diversification through the cultivation of commercial crops, timber sales, and livestock income. Diversification can improve sustainable agricultural productivity by increasing farmers' income, creating job opportunities, and contributing to poverty alleviation and improved community welfare.

B. Agroforestry and Agro-Ecology in Dili District

The most successful agroforestry systems in Timor-Leste generally involve mixed cultivation of fruit trees and timber-producing trees alongside spices. The main fruit crops selected include jackfruit, banana, mango, pineapple, and orange. Timber-producing trees commonly planted with fruit crops include mahogany, sandalwood, moringa, and albizia. Agroforestry in this region has adopted a modern approach focused on techniques such as crop rotation, intercropping, and agro-silvopasture.

Paudel *et al*. (2022) illustrated a commonly applied agroforestry model in Timor-Leste, including Dili District.

1. Alley Cropping in hillside areas along contour lines to reduce landslides and improve long-term water flow. The alley cropping planting system concept is shown in **Figure 6.5.**

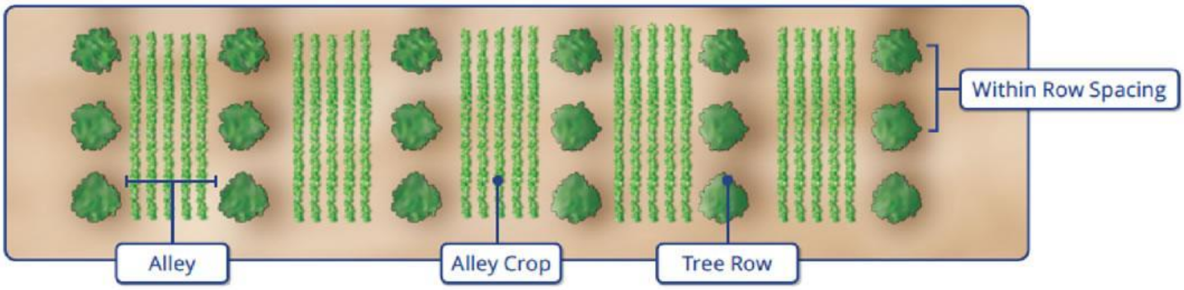


Figure 6.5 Alley Cropping Planting System Concept
(Source: https://www.fs.usda.gov/nac/practices/alley-cropping.php)

2. Hedge Planting, which involves creating boundaries/fences using trees or shrubs. This system is mostly implemented in steep hill areas to conserve soil. The concept of hedge planting is shown in **Figure 6.6.**

Figure 6.6 Hedge Planting Concept
(Source: https://www.flickr.com/photos/hedgerowmobile/322445711/)

3. Random Planting of both woody and annual crops with irregular spacing in lowland areas. The concept of random planting is shown in **Figure 6.7.**

Figure 6.7 Random Planting System Concept
(Source: https://ppid.menlhk.go.id/berita_foto/browse/264)

4. Alternating Row Planting, which involves regular planting with seasonal crops between the rows on flat and extensive land. An example of an agroforestry model that can be applied in Dili District is Clove (wood + fruit + spices), with clove as the main crop and supporting plants such as mahogany, jackfruit, mango, rambutan, coconut, coffee, and turmeric. Another agroforestry model that can be applied is Coffee (wood + fruit + spices), with coffee as the main crop and supporting plants like albizia, jackfruit, banana, gmelina, bamboo, and teak. This agroforestry model can be implemented at altitudes of 500 to 1500 meters with an average annual rainfall of 1500 to 3000 mm.

Cogné & Lescuyer (2024) combine agro-ecological and socio-technical data to identify types of Agroforestry Systems in Timor-Leste, which include home gardens integrating perennial crops, spices, and small livestock; the combination of crops and fallow land to develop food crops and trees at specific distances; the planting of perennial crops (papaya, banana, chili, etc.) combined with woody plants (palms); forest gardens typically located near water sources; and silvopastoral systems integrating trees, shrubs, and grazing livestock on the same land.

Dili District has three agro-ecological zones (AEZ) based on elevation and North-South orientation. These zones have biophysical parameters such as area elevation, average rainfall, and soil types, which are crucial in selecting the appropriate crops and agroforestry models for implementation in Dili District (**Table 6.2**). The agro-climatic zone map for Dili District is presented in **Figure 6.8**.

Table 6.2 Agro-Ecological Zones Data and Main Crop Types

Zone	Altitudes (m)	Rainfall (mm/year)	Main Crops
Zona A	<100	500-1500	Rice, Corn, Cassava, Wood, Coconut
Zona B	100-500	500-1500	Corn, Cassava, Rice, Cowpea
Zona C	500-1500	1500-3000	Red Bean, Coffee, Corn, Rice, Cassava

The following are recommendations for applying agroforestry based on agro-ecological zones according to the agroclimatic zone.

1. **Zone A**

Appropriate conservation practices include check dam gabion, ridge terraces, biopore holes, riverbank protection, rainwater reservoirs, and drainage systems. Suitable plants include mahogany, sandalwood, teak, and other valuable timber species with high economic value.

2. **Zone B**

Conservation techniques that can be applied include terraces with channels, bench terraces, rainwater reservoirs, drainage systems, grass planting, and check dams. Suitable plants include mahogany, sandalwood, cinnamon, coffee, cocoa, and vanilla.

3. **Zone C**

Soil conservation techniques that can be applied include terraces with channels, bench terraces, rainwater reservoirs, drainage systems, grass planting, and check dams. Suitable plants for development include mahogany, sandalwood, blackwood, coffee, vanilla, and clove.

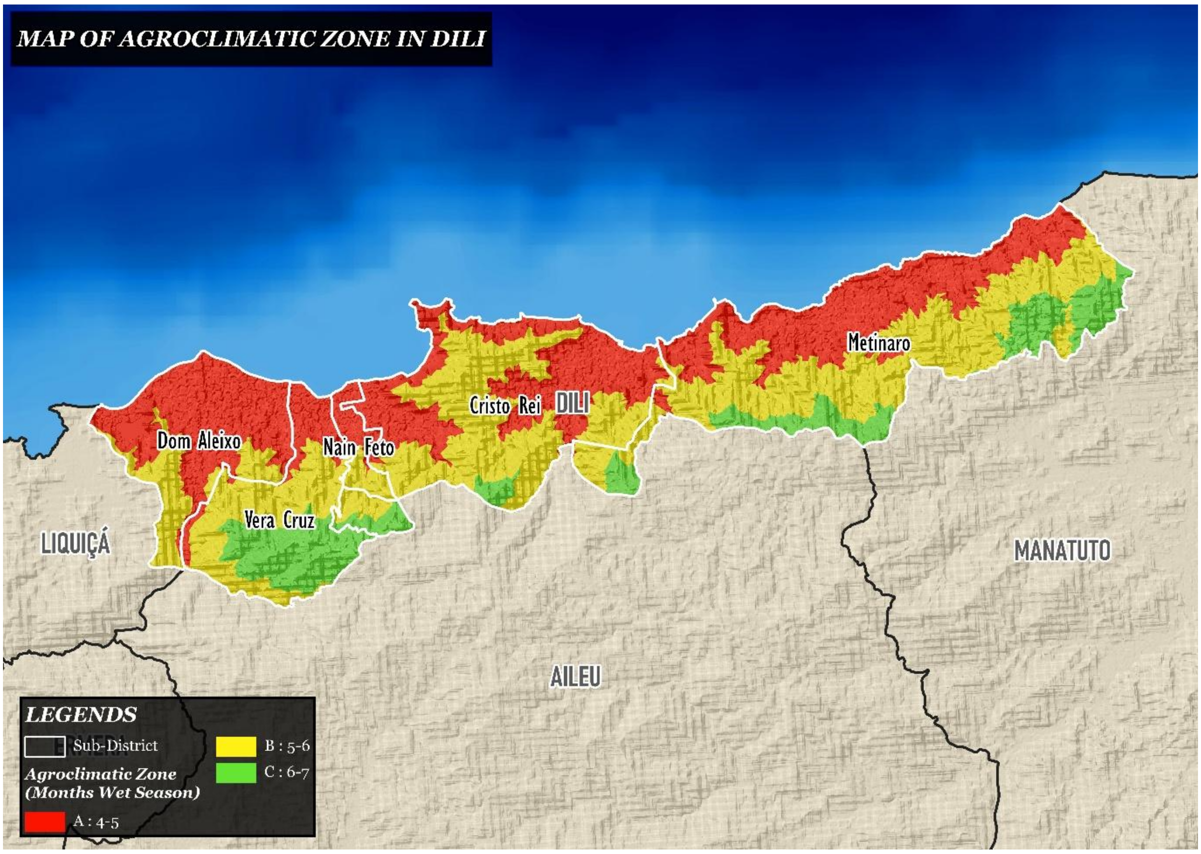


Figure 6.8 Agroclimatic Zone Map of Dili District

C. Conservation Techniques In Dili District

Soil conservation techniques are operational and managerial strategies to maintain and enhance the productive capacity of land that is vulnerable to degradation. In practice, conservation efforts include preventing or reducing erosion, preserving, and maintaining the land. Various soil and water conservation techniques have been widely applied in many regions across Asia, such as converting agricultural land back to forest or pastureland, terracing, mulching, and soil management (Huang *et al*., 2022).

1. Check Dam

A check dam is a small, low dam built in a riverbed or other water channels to reduce the flow velocity, minimize erosion, and promote the deposition of eroded material through a spillway. Dams are useful for preserving agricultural land and strengthening the structure of retaining dams in hilly and disaster-prone areas. Some types of check dams include:

a. **Brushwood**, A brushwood dam is made from wood or branches and is typically used in small river channels. It usually has an effective height of around 1 m above the ground surface, and the minimum foundation depth for the posts is 0.75–1 m. The brushwood conservation model is shown in Figure 6.9. Steps in building a brushwood dam*:*

1) Dig a trench about 5 cm wide, and insert wooden posts (150-200 cm) to a depth of about one-third to half the length of the post, with a distance of 30-50 cm between each post.
2) The center should be made lower than the sides to create a gap used to hold the maximum water flow.
3) Branches from trees (mahogany, rosewood, sesbania) and shrubs are woven between the wood to reach the desired height.
4) The ends of the tied materials must extend into the riverbed at least 30 cm.
5) The back of the check dam should be filled with soil.
6) The edges of the brushwood, about 1.5-2.0 times the height of the dam, should be protected from erosion and reinforced with galvanized wire.
7) Side walls should be built to direct water flow toward the dam.
8) Correct the steep gradient of the riverbed head.

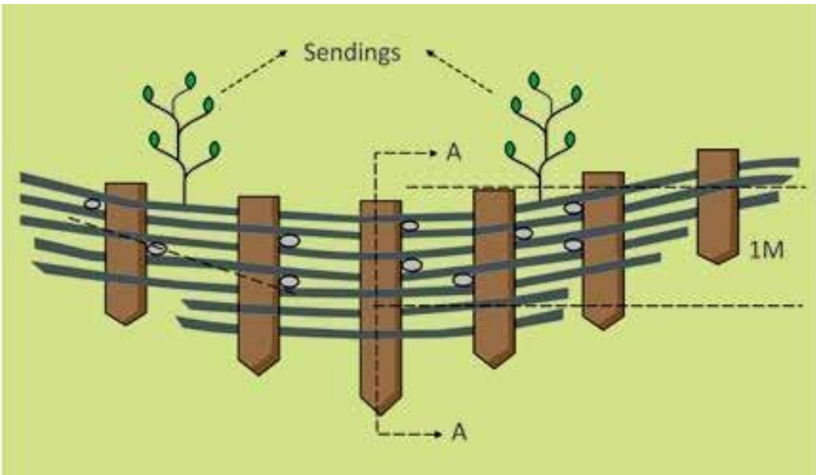


Figure 6.9 Brushwood Check Dam
(Source: Godinho *et al.,* 2023)

b. *Loose Stone*, The loose stone dam is made from loose rocks to block small to medium-sized river channels, while the boulder dam uses large rocks as the barrier, following the same principle as the loose stone dam. Typically, this dam has an effective height of 1–2 m, a minimum foundation depth of half the effective height, and the thickness of the dam at the spillway is between 0.5–1 m. The loose stone model is shown in Figure 6.10. Steps in building a loose stone or boulder dam:

1) Clear the site and mark the construction line using a rope.
2) Cut the riverbed slope with a 1:1 gradient. The foundation of the wing walls should be >0.5 m. The height of the wing walls should match the depth of the spillway.
3) The foundation of the dam should be longer than the spillway.
4) For larger dams, build two wing walls with foundations that match the height to direct the water flow into the spillway or gap and prevent damage to the riverbed edges.
5) Boulder stones are used at the gap and downstream side of the spillway. The center section should be kept lower for the spillway.
6) If there is a large volume of water flow, concrete may need to be used at the gap and the top of the dam or cover everything with wire mesh.
7) An apron made of stones should be built under the dam.
8) Large stones should be placed at the bottom of the dam, with stones about 50 x 30 cm used throughout the dam.
9) On the upstream side, the dam should receive soil filling to increase its stability.

Figure 6.10 Loose Stone Check Dam
(Source: https://www.flickr.com/photos/mocobio/27742059100)

c. **Gabion**, A gabion dam is constructed using hexagonal or square wire baskets filled with stones. The general specifications for gabions include a maximum effective height of <5 m, a maximum foundation depth of half the effective height, and a dam thickness at the spillway of <1 m. The gabion conservation concept is shown in **Figure 6.11**. Steps in building a gabion dam:
   1) The structure must extend at least 0.5 m into the riverbed and must be protected from floodwaters with wing walls.

2) Wing walls with suitable foundations must be built on top to direct the water flow into the spillway or gap and prevent damage to the riverbed edges. The space between the dam and wing walls should be filled with soil.
3) The foundation of the retaining dam should be longer than the spillway.
4) Large stones should be placed along the sides of the gabion box, while smaller stones are used to fill the center. The size of the stones used for construction should be larger than the size of the wire mesh (mesh size of 10 x 10 cm and 15 x 15 cm).
5) If there is debris, a concrete layer may be needed in front of the dam to protect the gabion wire from damage.
6) The spillway dimensions should be calculated based on the maximum flow from the river catchment area.
7) An apron should be built under the dam.
8) The back of the retaining dam needs to be filled with soil to enhance the dam's strength.
9) The gabion boxes should be tied with 12 gauge wire.

Figure 6.11 Gabion Check Dam
(Source: https://i.pinimg.com/originals/32/6e/5e/326e5e1d490cc5da1dd6a6ba9bdd477d.jpg)

2. Terracing

Terracing is a soil and water conservation method involving the construction of a series of terraces to reduce the length and steepness of slopes. Terracing can directly control water flow and reduce significant soil loss. It alters the continuity of the topography, shortening slopes by cutting runoff and increasing infiltration time. Terracing can also be combined with buffer strips to control soil erosion (Huang *et al*., 2022). The construction of terraces combined with agroforestry trees can help increase land cover and water infiltration gradually, reducing nutrient loss and improving crop productivity. Terracing is not suitable for shallow soils. The concept of conservation using the terracing system is shown in **Figure 6.12**, and the application of terracing is shown in **Figure 6.14.**

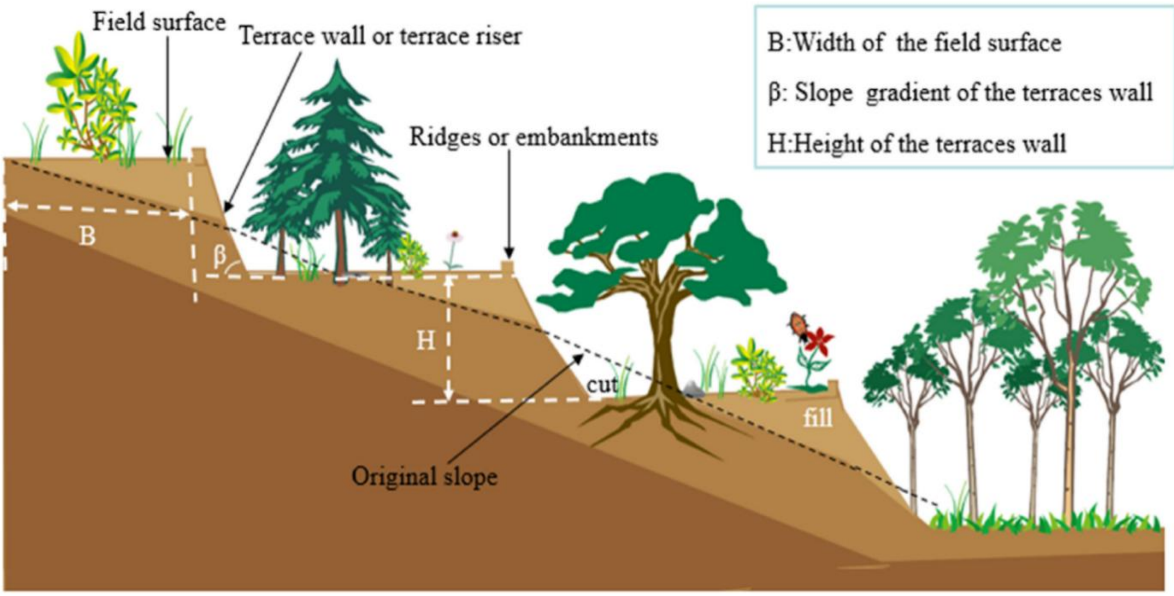
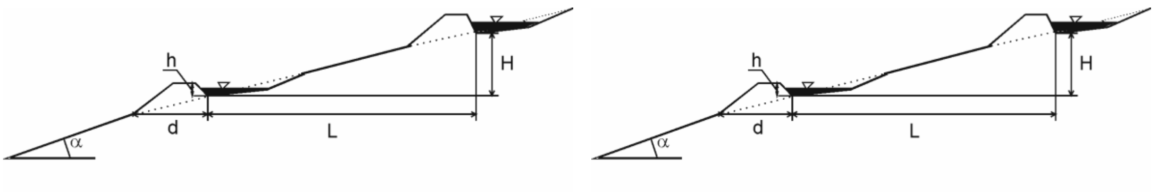


Figure 6.12 Terracing Conservation Concept
(Source: Deng *et al.,* 2021)

Some types of terraces based on their suitability for different slopes include:

a. **Broad Channel Terraces**, These are typically made to capture and direct excess water from fields. This type of terrace is suitable for wet areas and slopes not exceeding 20%.
b. **Ridge Terraces**, These are made to capture and hold excess water by spreading it across the land between hill ridges. These terraces are commonly applied on flat slopes (<3%) because the water spreads more widely without requiring tall ridges. Ridge terraces have water channels at the back of the ridge (embankment) to drain surface water into drainage channels and improve water absorption into the soil. The ridge terrace divides the slope into smaller hydrological units, reducing water flow paths and influencing water circulation across the slope and within the entire catchment area. According to Prochal (1984) in Baryła & Pierzgalski (2008), ridge terraces can be divided into two types: with and without water

outflow. Ridge Terraces without Water Outflow, These have a parallel shape with the contours and are built on water-permeable soil with relatively low rainfall. The flowing water is retained by the embankments and absorbed into the soil. Ridge Terraces with Water Outflow, These terraces have surface or subsurface drainage. For subsurface drainage, water is discharged through wells or underground pumps into ditches, rivers, or reservoirs. These terraces are used in areas with high precipitation and on soils with low water absorption capacity. The concept of ridge terrace division is shown in **Figure 6.13.**



Ridged terraces without water outflow (L, H – horizontal and vertical spacing, respectively)

Ridged terraces with water outflow (1 – well, 2 – pipe, 3 – pond)

Figure 6.13 Concept of Ridge Terraces: Without Outflow (Left); With Outflow (Right) (Source: Baryła & Pierzgalski, 2008)

c. **Bench (Step) Terraces**, Used on slopes of 20-50% to transform the land into a series of steps separated by vertical walls covered with stone or vegetation for protection. Step terraces can be made flat, sloping inward (axe slope), or sloping outward, typically built in ecosystems such as rainfed rice fields, dryland fields, and various agroforestry systems.
d. **Individual Terraces**, Terraces made around each individual plant, particularly for perennial crops. This type of terrace is commonly built in plantation areas or orchards.
e. **Orchard Terraces**, A type of terrace for perennial crops, especially plantation and fruit crops. Terraces are made with varying intervals depending on planting distances.

Terraces are built manually using the cut-and-fill method, where soil from higher levels is cut and moved to lower levels. The design specifications for terraces are as follows:

1. Terrace Length: Typically a maximum of 100 m in one direction of the drainage channel for humid tropical climates. Terrace length is limited by the size and shape of the land, degree of cutting, and soil type.
2. Terrace Width: The optimal width ranges from 2.5 - 5 m (manual construction) and 3.5 - 8 m (machine/tractor construction). The width is adjusted according to soil depth, land preparation tools, plant types, and other needs.
3. Terrace Gradient: The horizontal gradient of the terrace ranges from 0.5 - 1%, depending on the climate and soil type.
4. Height and Slope of Subterraces: Subterraces are made from compacted soil and protected with grass or stones. The height of the sub-terraces should not exceed 2 m. The Vertical Interval (VI) between two successive terraces can be calculated using the following formula:

   VI = (S x Wb) / 100 - (S x U)

   Descriptions:

   S = Slope (%)

   Wb = Bench Width (m)

   U = Slope of the sub-terrace (m)

Figure 6.14 Application of Terracing Conservation
(Source: https://www.freepik.com/)

3. Biopore Infiltration Holes

Biopore holes are cylindrical holes drilled into the soil to enhance water infiltration, reduce flooding, convert organic waste into compost, decrease greenhouse gas emissions (CO_2 and methane), and harness the role of soil and plant roots. Biopore holes can increase water infiltration by up to 40 times, improving soil moisture and maximizing groundwater reserves. Additionally, biopores can enhance soil fertility by converting kitchen waste into compost.

Biopore holes can be made by digging or using a drill to create holes between 30-100 cm deep, with a spacing of approximately 0.5-1 m between each hole. Biopore holes made around trees can have three holes arranged in an equilateral triangle around the tree. The edges of the holes should be reinforced with cement or short PVC pipes to prevent erosion. Only organic waste (kitchen and/or garden waste) should be placed in the holes. The waste should not be too compacted as it will disrupt water infiltration. The compost produced is typically ready within 2-8 weeks. The concept of applying biopore infiltration holes is shown in **Figure 6.15.**

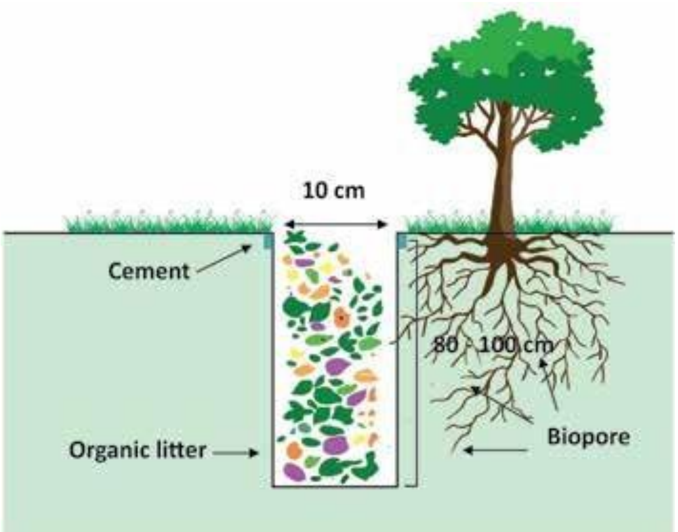


Figure 6.15 Biopore Infiltration Holes
(Source: Godinho *et al.,* 2023)

4. Riverbank Protection

Riverbank protection is a soil and water conservation technique applied along riverbanks to prevent landslides, reduce soil erosion, improve river water quality, and control sedimentation. This technique can be applied to open areas along riverbanks prone to erosion and landslides, steep riverbanks, denuded riverbanks, and areas with high rainfall. Riverbank management can be carried out by planting grasses, shrubs, and trees with deep roots and dense canopies, or by installing bamboo frameworks. The concept of riverbank protection with vegetation is shown in **Figure 6.16.**

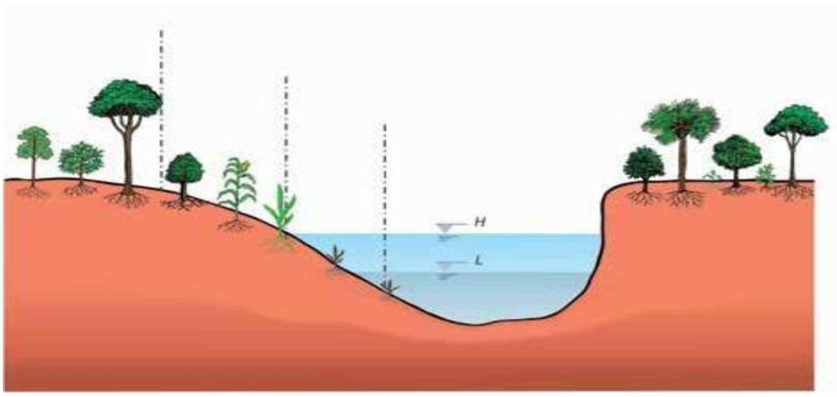


Figure 6.16 Riverbank Protection with Various Layers of Trees, Shrubs, and Grasses
(Source: Godinho *et al*., 2023)

5. Grass Planting

Grass planting is used to suppress soil erosion. The fibrous root system of grass can form a dense mass of interconnected lateral roots, strengthening, holding, trapping, and reinforcing the soil. Grasses with deep, strong, dense, and fibrous root systems can penetrate and bind soil particles, thereby reducing sediment. Grass can also be a functional component of the system, encouraging the formation of terraces even on steep slopes (Do *et al*., 2023). Grass planting can be done in three ways:

a. Horizontal/Contour Grass Planting, This method is used on slopes <65 degrees and erodible land. On slopes <30 degrees, planting distance is 1 x 1 m with 10 x 10 cm spacing; for slopes 30-45 degrees, the planting distance is 50 x 50 cm with 10 x 10 cm spacing; for slopes >45 degrees, the recommended planting distance is 30 x 30 cm with 10 x 10 cm spacing. The concept of horizontal/contour grass planting is shown in **Figure 6.17.**

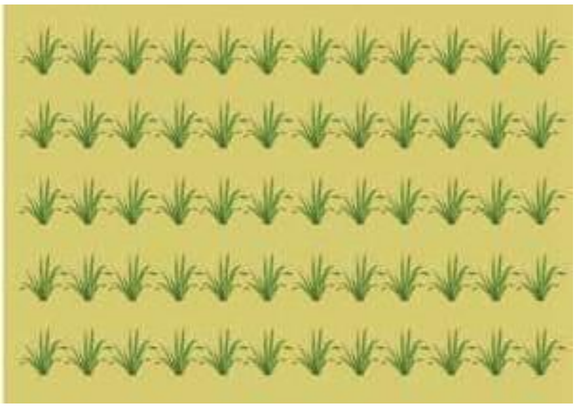


Figure 6.17 Horizontal Grass Planting
(Source: Godinho *et al.,* 2023)

b. Vertical and Downward Grass Planting, This method can be applied to slopes <65 degrees in moist areas. The recommended planting distance is

10 cm between plants and 50 cm between rows. The concept of vertical and downward grass planting is shown in **Figure 6.18.**

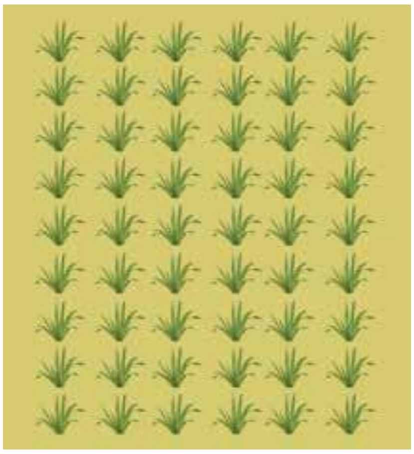


Figure 6.18 Vertical Grass Planting
(Source: Godinho *et al*., 2023)

c. Diagonal Grass Planting, This method is used on slopes <65 degrees with the recommended planting distance of 10 cm between plants and 50 cm between rows. The concept of diagonal grass planting is shown in **Figure 6.19.**

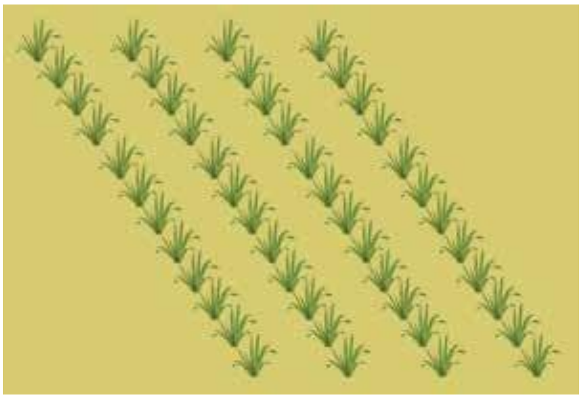


Figure 6.19 Diagonal Grass Planting
(Source: Godinho *et al.,* 2023)

6. Rainwater Reservoir

A rainwater reservoir is a water storage pond used to provide irrigation during the dry season, prevent or reduce flooding during the rainy season, improve water infiltration, increase soil productivity, extend the planting period, and enhance farmers' income. This conservation technique can be applied in areas with high rainfall and high surface flow conditions on slopes of 8-30%.

The construction of a rainwater reservoir involves digging, clay lining, and building drainage channels. When digging, the embankment or edges of the reservoir should be higher than the ground surface to prevent soil from entering the reservoir. Drainage channels are constructed to prevent overflow from the reservoir. The distance between the drainage channel and the surface of the reservoir should be between 25-50 cm. Next, the clay lining serves as reinforcement for the embankment or walls of the reservoir, which are usually 25 cm thick. The top cover of the reservoir should be sloped at 70-80 degrees or in steps to prevent landslides. For sandy soils, the dam walls should be lined with plastic, cement, or a mixture of lime and clay (1:1 ratio) to prevent rapid water infiltration. Lastly, the overflow channel should face the area to be irrigated, with a width between 15-25 cm and a depth between 10-15 cm. Furthermore, the rainwater reservoir needs to be maintained by cleaning the drainage channels, reservoir edges, and dam walls, and removing sediment buildup. The concept of creating a rainwater reservoir is shown in **Figure 6.20.**

Figure 6.20 Rainwater Reservoir Construction
(Source: Godinho *et al.,* 2023)

7. Drainage Channel Construction

Drainage channels are used to direct water to areas where it can be absorbed into the soil or stored. Typically, these channels are also equipped with small waterfalls to prevent erosion and soil loss. The construction of drainage channels begins by digging the soil to a minimum depth of 50 cm from the cultivation space, with a base width of 50 cm. The channel base in bench terraces is made with a slope of 0.1-0.5% outward. Along 1 m of the drainage channel, 20 cm of grass is planted across the channel. Next, a waterfall is constructed using two or three split bamboo poles placed horizontally on the waterfall with a depth of 0.5 m, with the outer part of the bamboo placed on the outside. Maintenance efforts include cleaning the channels of sediment, trimming weeds, and repairing any damaged bamboo structures. The concept of a drainage channel is shown in **Figure 6.21.**

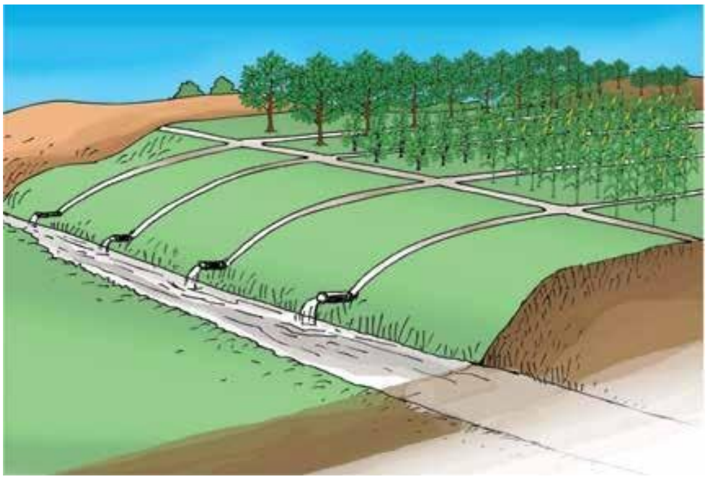


Figure 6.21 Drainage Channel
(Source: Godinho *et al.,* 2023)

8. Wattle Fence / Live Check Dam

A wattle fence is a line of short fences or walls made from vegetative materials and constructed along contours to capture debris moving down slopes, strengthen, and modify slopes. This conservation technique creates a microenvironment for various plant species.

The wattle fence is made by clearing vegetation (wood or branches) to serve as posts. Wooden posts (100 cm) are inserted at intervals of 100 cm along the fence line. Two posts, each 50 cm long, are placed between the main posts and should protrude about 20-30 cm from the ground surface. A trench (at least 15 cm deep) is dug along the contour between the installed posts. The bottom ends of plant cuttings are placed in the trench, and the cuttings are woven between the posts, tightly packing the soil back into the trench. The concept of wattle fence application is shown in **Figure 6.22.**

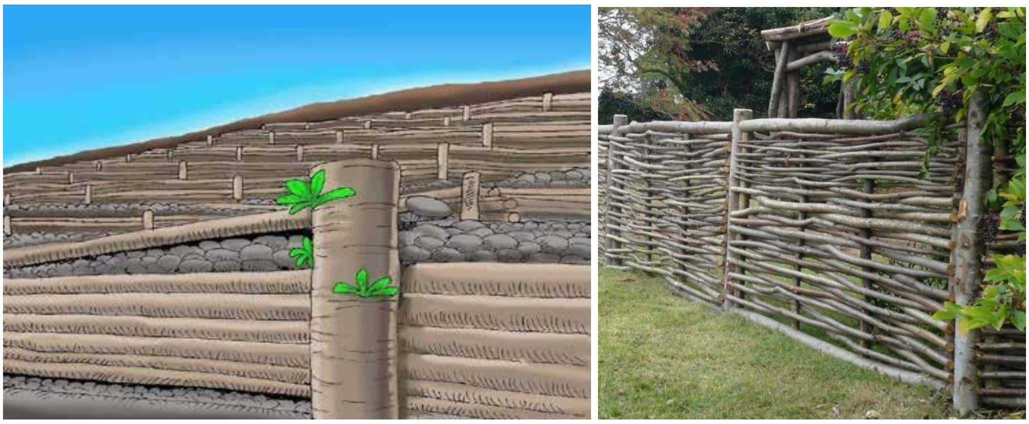


Figure 6.22 Wattle Fence

9. Vegetative Measures

Vegetative actions to achieve better soil and water conservation efficiency include alternating the planting of fruit trees, spices, and food crops. Conservation practices should minimize soil disturbance (minimum tillage), enhance land cover, and promote crop rotation to improve agricultural sustainability (Huang *et al*., 2022).

a. **Conservation Forest**, Soil and water conservation forests can reduce surface runoff erosion and maintain or restore soil fertility. Tree species and stand structure are the most important factors determining conservation effectiveness. Native tree species and layered vegetation structures (e.g., trees + shrubs + spices) are prioritized for greening patterns.
b. **Hedge Planting**, Using hedge plants is also effective in controlling soil erosion on slopes, retaining runoff, and enhancing soil fertility. Hedge plants that can be used include *Vetiveria zizanoides*, *Leucaena leucocephala*, Guinea grass, Gamal (*Gliricidia sepium*), Calliandra calothyrsus, elephant grass (*Pennisetum purpureum*), and others.
c. **Area Covering**, The intensity of land cover is divided into:
    1) Total Cover, Especially for areas that are highly erodible, mountainous regions, near rivers, and reservoirs.
    2) Half Cover, Land cover is only applied during certain seasons.
    3) Rotational Cover, Applied in areas with light erosion, divided into several sub-areas for rotational coverage.
    4) Cover Combined with Planting, For areas with moderate erosion and very low vegetation cover.

Additionally, increasing vegetation cover can be done using mulch made from leaves, compost, and manure to cover the soil surface. Mulching prevents soil moisture loss due to evaporation, prevents soil erosion, and controls weeds. Materials for mulching include rice and corn straw, legume residues, vetiver grass, and plastic film (Huang *et al*., 2022).

d. **Crop Rotation**, Crops grown in rotation produce higher yields than those grown continuously. The benefits from crop rotation also depend on seasonal weather conditions and long-term practices. Long-term crop diversification increases agroecosystem productivity compared to monoculture systems and reduces input use. Combinations of legume and brassica plants tend to have a positive impact on the soil due to the mix of tap and fibrous roots, making the soil organisms complex and diverse (Quintarelli *et al*., 2022).

e. **Water Reservoir,** According to Rustam (2010), a water reservoir is an artificial structure used to store and retain water with a specific small volume, smaller than a dam/reservoir. Reservoirs are usually built by damming small rivers or constructed outside of rivers. The water reservoir stores water during the rainy season and is used by a village during the dry season to meet needs in order of priority: people, livestock, and gardens or fields. The required amount of water will determine the height of the reservoir and its storage capacity. The concept of applying conservation by creating a reservoir is shown in **Figure 6.23.**

Figure 6.23 Water Reservoir Application

VII. AGRICULTURAL LAND SUITABILITY EVALUATION

Land suitability refers to the extent to which a land area is suitable for a specific use. For example, land may be evaluated as highly suitable for rice cultivation, moderately suitable for coffee, or marginally suitable for citrus crops. Land suitability can be assessed based on two conditions: the current condition and the condition after improvements.

7.1 LAND SUITABILITY FOR AGRICULTURE

Land suitability assessment based on the current condition uses data from field surveys. This evaluation reflects the land's capacity in its existing state without additional intervention. Actual land suitability, or current suitability, refers to the land's suitability in its natural state, not yet considering improvement efforts and management practices that could address the constraints or limiting factors present in each land unit/map unit. To determine the class of actual land suitability, an assessment is first made of each land quality based on the most limiting factor/poorest land characteristic, and then the land suitability class is determined based on the poorest or most limiting land quality.

Potential land suitability refers to the suitability of land after improvements have been made. For example, land that is marginally suitable (S3) in its current condition due to nutrient limitations may be upgraded to moderately suitable (S2) or even highly suitable (S1) after improvements. The assessment of potential land suitability involves making improvements to the land qualities that are limiting factors, so that its suitability class is expected to increase. Through technology, lands that naturally have a low land suitability class (current suitability) can be improved to a higher suitability class (potential suitability). However, not all land qualities or characteristics can be improved with the current technology available, and high levels of management may be required for improvement. In land use planning, the main focus is on potential land suitability, as this assessment provides an overview of the maximum potential of land for various uses after improvements are made. Thus, potential land suitability helps in planning land use effectively and sustainably, as well as determining the necessary improvement measures to achieve optimal results.

7.2 LAND SUITABILITY CLASSIFICATION STRUCTURE

The land suitability classification system according to the Framework of Land Evaluation (FAO, 1976) is widely used in Indonesia and other developing countries. The framework of the land suitability classification system utilizes four categories: order, class, subclass, and unit (Hardjowigeno, 2015). Systematically, land suitability is presented in **Table 7.1.**

Table 7.1 Land Suitability Classification (FAO, 1976)

Order	:	Indicates whether a land area is suitable or not for a specific use.
Class	:	Indicates the level of suitability of the land.
Sub-class	:	Indicates the type of constraints or types of improvements required within each class
Unit	:	Indicates the differences in the extent of limiting factors affecting the management of the subclass

Orders and classes are commonly used in reconnaissance soil mapping, subclasses are applied in semi-detailed soil mapping, and mapping units are used for detailed soil mapping. Orders are also used in soil mapping at coarse (exploratory) scales:

Order of Suitability

The order of suitability reflects the general suitability of land, determining whether a land area is suitable or not suitable for a specific type of land use. At the order level, land is classified into suitable (S) or not suitable (N) categories.

Suitable Order (S)

Land included in this order refers to land that can be used over the long term for a specific intended purpose. The benefits derived from managing this land will be satisfactory when calculated based on the inputs provided, with little to no risk of resource degradation.

Unsuitable Order (N)

Land included in this order refers to land that faces various constraints or obstacles, either physically (such as very steep slopes, rocky terrain, etc.) or economically (where the inputs provided do not balance with the outputs generated, preventing its use for the intended purpose).

Suitability Class

The suitability class indicates the degree of suitability of land within an order. At the class level, land classified under the suitable order (S) is divided into highly suitable (S1), moderately suitable (S2), and marginally suitable (S3). Land classified under the unsuitable order (N) is not further subdivided.

Highly Suitable Class (S1)

Land with no significant or apBitter Melonnt limiting factors against sustainable land use, or only minor limiting factors that do not noticeably reduce land productivity.

Moderately Suitable Class (S2)

Land with somewhat severe limiting factors that require specific management practices. These limitations will reduce productivity or profitability and increase the inputs required.

Marginally Suitable Class (S3)

Land with severe limiting factors that make it difficult to maintain the required level of management. These severe constraints will reduce productivity and profitability and necessitate additional inputs to achieve the desired outputs.

Not Suitable Class (N)

Land with very severe and difficult-to-overcome limiting factors that prevent its sustainable use in the long term.

N2 Class: Permanently Not Suitable. Land with permanent constraints that prevent any possibility of sustainable land use in the long term.

7.3 LAND SUITABILITY ASSESSMENT RESULTS

Land suitability analysis is a fundamental step in designing strategies for sustainable land resource management. This evaluation process is based on an integrated approach that includes the use of geospatial data, field observations, and laboratory analysis of physical and chemical soil properties. This approach allows for the identification of the potential and limitations of the land for developing various types of agricultural, horticultural, and forestry commodities.

Geospatial data is used to map the topography, land use distribution, and rainfall patterns in each District, while field observations provide direct information about the land’s biophysical conditions, such as slope gradient, vegetation cover, and drainage quality. Soil sample analysis in the laboratory complements this process by providing data on macronutrient content (nitrogen, phosphorus, potassium), organic matter, cation exchange capacity (CEC), pH, and soil texture.

Subsequently, the data obtained is analyzed based on the growing requirements of each crop type under current conditions, as well as their potential suitability after various land improvement efforts, such as fertilization, addition of organic matter, or the implementation of soil conservation techniques. This process generates comprehensive information to determine commodity development priorities, identify limiting factors, and design relevant technical solutions. The placement of several crops in the same column in **Table 7.2** indicates that these crops share similar growing requirements and limiting factors. This means they require similar environmental conditions to grow optimally and face relatively the same constraints in their cultivation processes. In contrast, crops placed in different columns have different growing requirements and limiting factors, necessitating management approaches tailored to their individual needs.

This scientific approach serves as the foundation for the land suitability evaluation in Dili District. The results of this analysis provide strategic guidance to maximize land productivity while ensuring the sustainability of natural resources in each area.

A. Land Suitability Evaluation of Cristo Rei Sub-District

Cristo Rei Sub-District has significant potential for the development of various agricultural commodities, including food crops, horticulture, industrial crops, forestry commodities, and forage crops. In the food crop sector, crops such as irrigated rice, rainfed rice, corn, and cassava show promising cultivation prospects, especially when adapted to the local agroclimatic conditions. In horticulture, vegetables like bell peppers and green bean can be developed intensively, while tropical fruits such as papaya, oranges, and durian offer good market prospects. Additionally, ornamental flowers like roses, asters, and sunflowers not only have economic potential but also support aesthetic and environmental conservation aspects.

To support the livestock sector, grazing areas in Cristo Rei Sub-District allow for the development of leguminous plants and forage crops such as elephant grass and setaria. This development needs to be accompanied by input additions in the form of fertilizers and proper land management to improve soil fertility and production efficiency. Overall, the agricultural potential in this area can be optimized through an integrated approach that combines ecological, technical, and socio-economic aspects, thereby supporting sustainable and competitive agricultural development. Spices and medicinal plants such as lemongrass and galangal also have high functional value and can be developed as part of agricultural diversification. In the industrial crop sector, crops like robusta coffee and sugarcane are examples of plants that can contribute to increasing local income and strengthening the local economy.

The main constraints in the development of agricultural crops in Cristo Rei Sub-District include the prolonged dry season, soil texture, rainfall intensity, slope gradient, Erosionon severity, drainage, flood potential, and soil depth. These factors can technically be addressed through irrigation system optimization, the creation of drainage channels, the addition of organic matter, and the implementation of soil conservation techniques, such as terracing with supporting and cover crops. However, there are also limiting factors such as temperature, surface rocks, and rock outcrops, which are permanent and cannot be remedied. Nevertheless, land management remains feasible through surface rock clearing and the creation of planting holes between rock outcrops, thus supporting cultivation efficiency and productivity.

This area has a relatively good land suitability potential to support sustainable agriculture. However, wheat cultivation is not recommended due to a permanent Temperature limitation that cannot be remedied. In addition to the crops mentioned, **Table 7.5** presents other crops that can be developed in Cristo Rei Sub-District.

B. Land Suitability Evaluation of Dom Aleixo Sub-District

Dom Aleixo Sub-District has significant agricultural potential for the development of various commodities, particularly in the horticulture, industrial crop, forestry, and forage sectors. In the fruit horticulture sector, crops such as jackfruit, soursop, and longan show promising cultivation opportunities, both for local consumption and regional markets. Additionally, ornamental flowers like roses, asters, and sunflowers have high aesthetic and economic value and can be developed as part of conservation and agritourism programs.

Spices and medicinal plants such as vanilla and nutmeg also present good development prospects, given their high market value and their benefits in the food and health industries. In the industrial crop sector, plants such as cacao, cloves, and *Melinjo* have the potential for further development to support economic diversification and increase the added value of agricultural products. To support the livestock sector, grazing areas in Dom Aleixo Sub-District allow for the development of leguminous plants and forage crops such as elephant grass and setaria. This development needs to be supported by the addition of fertilizers and proper land management to improve soil fertility and forage productivity. The main constraints in agricultural development in Dom Aleixo Sub-District include the long dry season, soil texture, rainfall intensity, slope gradient, Erosionon severity, drainage, flood potential, and soil depth. These factors can technically be addressed through irrigation system optimization, the creation of drainage channels, the addition of organic matter, and the implementation of soil conservation techniques, such as terracing with supporting and cover crops. However, there are also limiting factors such as Temperature, surface rocks, and rock outcrops, which are permanent and cannot be remedied. Nevertheless, land management remains feasible through surface rock clearing and the creation of planting holes between rock outcrops, thereby supporting cultivation efficiency and productivity.

This area has relatively good land suitability potential to support sustainable agriculture. However, species such as altingia, pine, and arabica coffee are not recommended for cultivation due to permanent Temperature limitations that cannot be remedied. In addition to the crops mentioned, **Table 7.5** presents other crops that can be developed in Dom Aleixo Sub-District.

C. Land Suitability Evaluation of Nain Feto Sub-District

Nain Feto Sub-District has significant potential for the development of various agricultural commodities, particularly in dryland areas. In the food crop sector, crops such as rainfed rice, corn, and sorghum show good adaptation to the local agroclimatic conditions and have strategic importance in supporting local food security. In horticulture, vegetables like bell peppers and beans can be developed intensively, while tropical fruits such as rambutan and guava have promising market prospects. Flower horticulture is also a potential sector, with species like roses, asters, and sunflowers not only providing aesthetic value but also supporting agritourism development and landscape conservation. Spices and medicinal plants such as vetiver root and nutmeg have high economic and functional value and can be utilized in both the food processing industry and traditional medicine. In the industrial crop sector, *Melinjo* and robusta coffee are commodities that have the potential for further development to increase farmers' incomes and strengthen the local economy. To support the livestock sector, the development of forage crops such as elephant grass and legumes in grazing areas needs to be encouraged through the addition of inputs and proper land management to improve soil fertility and forage productivity. In addition to the crops already mentioned, **Table 7.5** presents a list of other plants that have potential for development in Nain Feto Sub-District. The land suitability is influenced by several limiting factors, including slope gradient, rainfall intensity, drainage, soil depth, dry season duration, coarse materials, flood potential, and Erosionon severity. These factors can technically be addressed through irrigation system optimization, the creation of drainage channels, and the implementation of soil conservation techniques, such as terracing with supporting and cover crops. However, there are also limiting factors such as Temperature, surface rocks, and rock outcrops, which are permanent and cannot be remedied. Nevertheless, land management remains feasible through surface rock clearing and the creation of planting holes between rock outcrops, thus supporting cultivation efficiency and productivity.

This area has potential for sustainable agriculture. However, crops such as snow peas, garlic, and wheat cannot be developed in this region due to permanent Temperature limitations that cannot be remedied.

D. Land Suitability Evaluation of Vera Cruz Sub-District

Vera Cruz Sub-District has potential for the development of dryland food crops such as groundnut, rainfed rice, and soybeans. In the horticulture sector, vegetables like cucumber, bitter melon, and fruits such as snake fruit and grapes can be cultivated. Ornamental flowers such as roses, asters, and sunflowers also have potential for development. Spices and medicinal plants such as turmeric and cardamom can be explored as well. In the industrial crop sector, cotton and kapok are examples of plants that can be developed, while for grazing areas and livestock feed, crops like elephant grass and legumes are suitable. In addition to the crops mentioned above, **Table 7.5** presents other crops that can be developed in Vera Cruz Sub-District.

The land suitability in this area is influenced by several limiting factors, including slope gradient, rainfall intensity, drainage, soil depth, dry season duration, coarse materials, flood potential, and Erosionon severity. These factors can technically be addressed through irrigation system optimization, the creation of drainage channels, and the implementation of soil conservation techniques, such as terracing with supporting and cover crops. However, there are also limiting factors such as Temperature, surface rocks, and rock outcrops, which are permanent and cannot be remedied. Nevertheless, land management remains feasible through surface rock clearing and the creation of planting holes between rock outcrops, thus supporting cultivation efficiency and productivity.

This area holds potential for sustainable agriculture. However, garlic cannot be developed in this region due to permanent temperature limitations that cannot be remedied.

E. Land Suitability Evaluation of Metinaro Sub-District

Metinaro Sub-District has potential for the development of dryland food crops such as sorghum, rainfed rice, and taro. In the horticulture sector, vegetables like caisim, chili peppers, watermelon, and soursop can be cultivated. Ornamental flowers such as roses, asters, and sunflowers also have potential for development. Spices and medicinal plants like aromatic Ginger and vanilla are promising for further development. For grazing areas and livestock feed, crops such as elephant grass and legumes are suitable. In addition to the crops already mentioned, **Table 7.5** presents other crops that can be developed in Metinaro Sub-District.

The land suitability in this area is influenced by several limiting factors, including slope gradient, rainfall intensity, drainage, soil depth, dry season duration, coarse materials, flood potential, and Erosion on severity. These factors can technically be addressed through irrigation system optimization, the creation of drainage channels, and the implementation of soil conservation techniques, such as terracing with supporting and cover crops. However, there are also limiting factors such as temperature, surface rocks, and rock outcrops, which are permanent and cannot be remedied. Nevertheless, land management remains feasible through surface rock clearing and the creation of planting holes between rock outcrops, thereby supporting cultivation efficiency and productivity.

This area holds potential for sustainable agriculture. However, cinnamon and snow peas cannot be developed in this region due to permanent Temperature limitations that cannot be remedied.

Table 7.2 Land Suitability Evaluation Analysis Matrix in Dili District

Commodities	Sub-District	Limiting Factors	Potential Land Suitability / Land Improvement Efforts
FOOD COMMODITES			
Irrigated Rice	Cristo Rei	**S2:** Slope	S1
Dryland Food Crops			
Upland Rice	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Drainage, Erosion, Surface rocks **S2:** Coarse Fragment, Rock outcrops	**S2:** Coarse Fragment, Slope, Surface rocks, Rock outcrops
Corn Shorgum Peanut Mung Bean Cowpea	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Erosion, Slope **S3:** Drainage, Surface rocks **S2:** Rainfall, Rock outcrops	**S2:** Slope, Erosion, Surface rocks, Rock outcrops
Cassava	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Drainage, Erosion, Rock outcrops **S2:** Effective Depth, Surface rocks	**S2:** Effective Depth, Slope, Surface rocks, Rock outcrops
Soybean	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Drainage, Erosion, Surface rocks **S2:** Temperature, Rainfall, Rock outcrops	**S2:** Temperature, Slope, Surface rocks, Rock outcrops
Taro	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Temperature, Rainfall, Erosion, Surface rocks **S2:** Drainage, Rock outcrops	**S3:** Temperature **S2:** Slope, Surface rocks, Rock outcrops
Sweet Potato	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Dry month, Slope **S3:** Drainage, Erosion, Surface rocks, **S2:** Effective Depth, Rock outcrops	**N:** Dry month **S2:** Effective Depth, Slope, Surface rocks, Rock outcrops
Wheat	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Temperature, Slope **S3:** Drainage, Erosion, Surface rocks **S2:** Rainfall, Rock outcrops	**N:** Temperature **S2:** Slope, Surface rocks, Rock outcrops
VEGETABLE HORTICULTURAL COMMODITIES			
Potato	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Temperature, Slope **S3:** Drainage, Flood, Surface rocks, Erosion, Rainfall	**N:** Temperature **S2:** Slope, Surface rocks, Rock outcrops, Texture

		S2: Rock outcrops, Texture, N-total, Available-P, Available potassium, CEC, BS	
Carrot	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Temperature, Slope **S3:** Drainage, Flood, Surface rocks, Erosion **S2:** Rock outcrops, Texture, N-total, Available-P, Available potassium, CEC, BS	**N:** Temperature **S2:** Slope, Surface rocks, Rock outcrops, Texture
Bell Pepper Green Bean Broccoli	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Drainage, Flood, Surface rocks, Erosion **S2:** Temperature, Rainfall, Rock outcrops, N-total, Available-P, Available potassium, CEC, BS	**S2:** Slope, Surface rocks, Temperature, Rock outcrops
Shallot	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Drainage, Flood, Surface rocks, Erosion **S2:** Temperature, Rainfall, Rock outcrops, Texture, N-total, Available-P, Available potassium, CEC, BS	**S2:** Slope, Surface rocks, Temperature, Rock outcrops, Texture
Garlic	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Temperature, Slope **S3:** Drainage, Flood, Erosion **S2:** Rainfall, Rock outcrops, N-total, Available-P, Available potassium, CEC, BS	**N:** Temperature **S2:** Slope, Rock outcrops
Chili	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Rainfall, Slope **S3:** Drainage, Flood, Erosion, Surface rocks **S2:** Rock outcrops, N-total, Available-P, Available potassium, CEC, BS	**S2:** Slope, Surface rocks, Rock outcrops
Caisim	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Drainage, Dry month, Flood, Erosion, Surface rocks **S2:** Temperature, Rock outcrops, Texture, N-total, Available-P, Available potassium, CEC, BS	**S2:** Slope, Dry month, Surface rocks, Temperature, Rock outcrops, Texture
Snow Pea	• Cristo Rei • Metinaro • Nain Feto	**N:** Temperature, Slope	**N:** Temperature

	• Vera Cruz	**S3:** Drainage, Flood, Erosion, Surface rocks **S2:** Rainfall, Rock outcrops, N-total, Available-P, Available potassium, CEC, BS	**S2:** Slope, Surface rocks, Rock outcrops
Cucumber	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Rainfall, Drainage, Flood, Erosion, Surface rocks **S2:** Rock outcrops, N-total, Available-P, Available potassium, CEC, BS	**S2:** Slope, Surface rocks, Rock outcrops
Eggplant Bitter Melon Vegetable Tomato	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope, Flood **S3:** Rainfall, Drainage, Erosion, Surface rocks **S2:** Temperature, Rock outcrops, N-total, Available-P, Available potassium, CEC, BS	**S2:** Slope, Surface rocks, Temperature, Rock outcrops
Cabbage	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Drainage, Flood, Erosion, Surface rocks **S2:** Temperature, Rainfall, Rock outcrops, Texture, N-total, Available-P, Available potassium, CEC, BS	**S2:** Slope, Surface rocks, Temperature, Rock outcrops, Texture
Long Bean	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Drainage, Flood, Erosion, Surface rocks **S2:** Temperature, Rainfall, Rock outcrops, N-total, Available-P, Available potassium, CEC, BS	**S2:** Slope, Surface rocks, Temperature, Rock outcrops
HORTICULTURAL FLOWER COMMODITIES			
Fruit Horticultural Plant Group: 1. Papaya 2. Orange 3. Mango 4. Guava 5. Snake Fruit	• Cristo Rei • Dom Aleixo • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Erosion, N-total, Available-P **S2:** Rock outcrops, Surface rocks, Available potassium	**S2:** Slope, Rock outcrops, Surface rocks
Fruit Horticultural Plant Group: 1. Soursop 2. Longan	• Cristo Rei • Dom Aleixo • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Erosion, N-total, Available-P **S2:** Temperature, Rock outcrops, Surface rocks, Available potassium	**S2:** Slope, Temperature, Rock outcrops, Surface rocks

Fruit Horticultural Plant Group: 1. Watermelon 2. Melon	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Erosion, Slope **S3:** Rainfall, Surface rocks, N-total, Available-P **S2:** Drainage, Rock outcrops, Available potassium, Texture	**S2:** Slope, Erosion, Rock outcrops, Surface rocks
Fruit Horticultural Plant Group: 1. Custard Apple 2. Pineapple	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**S3:** Erosion, Slope, Surface rocks, N-total, Available-P **S2:** Rock outcrops, Available potassium	**S2:** Rock outcrops, Surface rocks
Banana	• Cristo Rei • Dom Aleixo • Metinaro • Nain Feto • Vera Cruz	**N:** Dry month **S3:** Erosion, Slope, N-total, Available-P **S2:** Drainage, Rainfall, Rock outcrops, Surface rocks, Available potassium, Texture	**S3:** Dry month **S2:** Rock outcrops, Surface rocks
Rambutan	• Cristo Rei • Dom Aleixo • Metinaro • Nain Feto • Vera Cruz	**N:** Slope **S3:** Rainfall, Erosion, N-total, Available-P **S2:** Rock outcrops, Surface rocks, Available potassium	**S2:** Slope, Rock outcrops, Surface rocks
Avocado	• Cristo Rei • Dom Aleixo • Metinaro • Nain Feto • Vera Cruz	**N:** Dry month **S3:** Erosion, Slope, N-total, Available-P **S2:** Temperature, Rock outcrops, Surface rocks, Available potassium	**S3:** Dry month **S2:** Temperature, Rock outcrops, Surface rocks
Jackfruit	• Cristo Rei • Dom Aleixo • Metinaro • Nain Feto • Vera Cruz	**S3:** Erosion, Slope, N-total, Available-P **S2:** Rainfall, Rock outcrops, Surface rocks, Available potassium	**S2:** Rock outcrops, Surface rocks
Breadfruit	• Cristo Rei • Dom Aleixo • Metinaro • Nain Feto • Vera Cruz	**S3:** Erosion, Slope, N-total, Available-P **S2:** Rock outcrops, Surface rocks, Available potassium, pH	**S2:** Rock outcrops, Surface rocks
Durian	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**S3:** Rainfall, Erosion, Slope, Surface rocks, N-total, Available-P **S2:** Effective Depth, Rock outcrops, Available potassium	**S2:** Rock outcrops, Surface rocks, Effective Depth
Strawberry	• Cristo Rei • Metinaro • Nain Feto	**N:** Erosion, Slope	**S2:** Temperature, Erosion, Slope, Rock outcrops, Surface rocks

	• Vera Cruz	**S3:** Surface rocks, N-total, Available-P **S2:** Temperature, Rock outcrops, Available potassium	
Grapes	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**S3:** Erosion, Slope, Surface rocks, N-total, Available-P **S2:** Effective Depth, Rock outcrops, Available potassium	**S2:** Rock outcrops, Surface rocks, Effective Depth
Passion Fruit	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**S3:** Temperature, Rainfall, Erosion, Slope, Surface rocks, N-total, Available-P **S2:** Effective Depth, Rock outcrops, Available potassium	**S3:** Temperature **S2:** Rock outcrops, Surface rocks, Effective Depth
HORTICULTURAL FLOWER COMMODITIES			
Rose Aster	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope dan Erosion **S3:** Drainage, dan Surface rocks **S2:** Temperature, Rock outcrops, C-organik, N-total, Available-P, Available potassium	**S2:** Temperature, Slope, Erosion, Surface rocks, Rock outcrops
Sunflower	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope, Erosion **S3:** Rainfall, Drainage, Surface rocks **S2:** Rock outcrops, N-total	**S2:** Slope, Erosion, Rock outcrops, Surface rocks
SPICE AND MEDICINAL COMMODITIES			
Ginger	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Rainfall, Dry month, Slope, Flood **S3:** Temperature, Erosion, Effective Depth, Surface rocks, Rock outcrops **S2:** Drainage, N-Total, Available-P, Available potassium	**S3:** Temperature, Dry month **S2:** Rainfall, Slope, Effective Depth, Surface rocks, Rock outcrops
Vetiver Root	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz • Dom Aleixo	**N**: Erosion, Slope, Rock outcrops, Flood **S3:** Drainage, Rainfall, Surface rocks **S2:** Temperature, N-Total, Available-P, Available potassium	**S3:** Rock outcrops **S2:** Temperature, Erosion, Slope, Surface rocks
Lemongrass	• Cristo Rei • Metinaro • Nain Feto	**N:** Rainfall, Erosion, Slope, Rock outcrops, Flood	**S3:** Rock outcrops **S2:** Temperature, Rainfall, Erosion, Slope, Surface rocks

	• Vera Cruz • Dom Aleixo	**S3:** Drainage, Surface rocks **S2:** Temperature, N-Total, Available-P, Available potassium	
Vanilla	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz • Dom Aleixo	**N:** Dry month, Erosion, Effective Depth, Slope, Rock outcrops, Flood **S3:** Drainage, Surface rocks **S2:** Temperature, Rainfall, N-Total, Available-P, Available potassium	**S3:** Dry month, Effective Depth, Rock outcrops **S2:** Temperature, Erosion, Slope, Surface rocks
Candlenut	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz • Dom Aleixo	**N:** Dry month, Erosion, Slope, Rock outcrops, Flood **S3:** Drainage, Surface rocks **S2:** Effective Depth	**S3:** Dry month, Rock outcrops **S2:** Erosion, Slope, Surface rocks, Effective Depth
Cinnamon	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz • Dom Aleixo	**N:** Temperature, Rainfall, Dry month, Surface rocks, Flood **S3:** Drainage, Erosion, Effective Depth, Slope, Rock outcrops	**N:** Temperature **S3:** Dry month, Surface rocks **S2:** Rainfall, Effective Depth, Rock outcrops
Nutmeg	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz • Dom Aleixo	**N:** Rainfall, Dry month, Erosion, Slope, Rock outcrops, Flood **S3:** Drainage, Surface rocks **S2:** Temperature, Effective Depth	**S3:** Dry month, Rock outcrops **S2:** Temperature, Rainfall, Erosion, Slope, Effective Depth, Surface rocks
Pepper	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz • Dom Aleixo	**N:** Rainfall, Dry month, Erosion, Slope, Surface rocks, Rock outcrops, Flood **S3:** Drainage	**S3:** Dry month, Surface rocks, Rock outcrops **S2:** Rainfall, Erosion, Slope
Jatropha	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz • Dom Aleixo	**N:** Erosion, Slope, Rock outcrops, Flood **S3:** Drainage, Surface rocks **S2:** Rainfall	**S3:** Rock outcrops **S2:** Erosion, Slope, Surface rocks
Aromatic Ginger	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Rainfall, Slope, Flood **S3:** Erosion, Effective Depth, Surface rocks, Rock outcrops **S2:** Temperature, Drainage, N-Total, Available-P, Available potassium	**S2:** Temperature, Rainfall, Slope, Effective Depth, Surface rocks, Rock outcrops

Turmeric Galangal	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Slope, Flood **S3**: Erosion, Effective Depth, Surface rocks **S2:** Temperature, Drainage, Rock outcrops	**S2:** Temperature**,** Slope, Effective Depth, Surface rocks, Rock outcrops
Cardamom	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Rainfall, Slope, Flood **S3:** Erosion, Effective Depth, Surface rocks, Rock outcrops **S2:** Drainage, N-Total, Available-P, Available potassium	**S2:** Rainfall, Slope, Effective Depth, Surface rocks, Rock outcrops
Sesame	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Rainfall, Dry month, Slope, Flood **S3:** Erosion, Effective Depth, Rock outcrops **S2:** Drainage, N-Total, Available-P, Available potassium	**S3:** Dry month **S2:** Rainfall, Slope, Effective Depth, Rock outcrops
INDUSTRIAL COMMODITIES			
Rubber	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz • Metinaro	**N:** Rainfall, Dry month **S3:** Erosion, Slope, Surface rocks, N-total, Available-P, Available potassium **S2:** Drainage, Rock outcrops	**S3:** Dry month **S2:** Surface rocks, Rock outcrops
Coconut	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz • Metinaro	**S3:** Temperature, Dry month, Erosion, Slope, N-total, Available-P, Available potassium **S2:** Rainfall, Effective Depth, Rock outcrops, Surface rocks	**S3:** Temperature **S2:** Dry month, Rock outcrops, batan permukaan
Oil Palm	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz	**N:** Dry month **S3:** Rainfall, Erosion, Slope, Surface rocks, N-total, Available-P, Available potassium **S2:** Rock outcrops	**S3:** Dry month **S2:** Surface rocks
Arabica Coffee	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz	**N:** Temperature, Dry month **S3:** Erosion, Slope, N-total, Available-P, Available potassium **S2:** Rock outcrops, Surface rocks	**N:** Temperature **S3:** Dry month **S2:** Rock outcrops, Surface rocks
Robusta Coffee	• Cristo Rei	**N:** Rainfall, Dry month, Slope	**S3:** Dry month

	• Dom Alexio • Nain Feto • Vera Cruz	**S3:** Erosion, N-total, Available-P, Available potassium **S2:** Temperature, Drainage, Rock outcrops, Surface rocks	**S2:** Temperature, Rock outcrops, Surface rocks
Cocoa	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz	**N:** Dry month, Slope **S3:** Rainfall, Erosion, Surface rocks, N-total, Available-P, Available potassium **S2:** Rock outcrops	**S3:** Dry month **S2:** Surface rocks, Rock outcrops
Clove	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz	**N:** Dry month **S3:** Rainfall, Erosion, Slope, Surface rocks, N-total, Available-P, Available potassium **S2:** Rock outcrops	**S3:** Dry month **S2:** Surface rocks, Rock outcrops
Tea	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz	**N:** Dry month **S3:** Temperature, Rainfall, Erosion, Slope, Surface rocks, N-total, Available-P, Available potassium **S2:** Rock outcrops	**S3:** Dry month, Temperature, Surface rocks **S2:** Rock outcrops
Tobacco	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz	**N:** Rainfall, Erosion **S3:** Slope, Surface rocks, N-total, Available-P, Available potassium **S2:** Rock outcrops	**S2:** Surface rocks, Rock outcrops
Sugarcane	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz	**N:** Erosion, Slope **S3:** Surface rocks, N-total, Available-P, Available potassium **S2:** Rock outcrops	**S2:** Surface rocks, Rock outcrops
Cashew	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz	**N:** Dry month **S3:** Erosion, Slope, Surface rocks, N-total, Available-P, Available potassium **S2:** Drainage, Rock outcrops	**S3:** Dry month **S2:** Surface rocks, Rock outcrops
Melinjo	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz	**N:** Dry month **S3:** Rainfall, Erosion, Slope, Surface rocks, N-total, Available-P, Available potassium **S2:** Rock outcrops	**S3:** Dry month **S2:** Surface rocks, Rock outcrops

Cotton Kapok	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz	**N:** Slope **S3:** Erosion, Slope, Rock outcrops, Surface rocks, N-total, Available-P, Available potassium	**S2:** Rock outcrops, Surface rocks
Quinine	• Cristo Rei • Dom Alexio • Nain Feto • Vera Cruz	**S3:** Temperature, Erosion, Slope, Surface rocks, N-total, Available-P, Available potassium **S2:** Rock outcrops	**S3:** Temperature **S2:** Surface rocks, Rock outcrops
GRAZING LAND AND FORAGE CROPS			
Forage Crop Group: Elephant Grass Setaria	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**S3:** Surface rocks, Rainfall, Erosion, Slope **S2:** Rock outcrops, Drainage, pH, N-total, Available-P, Available potassium	**S2:** Surface rocks, Rock outcrops
Leguminous Plants	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N:** Erosion, Slope **S3:** Surface rocks **S2:** Rock outcrops, Drainage, Rainfall, N-total, Available-P, Available potassium	**S2:** Erosion, Slope, Surface rocks, Rock outcrops
Grazing	• Cristo Rei • Metinaro • Nain Feto • Vera Cruz	**N**: Dry month **S3:** Rock outcrops, Surface rocks, Erosion, Slope **S2:** Rainfall, N-total, Available-P, Available potassium	**S3:** Dry month, Rock outcrops **S2:** Surface rocks

Descriptions: Moderately Suitable (S2); Marginally Suitable (S3); Not Suitable (N)

7.4 LAND IMPROVEMENT EFFORTS

Efforts to improve each limiting factor are crucial for enhancing the productivity and sustainability of the agricultural sector. Various constraints, such as shallow effective soil depth, poor drainage, Erosionon hazards, and surface rocks, require appropriate solutions to maximize the land's potential. On the other hand, certain soil chemical parameters, such as organic carbon (C-Organic) and nutrient levels (nitrogen, phosphorus, potassium), are relatively low in their current state, and land improvement efforts are necessary to increase them, making the land suitable for agricultural commodity development.

Recommendations for land improvement for each limiting factor, as a basis for implementing the enhancement of land suitability for agricultural and forestry commodity development, are presented in **Table 7.3**. The level of improvement required to transform actual land quality into potential quality, based on management practices, is presented in **Table 7.4**. This table serves as a guideline for the transformation of land suitability from actual to potential.

Table 7.3 Recommendations for Improvement Measures for Each Limiting Factor

No	Soil Quality/Characteritics	Type of Improvement Measures	Management Level
1	**Temperature (tc)** - Average annual Temperature	No Improvement possible replacement with suitable crops/varieties	Could not improved
2	**Water Availability (wa)** - Annual rainfall - Rainfall during growth period	 Irrigation, construction of reservoirs/drip irrigation Adjustment of planting patterns/planting calendar	 Medium, High
3	**Root Capacity (rc)** - Drainage - Texture - Effective Depth - Coarse Fragment	 Improvement of drainage system, such as construction of drainage channels, ridges/beds Cannot be improved, can be mitigated by adding organic matter Generally cannot be improved, except in soft and shallow hardpan layers by breaking it during land preparation Depends on the amount and distribution in the profile (if less than 35%, called Obstructing layer, root growth can be improved with organic matter addition and minimum tillage; if more than 90%, called restricting layer, root growth is limited and difficult to improve	 Medium, High High Medium, High High
4	**Nutrient Retention (nr)** - CEC - BS - pH - SOC	 Addition of organic matter Liming, addition of organic matter Liming if soil pH is low, adding sulfur or ZA fertilizer if pH is high Addition of organic matter/fertilizer, and returning plant residues to the soil	 Medium, High Medium, High Medium, High Medium, High
5	**Nutrient Availability (na)** - Total Nitrogen - Available Phosphorus (Avalaible-P) - Available Pottasium (Avalaible-K)	 Fertilization with N (urea and ZA) Fertilization with P (SP36 and TSP) Fertilization with K (KCl) Compound fertilizers (NPK)	 Low, Medium, High Low, Medium, High Low, Medium, High

6	Erosionon Hazard (eh) - Slope (%) - Erosionon hazard	Erosionon control, terracing, contour planting, cover crop planting, mulching, agroforestry implementation.	Medium, High
7	Flood Hazard (fh) - High - Duration	Construction of flood barriers, drainage channels to speed up water drainage, construction of infiltration well	High
8	Land Preparation (lp) - Surface Rock (%) - Rock Outcrops (%)	If few (remove rocks), if many/very many, apply TOT (No-Till), create planting holes, add organic matter	Medium, High
9	Technical Cultural Improvements	Establishing orchards, pruning, maintenance/care	Medium, High

Descriptions:

- *Low management level: Management can be carried out by farmers with relatively low costs.*
- *Medium management level: Management can be carried out by medium-level farmers, requiring medium capital and intermediate agricultural techniques.*
- *High management level: Management can only be carried out with relatively large capital, typically carried out by the government or large or medium-sized companies.*

Table 7.4 Level of Improvement for Actual Land Quality to Potential Based on Management Level

No	Soil Quality and Characteristics	Management Level Medium	High	Type of Improvement
1	**Radiation Regime**	-	-	-
2	**Temperature Regime**	-	-	-
3	**Air Humidity Regime**	-	-	-
4	**Water Availability**			
	- Dry months	+	++	Crop combination
	- Rainfall	+	++	irrigation
5	**Root Capacity**			
	- Drainage	+	++	Drainage channels*)
	- Soil Texture	-	+	Addition of organic matter
	- Effective Depth	-	+	Creation of planting holes and addition of organic matter
	- Peat, Maturity	-	-	-
	- Peat Thickness	-	-	-
6	**Nutrient Retention**			
	- Cation Exchange Capacity	-	+	Addition of organic matter
	- Base Saturation	-	+	
	- pH	+	+	
	- Soil Organic Carbon	+	++	
7	**Nutrient Availability**			
	- Total Nitrogen	+	++	Urea Fertilizer
	- Available-P	+	++	SP36 and TSP Fertilizer
	- Available-K	+	++	KCL Fertilizer
8	**Flood**			
	- Period	+	++	-
	- Frequency	+	++	-
9	**Salinity**			Irrigation and addition of organic matter
	- Salinity	+	++	
10	**Toxicity**			
	- Aluminium Saturation	+	++	Lime
	- Pyrite depth	-	+	Managing groundwater level
11	**Ease of Cultivation**	-	+	Mechanization
12	**Terrain (land) potensi mechanization potential**	-	+	Terracing
13	**Erosion**	+	++	Soil Conservation efforts

Descriptions:

- No Improvement possible
+ Improvement is possible and will result in a one-level increase (S3 to S2)
++ A two-level increase (S3 to S1) is possible
***)** Poor drainage can be improved to better drainage by constructing drainage channels, but rapid/very rapid drainage is difficult to change to moderate/good

7.5 LAND USE DIRECTION

The land use direction in this study is based on the results of the potential land suitability evaluation, considering various improvement interventions that can be implemented. This analysis follows a matching approach between the actual land characteristics and the growth requirements of crops, as outlined in Tables 7.3 and 7.4. This process results in land use recommendations that not only reflect the current biophysical conditions but also account for the potential for increasing suitability through management actions and land improvements. The land use directions for various agricultural commodities, forestry, and livestock grazing/forage crops are presented in Table 7.5.

The determination of recommended plant commodities is made carefully, based on technical criteria outlined in the land suitability evaluation document. This assessment involves various key limiting factors, including water availability, root zone characteristics, nutrient retention capacity and availability, Erosionon and flood risks, and the ease of land cultivation. Each factor is analyzed from the perspective of potential improvement, whether through mechanical, chemical, or biological approaches.

It is important to emphasize that although the evaluation results show that some specific commodities fall under the highly suitable land class (S1), this does not mean that plants will automatically grow and develop optimally solely based on the physical land conditions. The recommendations assume that all land management actions are carried out optimally, including balanced fertilization according to the specific needs of the crops, proper agronomic practices, appropriate irrigation management, local climate-adapted cropping patterns, and the application of adequate soil and water conservation techniques.

Thus, the land suitability classification presented in this document should be understood as the maximum potential that can be achieved if all technical recommendations and land management practices are consistently implemented. The implementation of land use directions requires synergy between farmers, agricultural extension workers, and institutional support from the government in the form of policies, technical guidance, and access to production resources.

This direction is expected to serve as a strategic reference in the planning of sustainable land resource utilization, while considering aspects of productivity, efficiency, and environmental sustainability. Furthermore, this document is expected to support decision-making in the determination of zoning for the development of key commodities, both at the site level and in regional planning scales.

Table 7.5 Land Use Directions (Recommendations) for the Development of Food Commodities, Industry, Horticulture, Spices and Medicinal Plants, Forestry, Livestock Feed, and Grazing Areas in Dili District

NO	DISTRICT	SUB-DISTRICT	FOOD CROPS	DRYLAND AGRICULTURE (PLANTATIONS & HORTICULTURE)	FORESTRY	FORAGE CROPS & GRAZING AREA
1	Dili	Cristo Rei	WETLAND FOOD CROPS **S1:** Irrigated Rice Fields DRYLAND FOOD CROPS **S2:** Upland Rice, Corn, Shorgum, Peanut, Mung Bean, Pigeon Pea, Cassava, Soybean **S3:** Taro, Sweet Potato	INDUSTRY **S3:** Rubber, Coconut, Oil Palm, Robusta Coffee, Cocoa, Clove, Tea, Cashew, *Melinjo* **S2:** Tobacco, Sugarcane, Cotton, Kapok FRUITS **S2:** Papaya, Orange, Rambutan, Mango, Guava, Durian, Watermelon, Melon, Jackfruit, Soursop, Custard Apple, Breadfruit, Snake Fruit, Pineapple, Longan, Strawberry, Grapes **S3:** Banana, Avocado, Passion Fruit VEGETABLES **S2:** Paprika, Green Bean, Broccoli, Shallot, Chili, Caisim, Cucumber, Eggplant, Bitter Melon, Vegetable Tomato, Cabbage, Long Bean FLOWERS **S2:** Rose, Sunflower, Aster SPICES & MEDICINAL PLANTS **S2:** Vetiver Root, Lemongrass, Vanilla, Nutmeg, Aromatic Ginger, Turmeric, Galangal, Sesame **S3:** Ginger, Candlenut, Pepper, Jatropha	**S3:** Teak, Mahogany, sengon, leucaena, Acacia, eucalyptus **S2:** Agathis, Melaleuca, sandalwood	**S2:** Elephant Grass, Setaria, Leguminous Plants **S3:** Grazing

2	Dili	Dom Aleixo		INDUSTRY **S3:** Rubber, Coconut, Oil Palm, Robusta Coffee, Cocoa, Clove, Tea, Cashew, *Melinjo* **S2:** Tobacco, Sugarcane, Cotton, Kapok FRUITS **S2:** Papaya, Orange, Rambutan, Mango, Guava, Durian, Watermelon, Melon, Jackfruit, Soursop, Custard Apple, Breadfruit, Snake Fruit, Pineapple, Longan, Strawberry, Grapes **S3:** Banana, Avocado, Passion Fruit VEGETABLES **S2:** Paprika, Green Bean, Broccoli, Shallot, Chili, Caisim, Cucumber, Eggplant, Bitter Melon, Vegetable Tomato, Cabbage, Long Bean FLOWERS **S2:** Rose, Sunflower, Aster SPICES & MEDICINAL PLANTS **S2:** Vetiver Root, Lemongrass, Vanilla, Nutmeg, Aromatic Ginger, Turmeric, Galangal, Sesame **S3:** Ginger, Candlenut, Pepper, Jatropha	**S3:** Teak, Mahogany, sengon, leucaena, Acacia, eucalyptus **S2:** Agathis, Melaleuca, sandalwood	**S2:** Elephant Grass, Setaria, Leguminous Plants **S3:** Grazing

3	Dili	Nain Feto	DRYLAND FOOD CROPS S2: Upland Rice, Corn, Shorgum, Peanut, Mung Bean, Pigeon Pea, Cassava, Soybean S3: Taro, Sweet Potato	INDUSTRY S3: Rubber, Coconut, Oil Palm, Robusta Coffee, Cocoa, Clove, Tea, Cashew, *Melinjo* S2: Tobacco, Sugarcane, Cotton, Kapok FRUITS S2: Papaya, Orange, Rambutan, Mango, Guava, Durian, Watermelon, Melon, Jackfruit, Soursop, Custard Apple, Breadfruit, Snake Fruit, Pineapple, Longan, Strawberry, Grapes S3: Banana, Avocado, Passion Fruit VEGETABLES S2: Paprika, Green Bean, Broccoli, Shallot, Chili, Caisim, Cucumber, Eggplant, Bitter Melon, Vegetable Tomato, Cabbage, Long Bean FLOWERS S2: Rose, Sunflower, Aster SPICES & MEDICINAL PLANTS S2: Vetiver Root, Lemongrass, Vanilla, Nutmeg, Aromatic Ginger, Turmeric, Galangal, Sesame S3: Ginger, Candlenut, Pepper, Jatropha	S3: Teak, Mahogany, sengon, leucaena, Acacia, eucalyptus S2: Agathis, Melaleuca, sandalwood	S2: Elephant Grass, Setaria, Leguminous Plants S3: Grazing

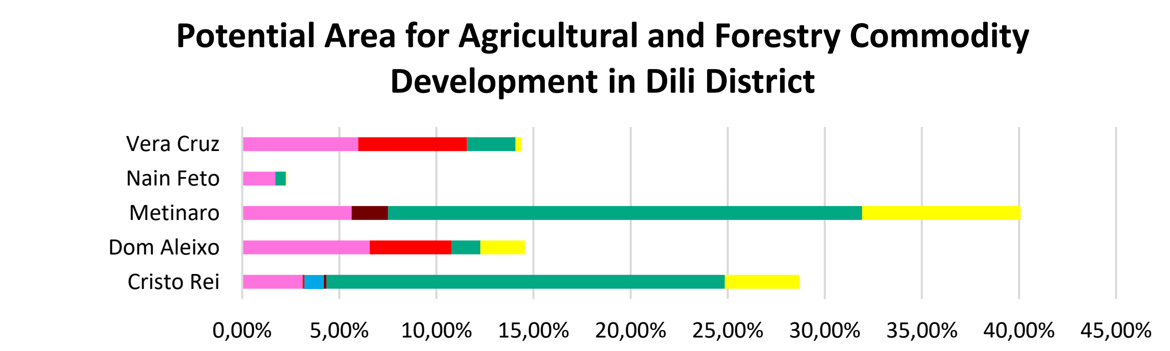
4	Dili	Vera Cruz	DRYLAND FOOD CROPS S2: Upland Rice, Corn, Shorgum, Peanut, Mung Bean, Pigeon Pea, Cassava, Soybean S3: Taro, Sweet Potato	INDUSTRY S3: Rubber, Coconut, Oil Palm, Robusta Coffee, Cocoa, Clove, Tea, Cashew, *Melinjo* S2: Tobacco, Sugarcane, Cotton, Kapok FRUITS S2: Papaya, Orange, Rambutan, Mango, Guava, Durian, Watermelon, Melon, Jackfruit, Soursop, Custard Apple, Breadfruit, Snake Fruit, Pineapple, Longan, Strawberry, Grapes S3: Banana, Avocado, Passion Fruit VEGETABLES S2: Paprika, Green Bean, Broccoli, Shallot, Chili, Caisim, Cucumber, Eggplant, Bitter Melon, Vegetable Tomato, Cabbage, Long Bean FLOWERS S2: Rose, Sunflower, Aster SPICES & MEDICINAL PLANTS S2: Vetiver Root, Lemongrass, Vanilla, Nutmeg, Aromatic Ginger, Turmeric, Galangal, Sesame S3: Ginger, Candlenut, Pepper, Jatropha	S3: Teak, Mahogany, sengon, leucaena, Acacia, eucalyptus S2: Agathis, Melaleuca, sandalwood	S2: Elephant Grass, Setaria, Leguminous Plants S3: Grazing

5	Dili	Metinaro	DRYLAND FOOD CROPS **S2:** Upland Rice, Corn, Shorgum, Peanut, Mung Bean, Pigeon Pea, Cassava, Soybean **S3:** Taro, Sweet Potato	FRUITS **S2:** Papaya, Orange, Rambutan, Mango, Guava, Durian, Watermelon, Melon, Jackfruit, Soursop, Custard Apple, Breadfruit, Snake Fruit, Pineapple, Longan, Strawberry, Grapes **S3:** Banana, Avocado, Passion Fruit VEGETABLES **S2:** Paprika, Mung Bean, Broccoli, Shallot, Chili, Mustard Greens, Cucumber, Eggplant, Bitter Melon, Vegetable Tomato, Cabbage, Long Bean FLOWERS **S2:** Rose, FLOWERS aster, Sunflower SPICES & MEDICINAL PLANTS **S2:** Vetiver Root, Lemongrass, Vanilla, Nutmeg, Aromatic Ginger, Turmeric, Galangal, Sesame **S3:** Ginger, Candlenut, Pepper, Jatropha	**S3:** Teak, Mahogany, sengon, leucaena, Acacia, eucalyptus **S2:** Agathis, Melaleuca, sandalwood	**S2:** Elephant Grass, Setaria, Leguminous Plants **S3:** Grazing

7.6 ZONING FOR AGRICULTURAL POTENTIAL DEVELOPMENT

The research findings indicate that Dili District has significant land resource potential to support the development of agriculture, forestry, and livestock sectors. To maximize this potential, a comprehensive scientific approach was employed in the land suitability evaluation, including field observations, laboratory testing of soil samples, and matching plant growth requirements with regional agroclimatic maps. This evaluation resulted in a systematic, science-based zoning to identify the development potential of various strategic commodities. This zoning reflects the diversity of land utilization potential to support sustainable agriculture, forestry, and livestock sectors, contributing to food security, environmental protection, and improved community welfare. With structured and sustainable management efforts, the vast potential of this region can be optimized through synergy between the government, policymakers, and local communities, ensuring that the benefits are widely shared. The zoning map and the area available for development are presented in **Figure 7.1**, with **Figure 7.2** showing the spatial distribution of the percentage of development areas by Sub-District in Dili District.

Dili District land development potential is divided into several main categories: protected forests 112.22 km² (49.45%), dryland agriculture 51.26 km² (22.98%), rainfed rice fields 33.25 km² (14.65%), irrigated rice fields 2.24 km² (0.99%), grazing areas 22.44 km² (9.89%), and mangrove forests 4.62 km² (2.04%). This zoning reflects the diversity of land utilization potential to support sustainable agriculture, forestry, and livestock sectors, contributing to food security, environmental protection, and improved community welfare.



	Cristo Rei	Dom Aleixo	Metinaro	Nain Feto	Vera Cruz
Dryland Farming	3,11%	6,57%	5,63%	1,70%	5,97%
Grazing Area	0,10%	4,19%	0,00%	0,00%	5,59%
Irrigated Rice Fields	0,99%	0,00%	0,00%	0,00%	0,00%
Mangrove Forest	0,15%	0,00%	1,89%	0,00%	0,00%
Protected Forest	20,50%	1,50%	24,41%	0,54%	2,51%
Rainfed Rice Fields	3,85%	2,29%	8,17%	0,02%	0,32%

Figure 7.1 Dili Area of Agricultural and Forestry Commodity Development in Dili District

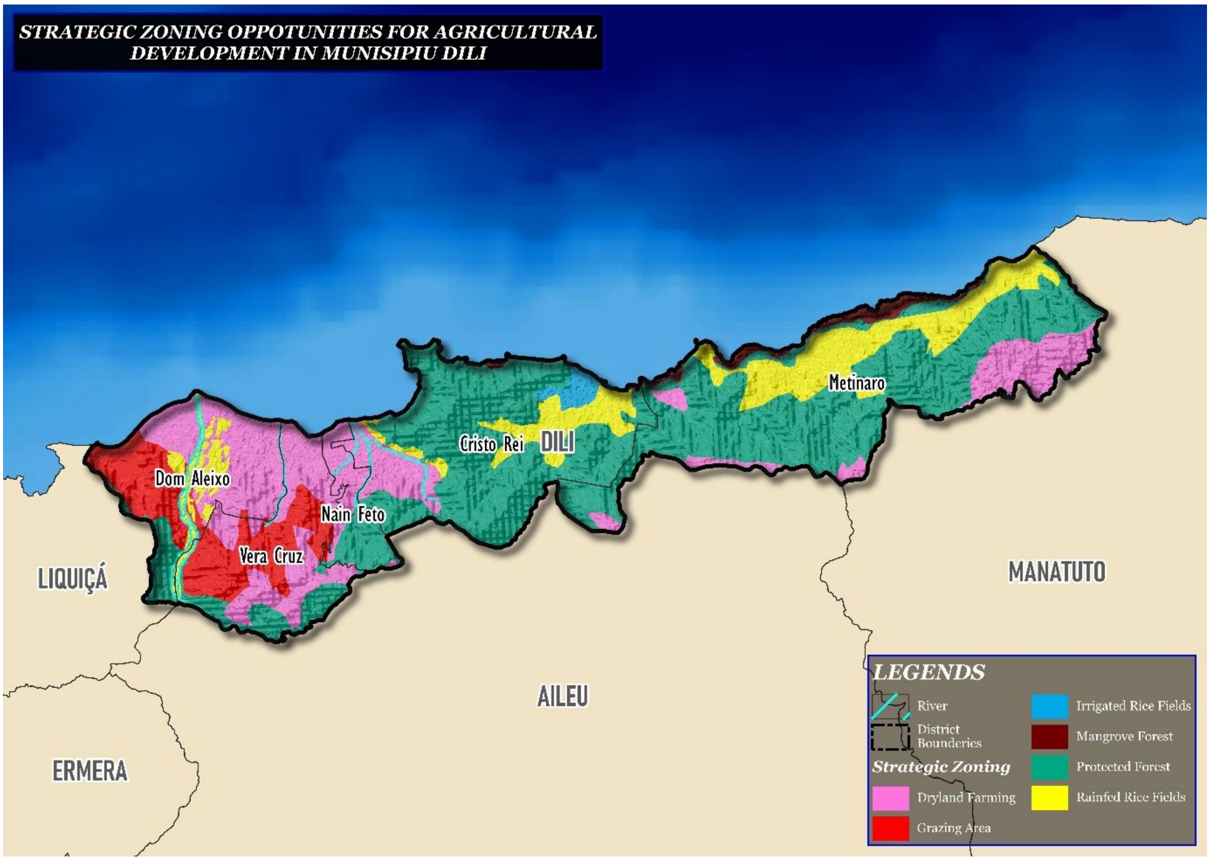


Figure 7.2 Spatial Distribution of Agricultural and Forestry Commodity Development in Dili District

A. Dryland Agriculture

Dryland agriculture is a key sector in Dili District, covering an area of 51.26 km^2, or approximately 22.98% of the total area. This zone is situated at elevations ranging from 20 to 700 meters above sea level, with slopes ranging from gentle to moderately steep. The dominant soil type is Inceptisol, although small areas of Entisol and alluvial soils are also present. Based on agroclimatic classification, this area falls within zones A, B, and C. The distribution of dryland agriculture varies across Sub-Districts. Dom Aleixo Sub-District has the largest area, contributing 6.57% of the total land area, followed by Vera Cruz Sub-District at 5.97%. Nain Feto Sub-District has the smallest area, covering only 1.70% of Dili District.

This area supports the development of various commodities, including staple crops such as rainfed rice, corn, sorghum, cassava, and legumes. Additionally, the horticulture sector includes vegetables, fruits, and flowers, while suitable industrial crops include sugarcane, cotton, and spices. Mixed cropping systems in this zone are seen as beneficial for increasing productivity and improving farmers' incomes. To reduce the risk of Erosion on moderately sloping land, soil conservation strategies, such as strip cropping and crop rotation, are recommended. These practices help maintain soil stability and support sustainable land fertility.

B. Rainfed Rice Fields

The rainfed rice fields in Dili District cover an area of 33.25 km^2, or about 14.65% of the total area, with a dry period lasting 7 to 8 months each year. Topographically, these fields are located at elevations ranging from 0 to 300 meters above sea level, extending to more than 500 meters. The primary soil type is Entisol.

The largest distribution of rainfed rice fields is found in Metinaro Sub-District, covering 8.17% of Dili District total area. This agricultural system is heavily influenced by seasonal rainfall, making water availability the key factor determining productivity levels.

Recommended management practices to enhance agricultural output include the construction of water reservoirs (embung), the use of drought-tolerant rice varieties, and efficient water management strategies. These measures will help ensure the sustainability of the rainfed rice farming system.

C. Irrigated Rice Fields

Irrigated rice fields in Dili District cover an area of 2.24 km², or 0.99% of the total area. These fields are located in lowland areas and alluvial valleys with slopes ranging from 0 to 8%, and the elevation is generally less than 100 meters above sea level. The region is primarily classified under agroclimatic zone A, with a monomodal rainfall pattern. The lithology is dominated by loose sediments ranging from clay to gravel, and the soils are predominantly Entisols and Inceptisols, which are quite responsive to water management.

Development in this area should focus on modernizing the tertiary irrigation network, precision land leveling, and the adoption of the alternate wetting and drying (AWD) technique to improve water use efficiency. Strengthening post-harvest systems is also critical. Key risks in this area include flooding, sedimentation, and saltwater intrusion in the estuary region. Mitigation efforts should include the construction of drainage channels, sediment control in the upstream areas, and the rehabilitation of mangrove ecosystems downstream. When selecting sites for irrigation, it is important to ensure they do not overlap with protected forests, riverbanks, or mangrove zones, in order to maintain ecological balance and sustainable land use.

D. Grazing Areas

The grazing areas in Dili District are relatively small, covering only 1.22 km² or about 0.15% of the total area. The main distribution of grazing areas is found in Vera Cruz Sub-Districts and Dom Aleixo. Land management for grazing focuses on implementing a rotational grazing system to prevent land degradation and increase forage productivity. Additionally, integrating agroforestry systems is recommended to strengthen both the ecological benefits and economic value of the land. Suitable livestock forage species to be developed in these areas include elephant grass, setaria, and legumes, which provide high nutritional content and support sustainable livestock operations.

VIII. FORESTRY POTENTIAL

8.1 LAND SUITABILITY EVALUATION RESULTS

Land suitability analysis is a fundamental step in designing strategies for sustainable land resource management. This evaluation process is based on an integrated approach that includes the use of geospatial data, field observations, and physical and chemical soil analysis in the laboratory. This approach allows for the identification of the potential and limitations of land for the development of various agricultural, horticultural, livestock, and forestry commodities.

Geospatial data is used to map topography, land use distribution, and rainfall patterns in each District, while field observations provide direct information on the land's biophysical conditions, such as slope gradient, vegetation cover, and drainage quality. Laboratory analysis of soil samples complements this process by providing data on macronutrient content (nitrogen, phosphorus, potassium), organic matter, cation exchange capacity (CEC), pH, and soil texture.

Subsequently, the obtained data is analyzed based on the actual growing requirements of each crop type, as well as their potential suitability after undergoing various land improvement efforts, such as fertilization, addition of organic matter, or the implementation of soil conservation techniques. This process generates comprehensive information to determine commodity development priorities, identify limiting factors, and design relevant technical solutions. The placement of several types of plants in the same column in **Table 8.2** indicates that these plants share similarities in their growing requirements and limiting factors. This means they require similar environmental conditions to grow optimally and face relatively similar challenges in the cultivation process. Conversely, plants placed in different columns have different growing requirements and limiting factors, requiring tailored management approaches to meet each plant’s specific needs.

This scientific approach serves as the foundation for land suitability evaluation in Dili District. The results of this analysis provide strategic guidance for maximizing land productivity while ensuring the sustainability of natural resources in each region.

A. Land Suitability Evaluation of Cristo Rei Sub-District

Cristo Rei Sub-District has significant potential for the development of forestry commodities such as Melaleuca (*Melaleuca spp.*) and sandalwood (Santalum album), which are important for both conservation and economic purposes, supporting sustainable natural resource management. The main constraints in agricultural development in Cristo Rei Sub-District include the long dry season, soil texture, rainfall intensity, slope gradient, drainage, and soil depth.

These factors can technically be addressed through planting during the rainy season, the creation of drainage channels, the addition of organic matter, and the implementation of soil conservation techniques, such as the use of cover crops. However, there are also limiting factors such as surface rocks and rock outcrops, which are permanent and cannot be remedied. Nevertheless, land management remains feasible through methods such as surface rock clearing and the creation of planting holes between rock outcrops, thereby supporting cultivation efficiency and productivity. This area has relatively good land suitability potential for supporting sustainable agriculture. In addition to the crops mentioned, **Table 8.1** presents other crops that can be developed in Cristo Rei Sub-District.

B. Land Suitability Evaluation of Dom Aleixo Sub-District

Dom Aleixo Sub-District also holds potential in the forestry sector, with the continued relevance of developing commodities such as sandalwood for both conservation and sustainable utilization. The main constraints in agricultural development in Dom Aleixo Sub-District include the long dry season, soil texture, slope gradient, and soil depth. These factors can technically be addressed through planting during the rainy season, creating drainage channels, adding organic matter, and implementing soil conservation techniques, such as terracing with support crops and cover crops. However, temperature, surface rocks, and rock outcrops are permanent limiting factors that cannot be remedied. Still, land management can be conducted through methods such as surface rock clearing and planting hole creation between rock outcrops to enhance cultivation efficiency and productivity.

This area has good land suitability potential for sustainable agriculture. However, crops such as altingia, pine, and arabica coffee are not recommended for cultivation due to the permanent temperature limitation that cannot be remedied. In addition to the crops mentioned, **Table 8.1** presents other crops that can be developed in Dom Aleixo Sub-District.

C. Land Suitability Evaluation of Nain Feto Sub-District

Nain Feto Sub-District has significant potential for developing forestry commodities such as agathis (*Agathis* spp.) and Albizia (*Paraserianthes falcataria)*, which play important roles in environmental conservation and providing raw materials for the timber industry. In addition to the mentioned commodities, **Table 8.1** presents a list of other plants with potential for development in Nain Feto Sub-District. Land suitability in this area is influenced by several limiting factors, including slope gradient, soil depth, dry season duration, and coarse materials. These factors can be addressed through planting during the rainy season, creating drainage channels, and implementing soil conservation techniques, such as the use of cover crops. However, temperature is a permanent limiting factor that cannot be remedied. Despite this, land management remains feasible through methods such as surface rock clearing and planting hole creation between rock outcrops, which supports cultivation efficiency and productivity.

D. Land Suitability Evaluation of Vera Cruz Sub-District

Vera Cruz Sub-District holds potential for the development of forestry plants such as teak (*Tectona grandis*), mahogany (*Swietenia macrophylla*), and altingia (*Altingia excelsa*). In addition to the mentioned plants, **Table 8.1** lists other plants that can be developed in Vera Cruz Sub-District.

Land suitability is influenced by several limiting factors, such as slope gradient, rainfall intensity, drainage, soil depth, dry season duration, coarse materials, flood potential, and erosion severity. These factors can be addressed through planting during the rainy season and implementing soil conservation techniques, such as cover crops. However, temperature, surface rocks, and rock outcrops are permanent limiting factors that cannot be remedied. Nevertheless, land management can still be carried out through surface rock clearing and the creation of planting holes between rock outcrops, which will support cultivation efficiency and productivity.

However, crops such as pine and altingia are not suitable for cultivation in this area due to permanent temperature limitations that cannot be corrected.

E. Land Suitability Evaluation of Metinaro Sub-District

Metinaro Sub-District has potential for the development of forestry plants, such as eucalyptus (*Eucalyptus spp.*) and Melaleuca *(Melaleuca spp.*). In addition to the mentioned plants, **Table 8.1** presents other plants that can be developed in Metinaro Sub-District.

Land suitability in this area is influenced by several limiting factors, such as slope gradient, soil depth, dry season duration, and coarse materials. These factors can be addressed through planting during the rainy season and implementing soil conservation techniques, such as cover crops. However, temperature, surface rocks, and rock outcrops are permanent limiting factors that cannot be remedied. Nevertheless, land management can still be conducted through methods like surface rock clearing and creating planting holes between rock outcrops to support cultivation efficiency and productivity.

This area has potential for sustainable agriculture. However, crops such as cinnamon and snow peas are not recommended for cultivation due to permanent temperature limitations that cannot be corrected.

Table 8.1 Land Suitability Evaluation Matrix for Dili District

Commodity	Sub-District	Limiting Factors	Land Suitability Potential/Improvement Effort
Teak	• Cristo Rei • Dom Aleixo • Nain Feto • Vera Cruz • Metinaro	N : Dry season, Slope S3 : Erosion, Surface rocks, Total Nitrogen, Available Phosphorus, Available Potassium S2: Drainage, Rainfall, Effective depth, Rock outcrops	S3 : Dry season S2 : Surface rocks, Effective depth, Rock outcrops, Slope
Mahagony	• Cristo Rei • Dom Aleixo • Nain Feto • Vera Cruz • Metinaro	N : Rainfall, Dry season, Slope S3 : Erosion, Surface rocks, Total Nitrogen, Available Phosphorus, Available Potassium S2 : Drainage, Effective depth, Rock outcrops, Texture	S3 : Dry season S2 : Surface rocks, Effective depth, Rock outcrops, Texture, Rainfall, Slope
Agathis	• Cristo Rei • Dom Aleixo • Nain Feto	N : Dry season, Slope	S3 : Dry season

	• Vera Cruz • Metinaro	S3 : Rainfall, Erosion, Surface rocks, Total Nitrogen, Available Phosphorus, Available Potassium S2 : Temperatur, Effective depth, Rock outcrops, Texture	S2 : temperature, Surface rocks, Effective depth, Rock outcrops, Texture, Slope
Altingia	• Cristo Rei • Dom Aleixo • Nain Feto • Vera Cruz • Metinaro	N : Temperatur, Dry season, Slope S3 : Erosion, Surface rocks, Total Nitrogen, Available Phosphorus, Available Potassium S2 : Rainfall, Effective depth, Rock outcrops, Texture	N : temperature S3 : Dry season S2 : Surface rocks, Effective depth, Rock outcrops, Texture, Slope
Albizia	• Cristo Rei • Dom Aleixo • Nain Feto • Vera Cruz • Metinaro	N : Rainfall, Dry season, Slope S3: Erosion, Surface rocks, Total Nitrogen, Available Phosphorus, Available Potassium S2 : Effective depth, Rock outcrops	S3 : Dry season S2 : Surface rocks, Effective depth, Rock outcrops, Rainfall, Slope
Leucaena	• Cristo Rei • Dom Aleixo • Nain Feto • Vera Cruz • Metinaro	N : Dry season S3 : Erosion, Surface rocks, Total Nitrogen, Available Phosphorus, Available Potassium S2 : Rainfall, Rock outcrops, pH	S3 : Dry season S2 : Surface rocks, Rock outcrops
Acacia	• Cristo Rei • Dom Aleixo • Nain Feto • Vera Cruz • Metinaro	N : Dry season, Slope S3 : Erosion, Surface rocks, Total Nitrogen, Available Phosphorus, Available Potassium S2 : Rainfall, Rock outcrops, pH, Texture	S3 : Dry season S2 : Surface rocks, Rock outcrops, Texture, Slope
Eucalyptus	• Cristo Rei • Dom Aleixo • Nain Feto • Vera Cruz • Metinaro	N : Dry season, Slope S3 : Erosion, Surface rocks, Total Nitrogen, Available Phosphorus, Available Potassium	S3 : Dry season S2 : Surface rocks, Rock outcrops, Texture, Slope

		S2 : Rock outcrops, Texture	
Melaleuca	• Cristo Rei • Dom Aleixo • Nain Feto • Vera Cruz • Metinaro	S3 : Drainage, Surface rocks, Total Nitrogen, Available Phosphorus, Available Potassium S2 : Rock outcrops, pH	S2 : Surface rocks, Rock outcrops
Pine	• Cristo Rei • Dom Aleixo • Nain Feto • Vera Cruz • Metinaro	N : Temperature, Rainfall, Dry season, Slope S3 : Erosion, Surface rocks, Total Nitrogen, Available Phosphorus, Available Potassium S2 : Drainage, Rock outcrops, Texture	N : Temperature S3 : Dry season S2 : Surface rocks, Rock outcrops, Texture, Rainfall, Slope
Sandalwood	• Cristo Rei • Dom Aleixo • Nain Feto • Vera Cruz • Metinaro	N : Slope, Surface rocks S3 : Erosion, Rock outcrops, C-organik, Total Nitrogen, Available Phosphorus, Available Potassium S2 : Temperature, Rainfall, Coarse fragments, pH	S3 : Surface rocks S2 : Temperature, Rock outcrops, Coarse fragments, Slope

Description : Moderately Suitable (S2); Marginally Suitable (S3); Not Suitable (N)

8.2 LAND IMPROVEMENT EFFORTS

Efforts to improve each limiting factor are strategic steps to increase productivity and ensure the sustainability of both the forestry and agriculture sectors. Biophysical limiting factors such as shallow effective soil depth, poor drainage, rock outcrops, unsuitable soil texture, and the presence of surface rocks are often the primary obstacles to land utilization. Without proper intervention, these conditions can reduce the soil's capacity to support the growth of vegetation, both forestry plants and agricultural commodities.

On the other hand, soil chemical parameters such as low organic carbon (C-Organic) content and deficiencies in essential macronutrients (nitrogen, phosphorus, potassium) further exacerbate soil fertility issues. Low soil quality not only limits plant productivity but also impacts the efficiency of agricultural inputs, leading to increased production costs and disrupting the sustainability of the cultivation system. Recommendations for improving each limiting factor, as the basis for implementing land suitability improvements, are presented in **Table**

7.4 in **Chapter VII**. This table serves as a guideline for transforming actual land suitability into potential suitability.

8.3 ZONING FOR FORESTRY POTENTIAL DEVELOPMENT

The research findings indicate that Dili District has significant land resource potential to support the development of the forestry sector. This evaluation has resulted in a systematic, science-based zoning process to identify the development potential of various strategic commodities. This zoning reflects the diversity of land utilization potential to support the forestry sector, contributing to food security, environmental protection, and improved community welfare. With structured and sustainable management efforts, the vast potential of this area can be optimized through synergy between the government, policymakers, and local communities, ensuring that the benefits are shared by all stakeholders.

Dili District's land development potential is divided into several main categories, including protected forests 11,222 ha (49.45%) and mangrove forests 462 ha (2.04%), as shown in **Figure 7.1** in **Chapter VII**.

A. Agroforestry

The development of coffee plants in the study area holds considerable potential when directed towards agroforestry zones. The agroforestry system is deemed suitable as it can integrate coffee with forestry species and other perennial plants, thus creating a balance between ecological, economic, and social aspects.

The recommended coffee variety for development is robusta coffee, given its suitability with the local agroclimatic conditions, especially in terms of elevation and temperature that support optimal growth. Robusta coffee generally thrives at elevations between 200 and 800 meters above sea level, with an average temperature of 24–30°C.

In terms of quality, robusta coffee has a distinctive taste profile, being more bitter, aromatic, and higher in caffeine content (about 2–2.7%) compared to arabica coffee (around 1–1.5%). This characteristic makes robusta coffee widely used as a blending ingredient in the instant coffee and ground coffee industries.

Figure 8.1 Agroforestry in Dili District
(Source: Research Documentation, 2025)

B. Protected Forests

The protected forests in Dili District cover an area of 112.22 km², or approximately 49.45% of the total area. These areas are primarily located in mountainous regions and upper catchment areas with slopes generally ≥30% and relatively high elevations. The primary function of these forests is no-conversion, as they play a critical role in preventing Erosionon, ensuring water infiltration, and controlling sediment, all of which support irrigation systems in the lowlands. Spatially, the largest protected forest area is found in Metinaro Sub-District, covering 24.41% of its area, followed by Cristo Rei Sub-District with 20.50%, Vera Cruz Sub-District with 2.51%, Dom Aleixo Sub-District with 1.50%, and Nain Feto Sub-District with the smallest coverage, at 0.54% of the total area of Dili District.

There are several Protected Areas (AP) in Dili District, each with varying sizes. These areas play a vital role in maintaining ecosystem balance, conserving biodiversity, and supporting ecological and social functions for local communities. The protected areas include AP Cristo Rei, covering 1,755.26 ha (0.51%); the Lagoa Tasitolu Protected Area, covering 1,055.36 ha (0.31%); AP Mangal Metinaro, covering 629.16 ha (0.18%); AP Monte Kuri, covering 163.82 ha (0.05%); and AP Mangal Hera, which covers 0.03%. Detailed information is presented in **Figure 8.2.**

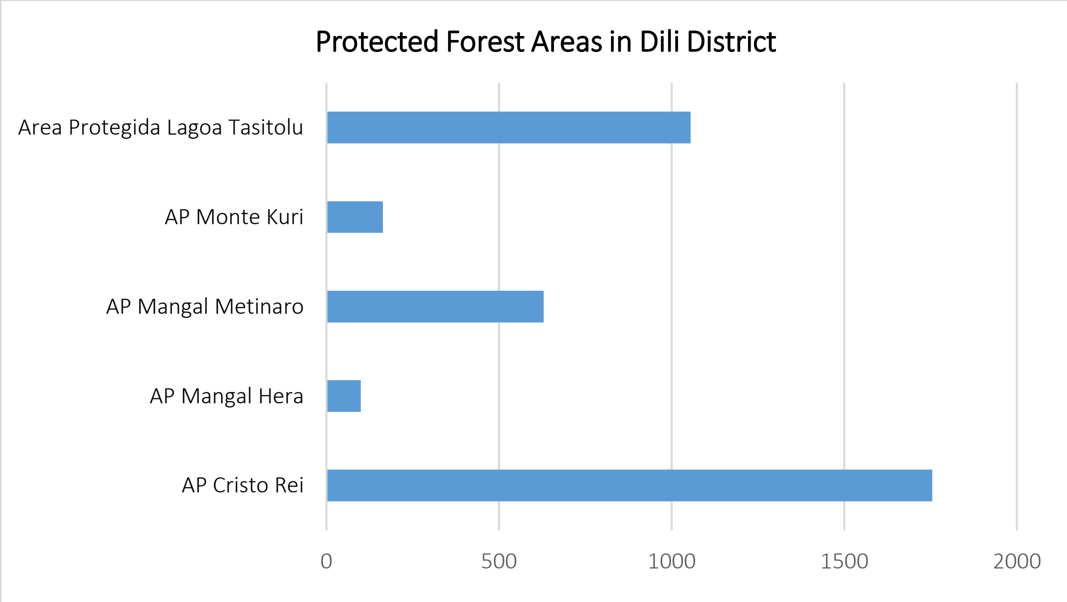


Figure 8.2 Protected Forest Areas in Dili District

C. Mangrove Forests

Mangrove forests are found in estuarine areas with very low elevations, predominantly on hydromorphic alluvial soils, and characterized by high salinity levels. These ecosystems play a significant role in blue carbon storage, mitigating wave action and coastal flooding, and providing important habitats for fisheries resources. All coastal utilization policies designate mangroves as protected zones that cannot be converted for other uses. In District Dili, mangrove forests cover an area of 4.62 km², or about 2.04% of the total land area. These mangroves are distributed across two Sub-Districts: Metinaro (1.89%) and Cristo Rei (0.15%). The management focus for these areas is on eco-tourism development while maintaining their ecological functions through strict monitoring and preservation efforts.

8.4 POTENTIAL FOR SANDALWOOD DEVELOPMENT

Sandalwood (*Santalum album* Linn) is a valuable natural resource with broad potential uses, including as a food flavoring, anti-carcinogenic and antiviral compound (Burdock & Carabin, 2008), in aromatherapy (Kim *et al.*, 2005; George & Ioana, 2008), and as an anti-cancer agent (Bommareddy *et al.*, 2012).

Sandalwood has attracted increasing global demand, particularly since the 1800s in the USA, due to its versatile uses (Burdock & Carabin, 2008). This species, *Santalum album* Linn, is considered prestigious due to its high economic value, especially its content of α-santalol (8.7–25.2%) and β-santalol (7.1–48.6%)

(Lawrence, 1991). The aromatic compound santalol contributes to its high demand worldwide.

The land suitability evaluation for sandalwood cultivation in District Dili indicates that the area has S2 (moderately suitable) to S3 (marginally suitable) ratings. The main limiting factors include rock outcrops, surface rocks, coarse materials, and slope. Improvements can be made by clearing surface rocks and utilizing them for terracing or as soil retaining walls. Sandalwood can also be planted in deeper soil gaps, and using organic mulch and tolerant host plants can support its growth.

For sloping land, applying soil and water conservation techniques such as terracing, embankments, or ridges is essential to reduce Erosionon, alongside planting cover crops and following contour planting practices. Additional strategies include selecting planting sites with sufficient soil depth, managing water through reservoirs or infiltration wells, and implementing agroforestry systems with food crops or shade trees to enhance land productivity and improve the environmental conditions for sandalwood growth.

IX. LIVESTOCK POTENTIAL

9.1 INTRODUCTION

Timor-Leste is a country largely consisting of mountainous regions and highlands. Administratively, Timor-Leste is divided into 14 Districts: Ainaro, Aileu, Autoridade Administrativa Ataúro, Bobonaro, Baucau, Covalima, Dili, Ermera, Lautém, Liquiçá, Manufahi, Manatuto, Região Administrativa Especial Oe-Cusse Ambeno (RAEOA), and Viqueque. The country experiences two seasons: the dry season, which lasts from June to November, and the rainy season, which occurs from December to May. The dominant hilly topography, coupled with its proximity to the Australian continent, results in Timor-Leste being influenced by the dry easterly monsoon winds. As a result, parts of the country tend to experience drought conditions. Additionally, low rainfall impacts vegetation growth across various regions of the country.

The hilly topography and low rainfall not only affect vegetation growth and agricultural activities but also limit the availability of forage for the livestock sector. The development of the livestock sector heavily relies on the potential of land resources, the appropriateness of land use, and the management methods employed. These factors play a crucial role in providing forage, which generally consists of grasses and legumes.

Forage for livestock can come from natural sources or cultivation, including grazing fields (Priyanto, 2016). The optimal use of land for livestock depends on both anthropogenic factors and the biophysical condition of the land. Therefore, applying various technological and institutional innovations is essential to ensure that land resources are used effectively and optimally (Suryana and Rahman, 2006).

In general, the livestock sector in Timor-Leste faces several challenges. One of the main causes is the traditional and extensive livestock management system, which leads to suboptimal production outcomes. The low levels of awareness, knowledge, and technological proficiency among farmers are also barriers, particularly when it comes to providing the appropriate type and quality of forage. Livestock are typically kept as household savings, which can be sold in emergencies. Moreover, some communities still use livestock as labor for land cultivation with traditional management systems.

The success of livestock enterprises is closely linked to three main factors: breeding, feed, and management (Aman *et al*., 2019). These factors form an interconnected system: if one of them is neglected or inadequately addressed, the management of the others, even if done excellently, will not yield optimal results. Livestock productivity, particularly in ruminants, heavily depends on effective feed management, which includes the quantity, quality, and sustainable availability of forage (Rokhayati and Evadewi, 2023). According to Winarni and Sukaesih (2015), feed plays a critical role in supporting livestock development because it directly influences production, productivity, and animal health. The quality of forage is influenced by the variety of forage, genotype, harvest maturity stage, season, and the management practices applied (Adesogan *et al*., 2015).

One of the initial steps that can be taken in the development of the livestock sector in Timor-Leste is the optimization of land use for sustainable forage production. For this purpose, it is essential to ensure that the characteristics of the land align with the types of forage to be cultivated. Therefore, land suitability evaluation becomes a crucial approach in assessing the potential and carrying capacity of land resources (Harahap *et al*., 2019). This evaluation not only assesses the land's potential but also determines its suitability for various uses based on the level of management applied (Nugroho *et al*., 2014). Land suitability evaluation requires environmental and soil quality data for a given area. This assessment is carried out by identifying various land characteristics, such as topography, climate, soil conditions and quality, and other physical environmental factors (Iswan *et al*., 2019). Through this evaluation process, information about the biophysical resources of the land, including climate and soil, is gathered, allowing for the determination of land suitability classes and the identification of limiting factors that need improvement (Jawang *et al*., 2018).

9.2 RESEARCH METHODS

The research was conducted using survey methods and descriptive analysis methods in a purposively selected research area, namely the KTS Center (Karau Timor Susubeen) and the recommended livestock lands. The types of data collected include quantitative and qualitative data sourced from primary and secondary data. Primary data comprises interview results, including livestock production and socio-economic aspects, as well as biophysical land observations and soil characteristics for the suitability of forage crops for livestock. The biophysical and soil properties were further analyzed according to laboratory standards. The secondary data used includes the Timor-Leste agricultural census data from 2019.

The interview data obtained were analyzed using a simple tabulation method based on the Miles and Huberman analysis model, which includes data reduction, data presentation, conclusion drawing, and verification. The biophysical land data and soil characteristics were analyzed and presented using a Geographic Information System (GIS) approach with GIS software, employing several methods depending on the data form and the objectives to be achieved (Rusdi *et al.*, 2015).

A. Research Procedures

1. Observation of Livestock Production and Socio-Economic Aspects

Observations were conducted through interviews with the following parameters:

- Livestock types
- Livestock population
- Land area
- Livestock management/housing systems
- Feed and nutrition management systems
- Water sources
- Breeding systems
- Livestock health management systems
- Livestock products
- Marketing
- Infrastructure
- Farmer characteristics
- Customs/traditions

2. Forage Crop Land Suitability

The procedure for researching forage crop land suitability has been detailed in Chapter III (Research Methods).

9.3 GENERAL OVERVIEW

The livestock sector plays an important role in supporting the livelihoods of many households in Dili District. The distribution of households engaged in livestock farming shows significant differences across each Sub-District. The largest number of households involved in the livestock sector is in Dom Aleixo Sub-District, with a total of 1,167 households. In contrast, Vera Cruz Sub-District has the fewest households involved in livestock farming, with only 116 households.

Nevertheless, their contribution remains significant in meeting local needs and preserving the livestock traditions that have been an integral part of the local community's way of life. Despite these differences, each Sub-District has its own contribution to the sustainability of the livestock sector in Dili. The number of agricultural households involved in the livestock sector is presented in **Figure 9.1.**

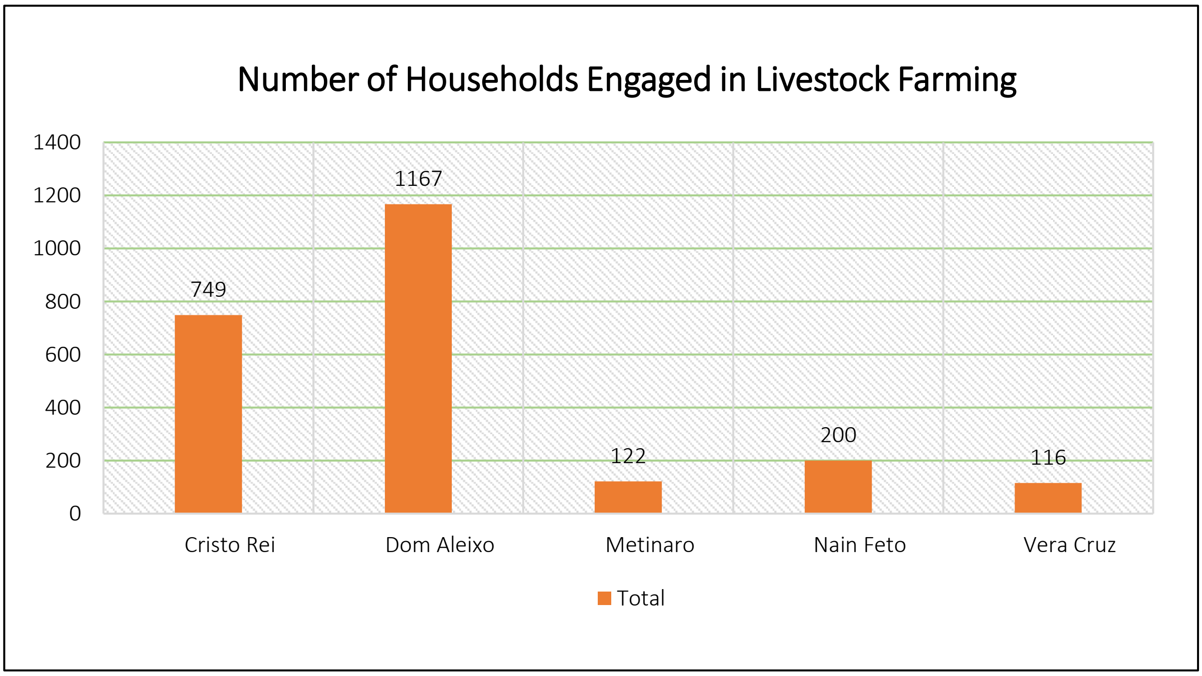


Figure 9.1 Number of Households Engaged in Livestock Farming
(Source: Timor-Leste Agriculture Census, 2019)

Figures 9.1 and **9.2** show that cattle farming, which involves large livestock, is the dominant form of livestock farming in Dili District. Cristo Rei Sub-District has the highest number of cattle-keeping households, with 389 households (49.18%) and a total cattle population of 1,388 animals. In contrast, Nain Feto Sub-District has the smallest number of cattle-keeping households, with only 7 households (0.88%) and a total of 25 cattle.

The highest number of households keeping horses is also in Cristo Rei Sub-District, with 20 households (37.74%) and a population of 28 horses. Conversely, Nain Feto Sub-District has the lowest number of horse-keeping households, with no households (0%) and a population of 0 horses.

For buffalo farming, Cristo Rei Sub-District shows dominance, with 97 households (43.11%) and a total of 295 buffaloes. In contrast, Nain Feto Sub-District has the lowest number of buffalo-keeping households, with 4 households (1.78%) and a population of 6 buffaloes.

Dom Aleixo Sub-District is the only one with dairy cattle farming, with a single household (100%) keeping dairy cattle **(Figures 9.3 and 9.4)**.

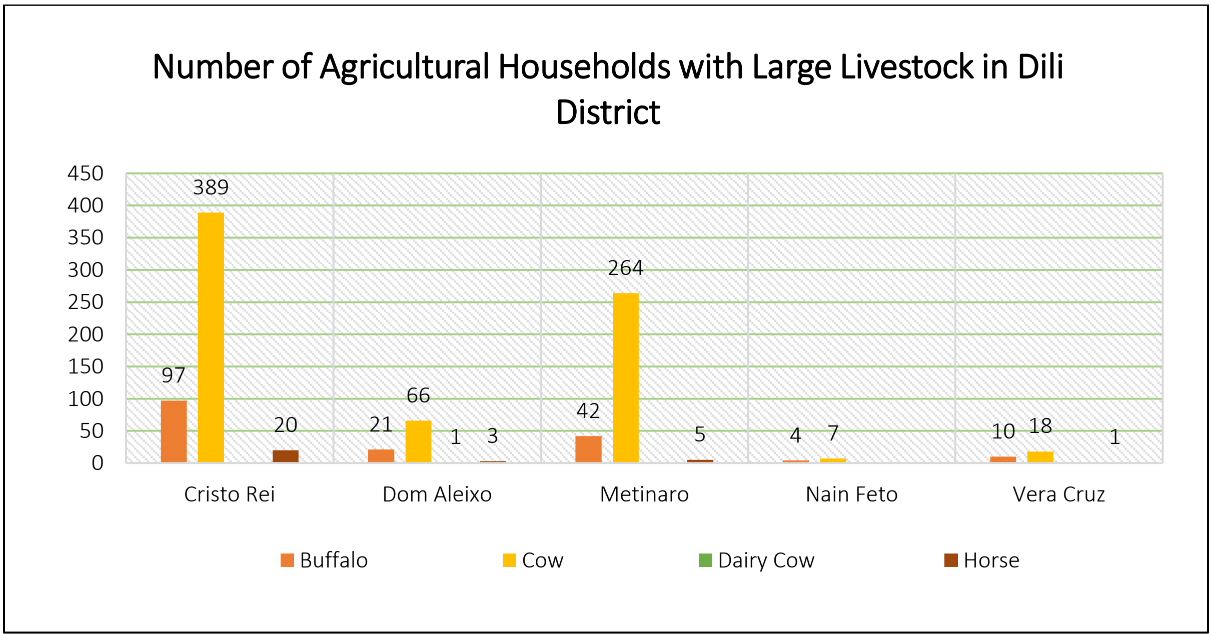


Figure 9.2 Number of Agricultural Households with Large Livestock in Dili District (Source: Timor-Leste Agriculture Census, 2019)

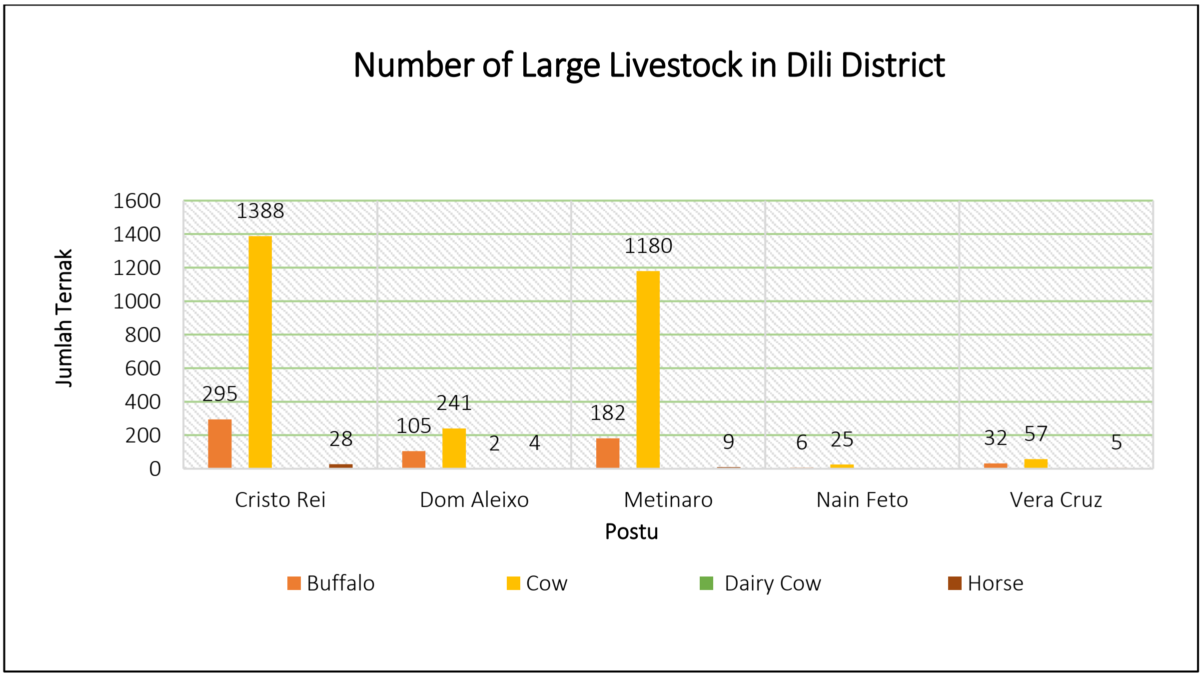


Figure 9.3 Number of Large Livestock in Dili District (Source: Timor-Leste Agriculture Census, 2019)

Dili District has pigs as the majority type of livestock kept. Cristo Rei Sub-District has the highest number of pig-keeping households, with 1,984 households (33.98%) and a total of 7,614 pigs. In contrast, Metinaro Sub-District has the lowest number of pig-keeping households, with 271 households (4.64%) and a total of 1,116 pigs **(Figures 9.5** and **9.6).**

The number of households keeping goats shows a varied distribution. Cristo Rei Sub-District has the most goat-keeping households, with 614 households (48.65%) and a population of 6,246 goats, while Nain Feto Sub-District has the fewest, with 51 households (2.47%) and a population of 131 goats.

In addition to goats, sheep are also kept, though in relatively small numbers. In Cristo Rei Sub-District, 15 households (53.57%) keep sheep, while the smallest number is found in Dom Aleixo Sub-District, with only 1 household (3.57%) keeping sheep.

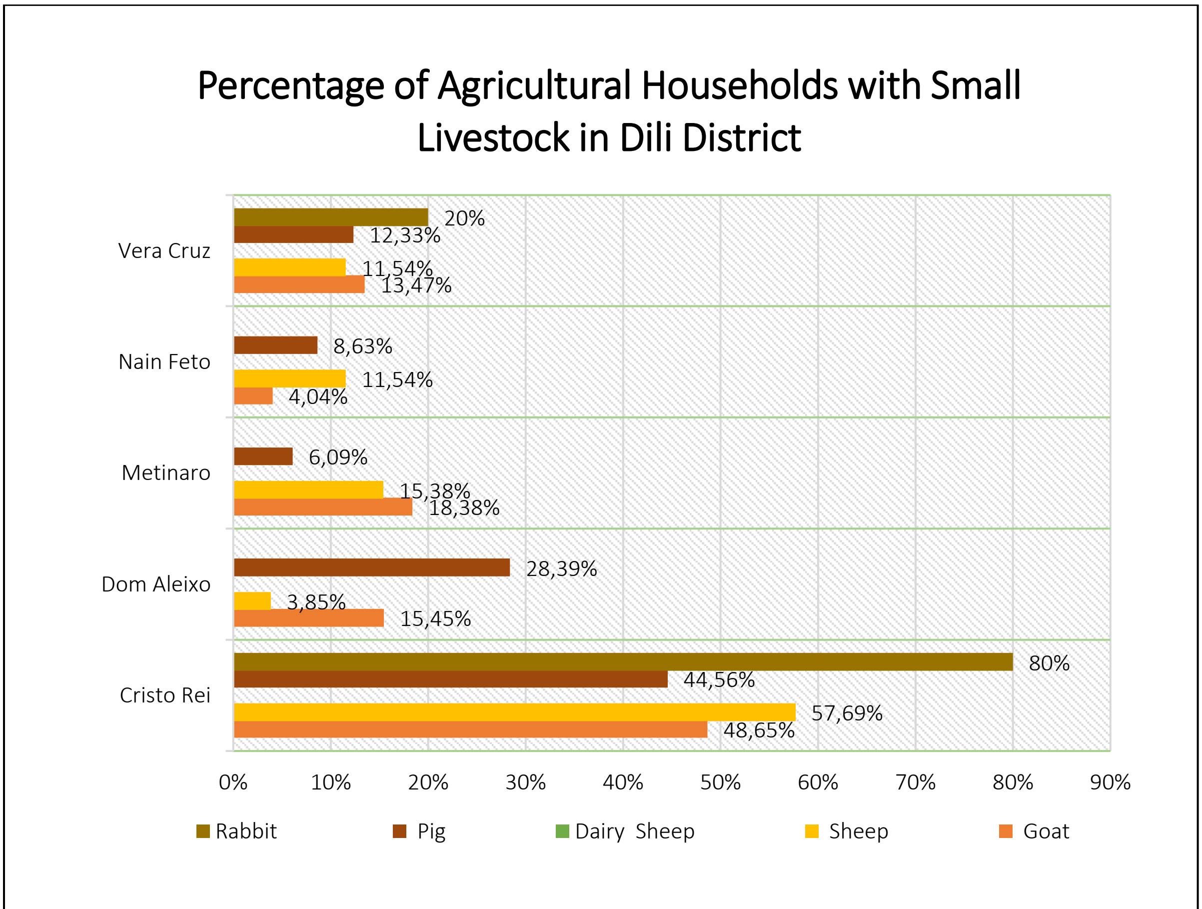


Figure 9.4 Percentage of Agricultural Households with Small Livestock in Dili District (Source: Timor-Leste Agriculture Census, 2019)

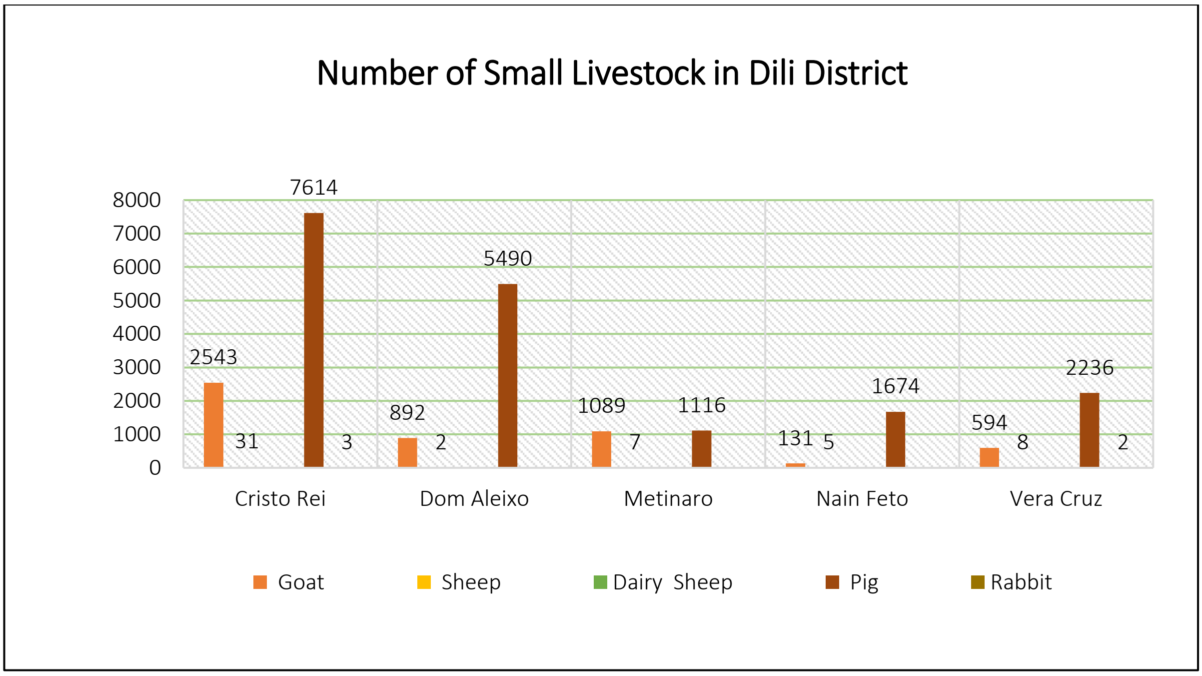


Figure 9.5 Number of Small Livestock in Dili District
(Source: Timor-Leste Agriculture Census, 2019)

The number of households keeping poultry in Dili District shows significant differences across Sub-Districts, with chickens being the most commonly kept poultry **(Figures 9.6)**. Cristo Rei Sub-District has the highest number of chicken-keeping households, with 1,680 households or approximately 35.02%, and a total of 14,357 chickens. Meanwhile, Metinaro Sub-District has the fewest chicken-keeping households, with 291 households (6.07%) and a total of 2,520 chickens **(Figures 9.6** and **9.7).**

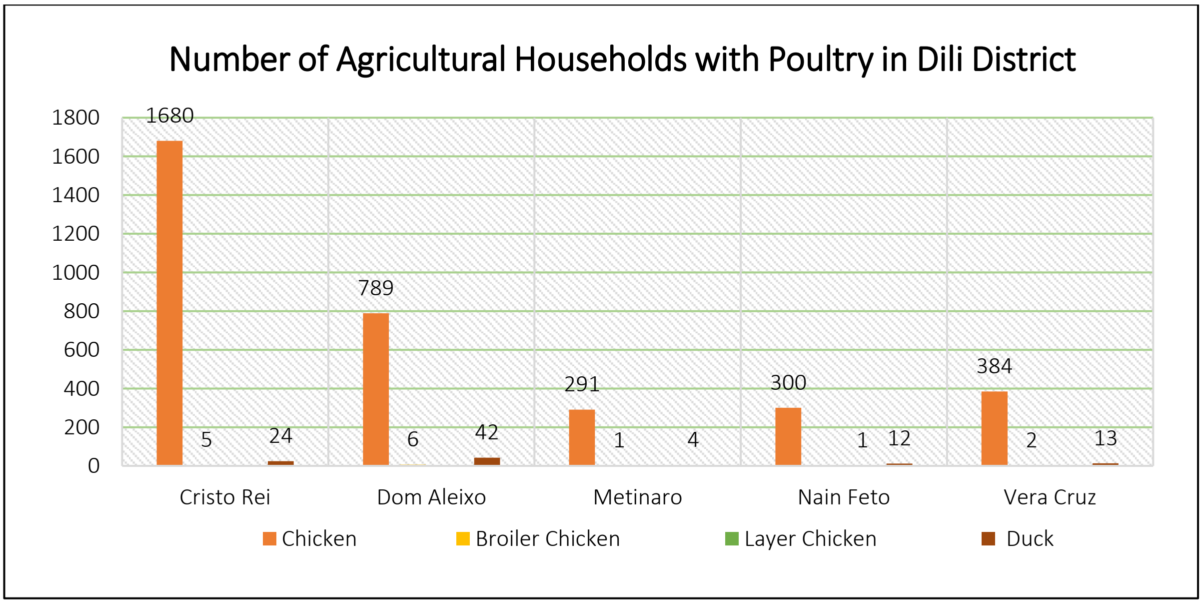


Figure 9.6 Number of Agricultural Households with Poultry in Dili District
(Source: Timor-Leste Agriculture Census, 2019)

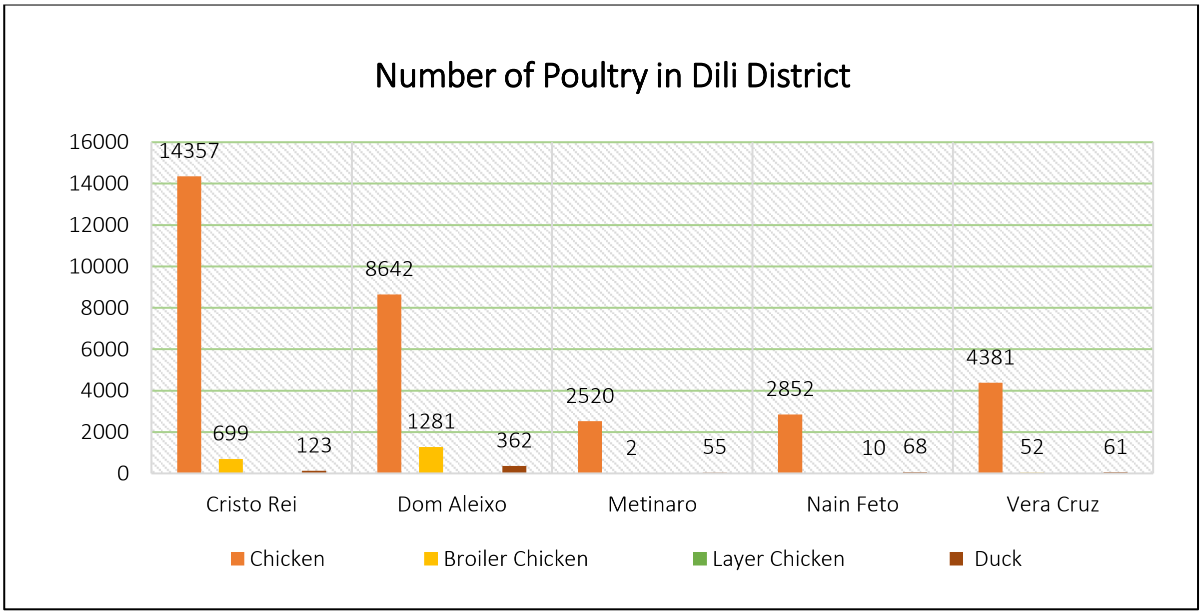


Figure 9.7 Number of Poultry in Dili District
(Sumber: Timor-Leste Agriculture Census, 2019)

Grazing Land Potential is an important asset that can serve as a primary source of livestock feed, particularly for animals such as cattle, goats, and sheep, which require high-quality grass to support growth and production in sustainable livestock farming. Dili District has two types of grazing land: temporary and permanent grazing fields.

The area of grazing land in Dili District varies across Sub-Districts. Metinaro Sub-District has the largest grazing area, with 50.19 ha (69.95%) for temporary land and 0.05 ha (2.65%) for permanent land, making it a strategic area to support large-scale livestock farming. Cristo Rei Sub-District also has a significant area, with 20.51 ha (94.43%) of temporary land and 1.78 ha (28.46%) of permanent land, showing the potential for the development of a sustainable grazing system. Dom Aleixo Sub-District has a very small grazing area, with only 0.19 ha (0.26%) of temporary land and no permanent grazing land (0%), while Nain Feto Sub-District has the smallest grazing land area, with only 0.02 ha (0.02%) of temporary land and 0.06 ha (2.92%) of permanent land, indicating the need for land-use intensification strategies. Vera Cruz Sub-District has no grazing land. With proper management, these grazing lands can enhance livestock productivity while maintaining the ecosystem balance of the region. The area of grazing land is presented in **Figure 9.8.**

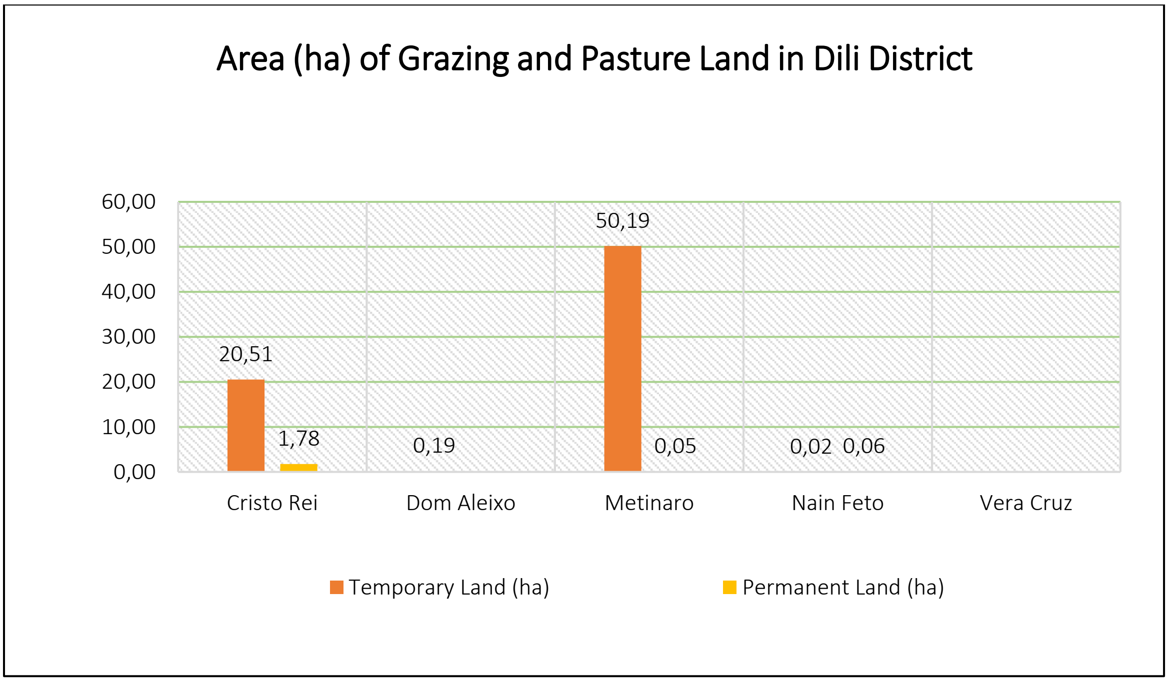


Figure 9.8 Area (ha) of Grazing and Pasture Land in Dili District
(Source: Timor-Leste Agriculture Census, 2019)

9.4 DISCUSSION

A. Evaluation of Forage Land Suitability

Land suitability analysis for forage crops in Dili District is a method used to evaluate the suitability of growth for various types of forage crops and grasses in grazing lands of a specific region. This analysis aims to facilitate the development of livestock feed resources while ensuring their optimal availability. According to Djaenudin *et al*. (2003), land suitability is defined as the degree of suitability of a land area for a specific use. Land suitability can be assessed based on current conditions (actual land suitability) or after improvements (potential land suitability). In Timor-Leste, land suitability evaluation is conducted using a matching method between land characteristics and quality data with the land suitability criteria based on the growth requirements of the evaluated plants. Several types of forage crops that are mapped in line with the land resource potential include elephant grass (Pennisetum purpureum), leguminous plants, and field grasses.

The land suitability evaluation results for Dili District show that Sub-Districts Dom Aleixo, Metinaro, Cristo Rei, Nain Feto, and Vera Cruz have potential for developing forage crops such as elephant grass, setaria, legumes, and grazing fields, as presented in **Table 7.3** of this book. According to the table, the land for grazing is quite varied, ranging from S2 (moderately suitable) to N (not suitable), with limiting factors including rainfall, drainage, available N-total, available P and Available potassium, pH, slope, erosion, and surface rocks. There are also limiting factors related to dry months for grazing. These factors can still be technically improved through actions such as crop pattern management, drainage construction and improvement, addition of NPK fertilizers, addition of organic materials, planting terrace-supporting plants, terracing, irrigation installation (e.g., sprinklers), and land clearing. However, some limiting factors, such as surface rock outcrops, are permanent and cannot be improved.

In efforts to enhance livestock development locations, especially in developing forage crops in Dili District, several key steps need to be taken to improve both the quantity and quality of forages, as follows:

1. Planting Leguminous Forages

Planting leguminous forages should be prioritized, as legumes generally contain higher nutritional value compared to grasses. However, due to the limitations of legumes in use, attention should be given to their proportion with grasses. As a reference, Susetyo (1980) recommends an ideal pasture composition of 60% grass and 40% legumes. Furthermore, according to Skerman (1977), legumes also play a role in preventing erosion, even better than forests, due to their strong and deep root systems.

2. Increasing Forage Species Diversity

Increasing the diversity of forage species, both legumes and grasses, is an important aspect of livestock feed development. The higher the species diversity of forages consumed by livestock, especially ruminants, the greater the likelihood of meeting complete nutritional needs. Some leguminous species with high nutritional content that have potential for development include *Indigofera*, *Kaliandra*, *Turi*, and *Stylo*. Common local leguminous species include *Lamtoro Taramba*. However, care should be taken when providing *Lamtoro* to pregnant livestock. Although it has a high nutritional content, the leaves of *Lamtoro* contain anti-nutritional substances such as mimosine and cyanide acid, which can be toxic if consumed in excess. This can be mitigated by providing *Lamtoro* in moderate amounts, mixed with other feeds, and ensuring it is wilting (air-dried) so that the levels of anti-nutritional substances are reduced.

B. Potential and Ecological Suitability for Livestock

Dili District has a total area of 22,667.46 ha, with 13,970.19 ha allocated for livestock sector development. The utilization of this potential needs to be carried out optimally through human resource empowerment and the use of available land. One important factor in determining the potential of an area for livestock development is the environmental suitability or ecological condition of the region. Areas that do not meet the ecological suitability indicators are considered less potential for livestock development. Therefore, the development of livestock enterprises in Dili District must consider ecological suitability aspects.

After obtaining measurements for each parameter in the field, such as geophysical parameters like temperature and rainfall, as well as chemical parameters like Cation Exchange Capacity (CEC), Base Saturation (BS), Organic Carbon (SOC), etc., these data are analyzed using Geographic Information System (GIS) applications to determine the ecological suitability level for five types of livestock: sheep, beef cattle, dairy cattle, pigs, and buffalo. The ecological land suitability map for livestock can be seen in Figure 9.9.

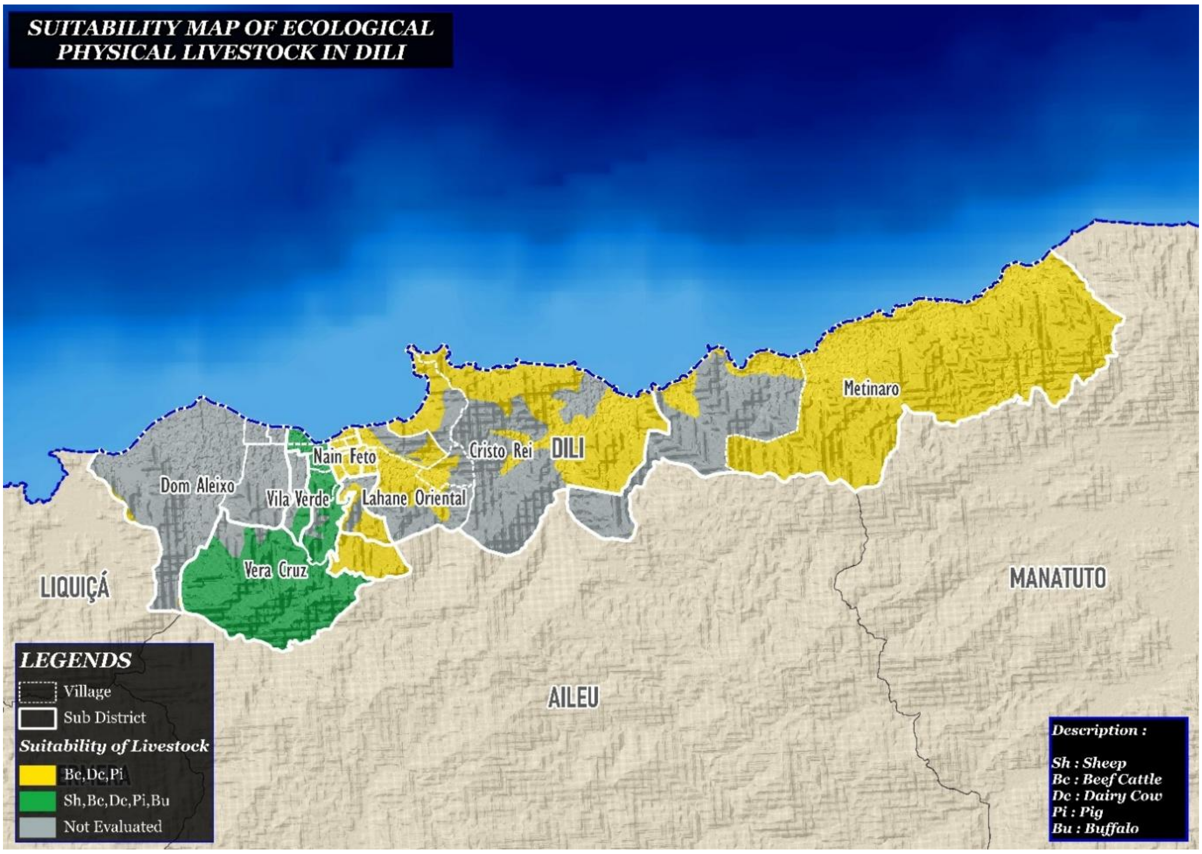


Figure 9.9 Ecological Physical Suitability Map for Livestock in Dili District

The available land for livestock development in Dili District consists of areas designated for mixed gardens and grazing lands. These lands are categorized as available because they are assumed to be capable of producing livestock forage, such as grasses, legumes, and crop residues. On the other hand, land categorized as unavailable for livestock development includes areas designated for forests and rice fields. Technically, this factor can be addressed through proper housing systems with good air circulation and ventilation. However, for dairy cattle, temperature is a critical factor that must be met in their cultivation.

Table 9.1 Livestock Development Area in Dili District

Sub-District	Livestock Development Suitability Results					Area (ha)
	Sheep	Beef Cattle	Dairy Cattle	Pig	Buffalo	
Dom Aleixo	N	S	S	S	N	38,23
Metinaro	N	S	S	S	N	6.998,37
Cristo Rei	N	S	S	S	N	3.702,94
Nain Feto	N	S	S	S	N	373,84
Vera Cruz	S	S	S	S	S	2.853,81

Based on the data analysis presented in **Table 9.1**, Vera Cruz Sub-District shows a high level of suitability for the development of the five main types of livestock: sheep, beef cattle, dairy cattle, pig, and buffalo. The biophysical conditions in this region support the ecological needs of each type of livestock, making it a priority area for integrated livestock development planning. In contrast, Sub-Districts Metinaro, Cristo Rei, Lahane Oriental, Nain Feto, and Dom Aleixo are only suitable for the development of beef cattle, dairy cattle, and pigs. The land suitability for sheep and buffalo in these areas is considered low, due to climate limitations, particularly temperature and rainfall, which are not favorable for the growth and productivity of these two types of livestock.

The ecological suitability for poultry farming in the study area shows a very high and uniform level of suitability, with coverage reaching 100%. This reflects the biological characteristics of poultry, which have a wide adaptability to various environmental conditions, enabling poultry farming in nearly all types of available land.

To support the livestock sector development program, it is necessary to identify and map areas that primarily function as livestock farming locations and forage crop cultivation. It is known that Dili District has an average environmental temperature of approximately 25.91°C and annual rainfall of 1,292.47 mm/year, providing ecological conditions conducive to supporting the sustainability of livestock enterprises. This also supports the availability of forage crops for livestock throughout the year. Environmental temperature plays a central role in determining thermal comfort and livestock productivity. If the environmental temperature is too low, it can cause cold stress in livestock, triggering an increase in body heat production and basal metabolic rate. If this condition persists without adequate feed support, the livestock's metabolic energy will decrease, reducing their resistance to extreme temperatures. This situation negatively impacts livestock growth, lowers productivity, and significantly increases the risk of disease outbreaks.

Conversely, if the environmental temperature is too high, livestock may reduce feed intake and increase water consumption. This decrease in nutritional intake directly impacts livestock production performance. Therefore, optimal environmental management, particularly regulating temperature and humidity, is a critical prerequisite for a sustainable livestock farming system. These efforts aim to create conditions that support the physiological balance of livestock, thereby maximizing productivity.

C. Socio-Economic Role of Livestock in the Community

For the people of Dili District, livestock plays a vital and multifaceted role, far exceeding its function as a source of food. Livestock is an integral part of the subsistence farming system and the developing civilization. It is common for people to use livestock, such as cattle, buffalo, and horses, as draft animals for plowing rice fields and farms. The use of animal power allows farmers to cultivate larger areas of land, significantly increasing agricultural productivity. In addition, in some cultures, livestock has social, economic, or ritual significance. For example, in certain traditions, livestock is used as a dowry or offering in cultural ceremonies. Furthermore, the number of livestock owned by an individual is often used as a measure of wealth and social status in the community.

One of the endemic livestock species in Timor-Leste is the Timor buffalo (*karau timor*). The Timor buffalo plays an important role in the social life of the Timorese people, especially as a ceremonial offering during death, birth, and wedding ceremonies. The Timor buffalo is also used in traditional transactions such as land sales, its manure is used as fertilizer for crops, and historically, its milk has been consumed for animal protein, making it highly valued.

Buffalo milk has been consumed by the community for a long time and is one of the preferred types of milk, alongside cow and goat milk. Buffalo milk is thicker and has a distinctive odor compared to cow’s milk. In the past, the community consumed Timor buffalo milk directly, without further processing, which made it a cultural symbol.

Livestock farming in general is still practiced using traditional systems of free-range grazing, known as extensive systems. According to Williamson and Payne (1993), in the extensive system, livestock are raised freely and graze on available vegetation. In this system, animals are released into the pasture in groups of males and several females within a single population. A key feature of this system is the lack of shelters and supplemental feeding (Jamili, M.A., 2022). The advantages of the extensive system include low labor requirements, minimal working hours, and the ability of animals to forage in grazing lands and former agricultural lands. However, the disadvantages include difficulty in controlling nutritional intake, and the livestock are more prone to diseases and mortality. Livestock left unattended and unsupervised can lead to social issues, such as livestock theft and damage to farmers' crops.

Livestock farming practices are still based on local knowledge passed down through generations. The lack of large-scale livestock industries means that production has not reached optimal levels, with many aspects still needing improvement. The distribution of livestock within the community remains low due to limited capital and poor breeding practices. This is because increasing livestock numbers requires substantial investment and time, making livestock farming more of a supplementary source of income rather than a primary income-generating activity. As a result, livestock production in the area remains limited (Serey *et al*., 2014).

According to interviews, the community received assistance in the form of cattle and buffalo in 2014 from MAPPF. However, over time, due to poor oversight and a lack of education, the assistance did not develop as initially intended. The livestock provided were used to meet household needs or as dowries. Consequently, attention to the sustainability of livestock breeding has been neglected, potentially hindering long-term development.

Other challenges faced by the livestock sector are complex, ranging from upstream to downstream issues, including inadequate infrastructure and facilities. In terms of breeding, the community still uses natural mating systems and lacks knowledge of artificial insemination (AI) technology, making livestock breeding for sustainability difficult. There is also a lack of awareness regarding good livestock management practices. The community has not been educated about proper feed management to ensure livestock productivity. Additionally, in terms of marketing, farmers can only sell live animals, making it difficult to increase the selling price of livestock products. Despite improved access from Dili to other Districts, many roads remain inadequate, hindering farmers' ability to market their livestock products to a wider market.

Given the many challenges faced in both pre-production and post-production phases, it is essential to focus on addressing these issues to form the basis for designing a master plan for livestock development in Dili District. Recommendations for improvement should begin with educating the community on the importance of good livestock management. This will encourage Dili’s residents to adopt a more economically driven approach to livestock farming, rather than seeing it only as a family asset. The government should not only provide education but also offer financial support through credit schemes to facilitate the livestock businesses. Improving the marketability of livestock products can be achieved by educating the community and opening up new sales channels, which would not be limited to live animal sales.

Dili District is recommended as a central hub for post-production livestock development, based on spatial and economic strategies that position the capital region as a logistics, processing, and distribution center for livestock products, rather than the primary livestock production center. This strategy is particularly relevant for densely populated urban areas where land availability is limited, and environmental issues, such as waste and pollution, are primary concerns.

In this model, the main role of Dili District is to serve as a hub linking livestock production centers in surrounding areas with the large consumer market. Dili will act as a downstream processing center, where live animals or carcasses from outside the city are processed into value-added products, such as packaged meat, sausages, nuggets, or dairy products. To support this role, investment should focus on building modern infrastructure, such as internationally standard slaughterhouses (RPH), cold storage facilities, and efficient transportation networks.

1. Strengthening the Supply Chain and Logistics

Dili District can be focused as a distribution and processing hub for livestock products, rather than as a primary livestock production center. Policies should be directed toward facilitating the flow of live animals and carcasses from production centers outside the city. This includes the development of logistical infrastructure such as modern cold storage, hygienic slaughterhouses, and efficient refrigerated transportation systems. Additionally, clear regulations on quality standards, food safety, and traceability of livestock products entering the capital are essential.

2. Development of Downstream Industry and Processing

As a post-production area, the primary focus should be on downstream industries. Policies should encourage investment in the processing of meat, milk, and other products. For example, the development of factories for sausages, nuggets, cheese, or yogurt. Providing fiscal incentives and simplifying licensing processes for these industries will accelerate economic growth and create employment opportunities. Furthermore, innovations in value-added products utilizing livestock waste, such as organic fertilizer or bioenergy production, should be encouraged.

3. Improving Market Access and Promotion

Dili District is the largest market with high purchasing power. Policies should facilitate direct access to livestock products from producers to consumers. This can be achieved through the establishment of wholesale markets, specialized e-commerce platforms for livestock products, and strategic partnerships between producers and traders. Promotional campaigns and education about the importance of consuming safe, healthy, and high-quality livestock products should also be promoted to increase demand and support farmers.

By directing policies toward these three aspects, Dili District will function optimally as a center for distribution, processing, and consumption, while production centers in other regions can focus on efficient livestock breeding.

X. FRESHWATER FISHERIES POTENTIAL

10.1 INTRODUCTION

Timor-Leste, as an archipelagic country, has vast natural resource potential, especially in the marine and fisheries sector. Dili District, as one of the administrative regions, offers a variety of topographic, soil, water quality, and climatic conditions that have great potential for the development of both freshwater and brackish water aquaculture. Aquaculture not only contributes to local food security but also opens sustainable economic opportunities for the surrounding communities.

However, the development of aquaculture ventures requires in-depth studies on land suitability. Selecting the right location is crucial for the success of these ventures, as each fish species has different tolerances to environmental factors such as topography and hydrology, soil conditions, water quality, and climate. Therefore, land suitability analysis is a critical initial step in aquaculture planning.

This study aims to evaluate land suitability in Dili District based on a number of biophysical parameters identified in the evaluation matrix. The matrix includes four main factor groups: topography and hydrology, soil conditions, water quality, and climate. Each factor has a specific weight reflecting its importance in determining land suitability for aquaculture.

Utilizing the evaluation matrix is key to determining whether the land in Dili District can support a sustainable and efficient aquaculture production system. This evaluation not only focuses on technical analysis but also integrates local policy aspects, community participation, and traditional practices in water resource management, ensuring that the results can be optimally applied in Dili District. The study focuses exclusively on freshwater aquaculture, particularly on aquaculture activities carried out by communities in lowland and coastal areas.

10.2 RESEARCH METHODS

This study began with a literature review, data collection, data analysis, and preparation of recommendations. In general, the work was divided into stages that included: (a) literature review and regional–demographic information, (b) identification of aquaculture land suitability variables, (c) design of the aquaculture land suitability matrix and parameters, (d) aquaculture land suitability assessment (weighting and scoring), (e) field survey, (f) laboratory soil analysis, and (g) land suitability analysis, as shown in the diagram in Figure 10.1.

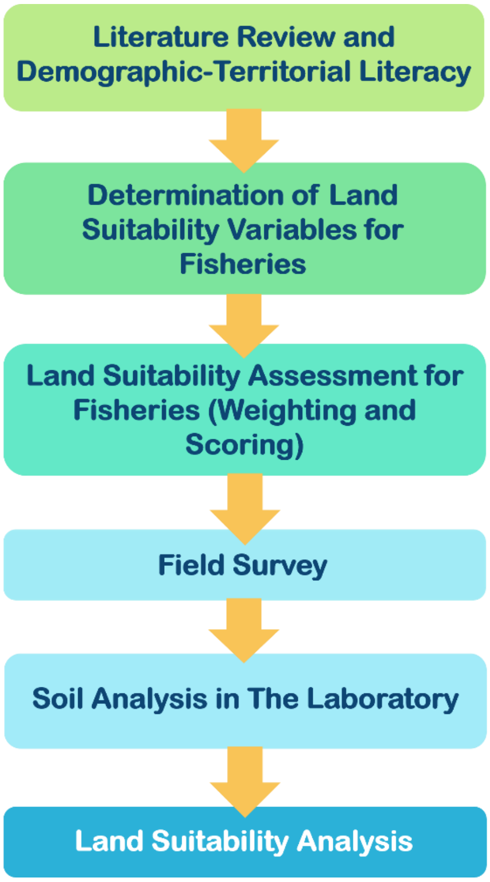


Figure 10.1 Flowchart Of The Research Process for Land Suitability in the Aquaculture Sector

A. Literature Review and Regional–Demographic Information

Data and information collection primarily comprised a review of secondary sources available from: (a) government-funded projects, (b) reports of local and regional non-governmental organizations (NGOs), and (c) other reference journals using the keywords "Timor-Leste" and "aquaculture Timor-Leste." All reference data were research outputs and assessments from the past 5 to 10 years to obtain the theoretical basis, research methods, and findings relevant to the problems studied.

Collection of regional information included a review of the geographic conditions of the study area, comprising: (a) the base map (RBI) of Timor-Leste administrative boundaries, (b) the hydrology map, (c) the most recent Population Census report (2022), and (d) the most recent Agricultural Census report (2019) for Timor-Leste.

B. Determination of Aquaculture Land Suitability Variables

Based on the literature review, the factors influencing land for fisheries activities, particularly aquaculture, were identified as: (a) topography, (b) soil conditions, (c) water quality, and (d) climate. The variables were determined based on several assumptions, which are presented in **Table 10.1.**

Table 10.1 Considerations for Factors Assumed in Determining Variables for Aquaculture Land Suitability

Factor / Variable	Applicable Assumptions (Used)
Factors / Variables	The applicable assumptions (employed in this study)
Topography	The fisheries sector requires specific elevation conditions to operate and to determine the design of aquaculture ponds.
Soil Conditions	The simplest medium for aquaculture operations is the earthen pond, in which the soil is in direct contact with the water and strongly influences water quality.
Water Quality	Water is the medium in which fish live, and fish carry out all metabolic and non-metabolic activities in the pond water.

C. Design of the Aquaculture Land Suitability Matrix and Parameters

Land potential assessment for specific uses is carried out through land evaluation using certain methods, which will serve as the basis for decision-making on land use, such as for ponds (Mustafa *et al*., 2007). Land evaluation is based on the analysis of the relationship between land and land use, as well as estimating the required inputs and desired outputs.

Two main aspects of land evaluation are: (a) physical resources, including soil, water, topography, and climate; and (b) socio-economic resources, including farm size, management level, availability of labor, market location, and other human activities. Physical resources are considered relatively stable, while socio-economic resources are more variable and dependent on social and political decisions. For pond aquaculture, land evaluation criteria are limited to physical resources only. Important aspects to consider in pond aquaculture land evaluation include water sources, soil quality, and infrastructure availability (Chanrantchakool *et al.*, 1995). Ecological, topographical, soil, and biological aspects must meet the requirements for pond aquaculture evaluation (Poernomo, 1979). Engineering aspects, soil quality, water quality, and infrastructure facilities are considered by Karthik *et al.* (2005) in pond aquaculture land evaluation.

Specific growth, survival, and production requirements are needed for all types of commodities, including land-based aquaculture (Mustafa *et al.*, 2007b; 2008). Minimum, optimal, and maximum range boundaries are established for growth or land use requirements for each commodity. These requirements serve as the basis for establishing land suitability classes, which are linked to land characteristics to determine land suitability. The land characteristics that are optimal for the commodity or land use needs define the boundary for the highly suitable class (S1). Land quality below optimal defines the boundary between the moderately suitable class (S2) and/or marginally suitable class (S3). Physically unsuitable land (N class) lies outside these boundaries. The factors/sub-models and variables used as land suitability criteria for various pond commodities are explained in the following section.

Table 10.2 Relationship between parameters, data acquisition, and data sources

No	Factor, Parameter	Unit	Instrument	Measurement Method
1.	**Topography**			
	- Slope gradient	%	Remote Sensing/ Climatology	Ex Situ / Digital
2.	**Soil Conditions**			
	- Clay content	%	Gravimetric tools	Laboratory
	- pH_F-pH_{FOX}	-	Spectrophotometer	Laboratory
	- Organic Carbon	mg/L	Spectrophotometer	Laboratory
3.	**Water Quality**			
	- Temperature	°C	Multimeter EZ-9901	In Situ
	- Salinity	ppt	Refractometer	In Situ
	- pH	-	Multimeter EZ-9901 / pH-meter	In Situ
	- Total Dissolved Solid (TDS)	mg/L	Multimeter EZ-9901	In Situ
	- Ammonia	mg/L	Tetra-Kit (TAN conversion)	In Situ
	- Dissolved Oxygen (DO)	mg/L	DO-meter	In Situ
4.	**Climate**			
	- Annual rainfall	mm/year		Ex Situ / Digital

	- Dry months	-	Remote Sensing/ Climatology Remote Sensing/ Climatology	Ex Situ / Digital

a. Topography

The influence of topography, such as landform or slope gradient, on the pond's water exchange capacity has been reported, particularly for traditionally (extensively) and semi-intensively managed ponds. Generally, land in coastal areas is classified as flat, although certain areas are classified as gentle or undulating. Flat land is recommended for pond aquaculture (Chanrantchakool *et al*., 1995). Despite the often-flat nature of pond areas, elevation above the highest high-water mark can hinder gravity-fed water intake. Conversely, elevation below the lowest low-water level can complicate pond drainage or water discharge (Liu *et al*., 2021). Therefore, the optimal pond elevation minimizes excavation but allows for the desired pond depth. Additionally, pond construction costs can be minimized while maintaining the fertility of the pond base. The ideal pond base elevation is one where the pond can be drained at any time and filled by gravity within 5 days from each tidal cycle (Bose *et al*., 1991; Pulido-Calvo *et al*., 2023). Compared to ponds for milkfish and tilapia, shrimp ponds, particularly for vannamei shrimp, require greater water depth.

b. Soil Conditions

Soil properties change gradually over long periods. Chemical and physical weathering, even under ideal conditions, requires hundreds or even thousands of years to develop mature, fully developed soil. Therefore, in selecting soil quality criteria for pond aquaculture, variables that strongly affect aquaculture production are chosen, but these variables are stable or difficult to change.

Pyrite (FeS_2) is a compound found in high concentrations in acid sulfate soils. In its natural reduced state, pyrite does not pose a problem in aquaculture. However, when pyrite is exposed to air during pond construction, oxidation of pyrite occurs, leading to a drastic decrease in soil pH and a sharp increase in the solubility of toxic elements, which consequently reduces pond productivity. Therefore, pyritic layers should be avoided when selecting locations for pond aquaculture.

Soil texture refers to the proportion of clay, silt, and sand in the soil. Pond soil texture strongly affects porosity and the growth of klekap, which can become a food source for fish and shrimp. Ponds with coarse-textured soils like sand and sandy loam have high porosity, and as a result, they cannot retain water. Pond soils often have fine textures, with clay content ranging from 20% to 30% to prevent lateral seepage (Boyd, 1995). The ideal soil texture for ponds includes clay, clay loam, clayey silt, silty loam, and sandy clay loam (Ilyas *et al*., 1987).

pH_F is the pH measured directly in the field, while pH_{FOX} is the pH measured after oxidation with 30% hydrogen peroxide. Both are characteristic variables of acid sulfate soils. The difference between pH_F and pH_{FOX} ($pH_F – pH_{FOX}$) can be used as an indicator of the acid potential in acid sulfate soils. In this case, The greater the value of pH_F-pH_{FOX}, the higher the potential acidity in acid sulfate soils.

Most soils are mineral soils but contain organic matter. Organic matter in ponds can affect soil stability, oxygen consumption, nutrient availability, and habitat suitability for pond organisms. Surface soils (0 to 0.2 m) of mineral soils used in agriculture rarely contain 5% to 6% organic matter, and in tropical and subtropical regions, organic matter content is typically lower (Boyd, 1995). For soils with high clay content (>60%), Boyd (1995) considers organic matter content below 8% to be slight, meaning it is beneficial and easy to manage for pond aquaculture. However, very high organic matter content can reduce the environmental quality of pond ecosystems. Its decomposition produces toxic compounds, which are a negative impact of organic matte.

c. Water Quality

Since the organisms cultured in ponds live in the water, water quality is a critical factor in the success of aquaculture. Good water quality supports the life of aquatic organisms and their food sources throughout the culture stages. Important water quality variables for pond aquaculture include turbidity, temperature, salinity, pH, and NH_3.

Water clarity in ponds is determined by the degree of turbidity, which results from the suspension of organic particles, colloidal soil, or plankton density. In newly established ponds on peat or acid sulfate soils, water clarity may decrease due to suspended particles or iron hydroxide ($Fe(OH)^3$) compounds or organic acids and tannins leached from plant root residues, resulting in brownish-black colored water (Poernomo, 1988). The optimal temperature for vannamei shrimp growth is 28°C to 30°C (Ponce-Palatox *et al*., 1997). The ideal water temperature for milkfish culture is 27°C to 31°C (Ismail *et al*., 1993). The optimal water temperature for tilapia culture is 25°C to 30°C (Stickney, 2000; Hossain *et* *al*., 2007), with tolerance for temperatures between 15°C and 37°C (Wiryanta *et al*., 2010).

Salinity refers to the total dissolved solids in saltwater when carbonates have been converted into oxides, bromides and iodides replaced by chlorides, and organic material has been fully oxidized (Boyd, 1995). The direct effect of salinity on aquatic organisms is through its impact on osmotic pressure and fluid content within the organisms (Poxton, 2003). In coastal waters, salinity values are greatly affected by freshwater input from rivers. Vannamei shrimp, milkfish, and tilapia are euryhaline organisms; however, since they are farmed commercially, maintaining an optimal salinity range is necessary. Vannamei shrimp typically grow best at 15 to 20 ppt salinity (Bray *et al*., 1994). Milkfish grow optimally at 15 - 30 ppt salinity (Ismail *et al*., 1993). Tilapia can live in a broad range of salinity, making them suitable for both freshwater and brackish water aquaculture (Watanabe, 2000; Hossain *et al*., 2007).

The tolerance limits of aquatic organisms to pH vary and are influenced by factors such as dissolved oxygen, alkalinity, the presence of ions, and the organism's stage of development. Milkfish grow optimally at a pH range of 7.0 to 8.5 (Ismail *et al*., 1993). According to Swingle (1968), the ideal pH for aquatic organisms is between 6.5 and 9.0, while values between 9.5 and 11.0 or 4.0 and 6.0 result in low production. pH values below 4.0 or above 11.0 are toxic to fish.

Ammonia can exist in molecular form (NH_3) or as ammonium ions NH_4 , with NH_3 more toxic than NH_4 (Poernomo, 1988). NH_3 can penetrate cell membranes faster than NH_4. NH_3 concentrations of 0.05 to 0.20 mg/L inhibit the growth of aquatic organisms in general. When NH3 levels exceed 0.2 mg/L, the water becomes toxic for certain fish species (Sawyer & McCarty, 1978). Stickney (2000) noted that tilapia are relatively tolerant to high ammonia concentrations. Fish cannot tolerate excessive NH_3 levels as it disrupts oxygen binding by blood, potentially causing hypoxia or common carps mortality.

d. Climate

The long-term average weather conditions, known as climate, play an essential role in pond aquaculture. Key climatic elements for pond aquaculture include rainfall. Rainfall between 2,000 and 3,000 mm/year, with 2 to 3 dry months, is optimal for pond aquaculture (Mustafa *et al*., 2011). The dry months, as defined by the Schmidt & Ferguson (1951) climate classification, are those with rainfall < 60 mm. Pond preparation is one of the activities that must be done before stocking. During pond preparation, pond drying is carried out to improve soil physical properties, enhance organic matter mineralization, and remove toxic substances like hydrogen sulfide, ammonia, and methane. Therefore, certain dry months are necessary each year for proper pond preparation.

D. Land Suitability Assessment for Aquaculture

The land evaluation guideline used in this study is the FAO Land Evaluation Framework (FAO, 1976). Specifically, for pond aquaculture, Hardjowigeno *et al*. (1996) developed land suitability criteria for brackish water fishponds, which also referred to the FAO (1976) land evaluation framework. However, the land suitability criteria presented are still quite limited. Land suitability classification involves comparing land quality with the requirements for the desired land use.

The land suitability assessment for selecting fish pond locations is carried out by constructing a land suitability matrix based on a weighting system. The suitability of the parameters for earthen pond aquaculture is divided into four levels for each parameter: Highly Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3), and Not Suitable (N). The land suitability classification structure, according to the FAO (1976) framework, consists of four categories, as shown in **Table 10.3** below:

Table 10.3 Land Suitability for Pond Aquaculture Parameters

Class Code	Class Quality	Land Description
S1	Highly Suitable	The land has no severe limiting factors for sustainable use or only has minor limiting factors that do not significantly affect production or lead to increased inputs in general.
S2	Moderately Suitable	The land has moderately severe limiting factors that require significant management efforts to maintain. These limiting factors will reduce productivity and profits, and increase required inputs.
S3	Marginally Suitable	The land has very severe limiting factors that make it difficult to maintain the necessary management levels. These limiting factors will significantly reduce productivity and profits, requiring increased inputs.
N	Not suitable	Land in this class has limiting factors so severe that they prevent continued use for the planned purpose.

Parameters that are expected to have a greater influence as limiting factors for aquaculture organisms are given higher weights. The land suitability criteria are formulated based on the required parameters, referencing the suitability matrix (**Table 10.6**). The assignment of weights and scores in **Table 10.2** takes into account the impact of the variables determining the success of fish farming (Hastari *et al*., 2017). Scores are assigned with values of 1 (N), 2 (S3), 3 (S2), and 4 (S1). An example of the calculation/score is shown in **Table 10.4.**

Table 10.4 Land Suitability Scoring Calculation

Factor and Variable	Weight	Score	Weight × Score	Final Evaluation
Slope Gradient (%)	0.12	4	0.48	4 (Highly Suitable)
Clay (%)	0.12	4	0.48	
pH_f-pH_{fox}	0.08	4	0.32	
Organic Carbon	0.02	4	0.08	
Temperature (°C)	0.05	4	0.2	
Salinity (ppt)	0.1	4	0.4	
pH	0.07	4	0.28	
TDS (*Total Dissolved Solid*)	0.07	4	0.28	
DO	0.15	4	0.6	
Ammonia (mg/L)	0.06	4	0.24	
Annual Rainfall (mm/year)	0.06	4	0.24	
Dry Months	0.1	4	0.4	

E. Field Survey

The field survey team aims to validate the literature study against real-time field conditions. The areas visited include 14 Districts, with consultations held with local stakeholders at various locations. The field visits were focused on observing locations recommended by local stakeholders, including: (a) the President Authority of the *Munisípiu* (PAM), which is the district head equivalent to a governor in the District; (b) the *Servisu Munisípiu de Agrikultura* (SMA), the agricultural agency equivalent to the agricultural office in the District; and (c) the Field Fisheries Extension Agent, who directly interacts with fishpond farmers and aquaculture practitioners in the local area. These parties serve as links in the field survey activities for aquaculture farmers and also point out potential locations for aquaculture development. The recommended potential locations are listed in **Table 10.5.**

Table 10.5 Field Survey Activities by Area in Dili District

No.	Schedule	Sub-District	Village	Purpose (Ownership)
1	17 May 2025	Cristo Rei	Balibar	Business (Group)
2	17 May 2025	Metinaro	Sabuli	Business (Group)
3	17 May 2025	Cristo Rei	Hera	Business (Private)

The selection of locations for the field visits and the scheduling of consultations with local stakeholders was carried out collaboratively by the survey team, taking into account:

a) The balance between districts with potential for inland freshwater and coastal aquaculture development;
b) The inclusion of districts that have been identified by the Ministry as having aquaculture development potential.

F. Soil Analysis in the Laboratory

Soil conditions in coastal and aquatic ecosystems (such as ponds, estuaries, or mangrove forests) are interconnected. The physicochemical properties of the soil affect: (a) water column quality (pH, salinity, heavy metal content); (b) nutrient availability; and (c) habitat suitability for organisms such as fish, shrimp, mollusks, macroalgae, and mangrove plants. Soil analysis, integrated with an understanding of aquatic habitats, provides added value in the planning of conservation, aquaculture, and rehabilitation of aquatic ecosystems, as shown in **Table 10.6.**

Table 10.6 Soil Analysis Parameters and Their Relationship and Significance to Aquatic Commodity Habitats

Soil Parameter	Purpose & Significance	Relationship with Water Quality	Impact on Aquatic Commodity Habitat
Clay Content	Clay fraction plays a key role in soil physical properties such as water retention, permeability, and nutrient retention. High clay content enhances the soil's ability to store nutrients but can hinder aeration.	Affects water infiltration and retention as well as sediment transport.	High clay → ideal habitat for mollusks, but poor for demersal fish that need coarse substrates.
pH_F-pH_{FOX}	The difference between pH_F and pH_{FOX} indicates latent acidity potential. A significantly lower pH_{FOX} indicates potential acid sulfate soils, which is important for wetland restoration or land use planning.	Indicator of latent soil acidity → affects water column pH.	Low pH → physiological stress on fish and shrimp; affects metal bioavailability.
Organic Carbon	Organic carbon is a primary indicator of soil fertility and quality. High organic carbon content suggests healthy soil conditions and has potential as a carbon sink (blue carbon), especially relevant in mangrove and wetland ecosystems.	Source of organic nutrients in remineralization processes → influences DO and primary productivity.	Determines soil fertility for aquaculture and the growth substrate for macroalgae and seagrasses.

G. Aquaculture Land Suitability Analysis

The observations in the field and the results from laboratory analyses are then tabulated into data on aquaculture land characteristics. The land suitability for aquaculture is analyzed by matching the land characteristic data with the habitat requirements for fish and other aquaculture commodities. This results in land suitability classes based on the criteria of Mustafa *et al*. (2012). The land suitability classification is analyzed down to the unit land level. Potential land suitability is determined by considering the inputs and management actions applied to each aquaculture unit, assuming that efforts are undertaken. As an example, the land suitability criteria for tilapia farming are presented in **Table**

10.7, which is the most dominant fish commodity in almost every aquaculture pond in Timor-Leste, and the land suitability criteria for carp farming are presented in **Table 10.8**.

Table 10.7 Land Suitability Criteria for Tilapia Farming (*Oreochromis niloticus*)

Usage Requirements/Parameters	Suitability Class			
	S1	S2	S3	N
Topography				
- Slope Gradient (%)	< 0,1	0,1-1,0	1,0-2,0	> 2,0
Soil Conditions				
- Clay Content (%)	10-20	20-30	30-60	< 10 > 60
- pH_F-pH_{FOX}	< 1,5	1,5-3,5	3,5-6,0	> 6,0
- Organic Carbon	1,5-2,5	0,5-1,5	< 0,5 2,5-8,0	> 8,0
Water Quality				
- Temperature (°C)	28-30	20-28 30-35	12-20 35-40	< 12 > 40
- Salinity (ppt)	< 10	10-25	25-35	> 35
- pH	7,5-8,5	6,0-7,5 8,5-9,5	4,0-6,0 9,5-11,0	< 4,0 > 11,0
- TDS (ppm)	<1000	1000–1500	1500–2000	>2000
- Ammonia (mg/L)	< 0,3	0,3-0,4	0,4-0,5	> 0,5
- DO (mg/L)	>5	4–5	3–<4	<3
Climate				
- Annual Rainfall(mm/year)	2.500-3.000	2.000-2.500	1.000-2.000 3.000-3.500	< 1.000 > 3.500
- Dry Months	1-2	2-3	3-5	< 1 > 5

Source: Mustafa (2012)

Table 10.8 Land Suitability Criteria for Carp Farming (*Cyprinus carpio*)

Usage Requirements/Parameters	Suitability Class			
	S1	S2	S1	N
Topography				
- Slope Gradient (%)	< 0,1	0,1-1,0	1,0-2,0	> 2,0
Soil Conditions				
- Clay Content (%)	10-20	20-30	30-60	< 10
				> 60
- pH_F-pH_{FOX}	< 1,5	1,5-3,5	3,5-6,0	> 6,0
- Organic Carbon	1,5-2,5	0,5-1,5	< 0,5	> 8,0
			2,5-8,0	
Water Quality				
- Temperature (°C)	24-28	22≤24	20≤22	< 20
		28-30	30-32	> 32
- Salinity (ppt)	< 10	10-25	25-35	> 10
- pH	6,5-8,5	6,0≤6,5	5,5≤6,0	< 5,5
		8,5-9,0	9,0-9,5	> 9,5
- TDS (ppm)	<1000	1000–1500	1500–2000	>2000
- Ammonia (mg/L)	< 0,05	0,05-0,1	0,1-0,5	> 0,5
- DO (mg/L)	>5	4–5	3–<4	<3
Climate				
- Annual Rainfall(mm/year)	2.500-3.000	2.000-2.500	1.000-2.000	< 1.000
			3.000-3.500	> 3.500
- Dry Months	1-2	2-3	3-5	< 1
				> 5

Source: Mustafa (2012)

10.3 EXISTING CONDITIONS AND OBSERVATION RESULTS

A. Capture Fisheries

1. Number of Fishing Households

Based on data collected from five sub-districts in Dili District, a total of 385 fishing households were recorded along the coastal region. Among these, Cristo Rei Sub-District had the highest concentration of fishing households, with 206 households (53.51%) of the total. This dominance indicates the strategic role of this area in supporting capture fisheries activities, likely linked to the length of the coastline and accessibility to marine resources.

It was followed by Dom Aleixo Sub-District with 89 fishing households (23.12%), and Metinaro Sub-District with 55 fishing households (14.29%).

Meanwhile, Nain Feto and Vera Cruz recorded much smaller numbers, with 26 households (6.75%) and 9 households (2.34%), respectively. The small number of fishing households in these two sub-districts may be due to limited active coastline, high urbanization rates, and the dominance of non-fisheries sectors in the local economy. The distribution of fishing households is shown in **Figure 10.2** and **Figure 10.3**.

This distribution provides important insights into the utilization patterns of coastal and marine resources in Dili District. This information can serve as a basis for formulating policies for sustainable fisheries development, including strengthening fisherfolk capacity and diversifying livelihoods through the development of freshwater and brackish water aquaculture, particularly in areas under high pressure from capture fisheries resources.

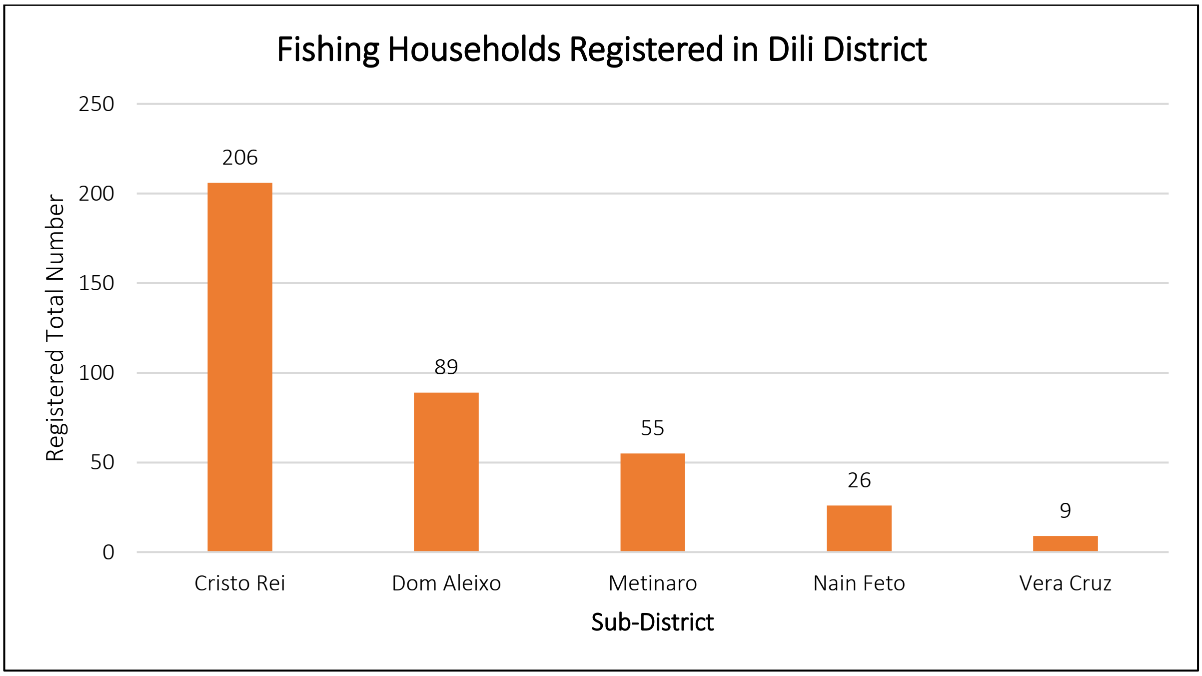


Figure 10.2 Fishing Households in Dili District
(Source: Timor-Leste Agriculture Census, 2019)

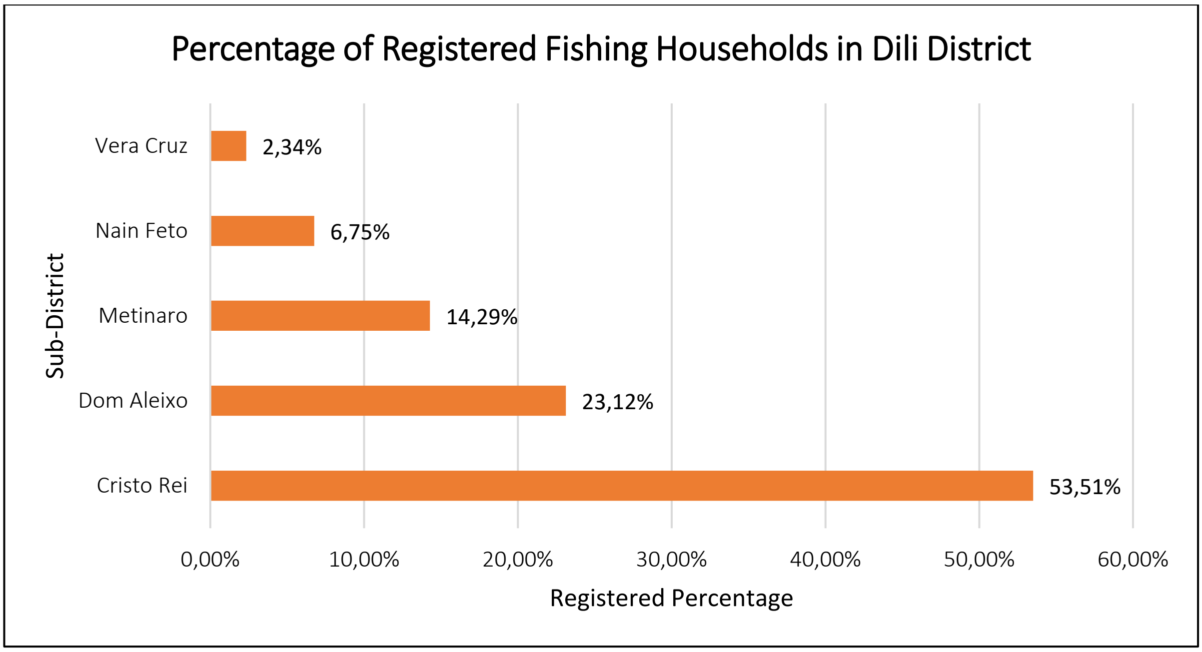


Figure 10.3 Percentage of Fishing Households in Dili District
(Source: Timor-Leste Agriculture Census, 2019)

2. Households Involved in Fishing Activities

Fish capture activities in Dili District are still predominantly carried out by households for personal consumption and social obligations. Out of the total 383 households involved in these activities, 65 households (17%) engage in fish capture for personal consumption and social events such as traditional ceremonies or religious obligations, 255 households (66.6%) capture fish for consumption and occasional sales, and 63 households (16.4%) capture fish for direct sales as their primary source of income.

The distribution by sub-district shows that Cristo Rei Sub-District plays a dominant role across all categories. About 56.47% of households that capture fish for consumption and occasional sales come from this sub-district, as well as 57.14% of households selling their catch directly. Additionally, 40% of households capturing fish for consumption and social obligations are also in Cristo Rei. This reflects the high dependence of the Cristo Rei community on marine resources as both a livelihood and a social component.

Dom Aleixo Sub-District ranks second, contributing significantly to the consumption and social obligations category at 46.15%, as well as 28.57% in the direct sales category. Meanwhile, Metinaro, Nain Feto, and Vera Cruz show relatively low contributions in all categories, with percentages not exceeding 18% for any category. This indicates limited access to fisheries resources in these areas or a potential shift in household economic orientation towards other sectors in more urbanized areas. The number of households involved in fish capture activities is shown in **Figure 10.4** and **Figure 10.5** .

These findings suggest that most fishing households in Dili District do not fully rely on fish capture as their primary economic source. Instead, many engage in it on a subsistence or occasional basis. This information is crucial in designing strategies for the development of aquaculture as a sustainable alternative or complement, particularly in areas with high capture intensity such as Cristo Rei and Dom Aleixo.

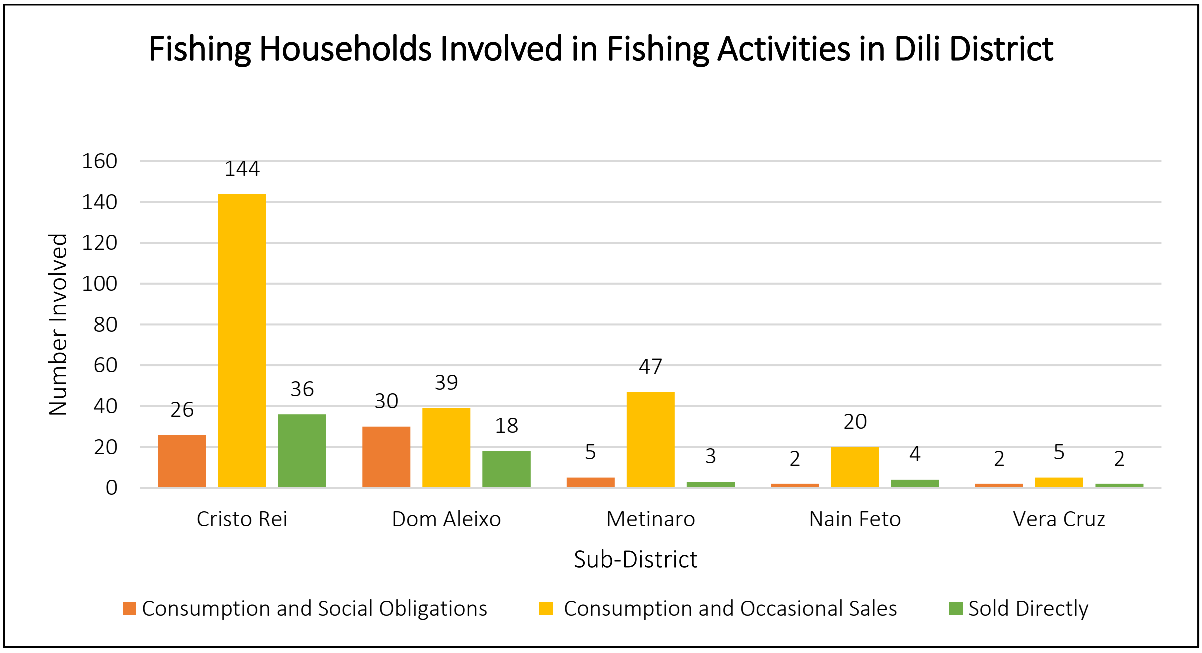


Figure 10.4 Number of Households Involved in Fishing Activities
(Source: Timor-Leste Agriculture Census, 2019)

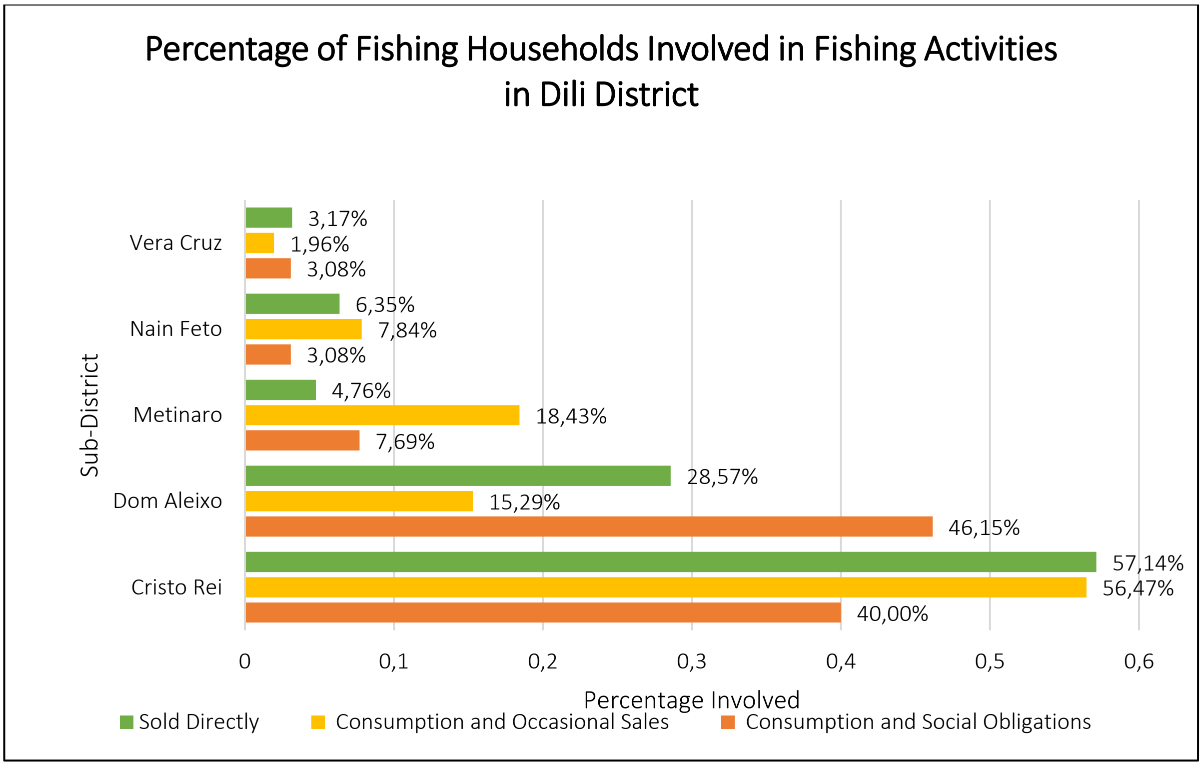


Figure 10.5 Number of Households Involved in Fishing Activities
(Source: Timor-Leste Agriculture Census, 2019)

B. Aquaculture

1. Proportion of Land for Aquaculture

The total land used for aquaculture activities in Dili District is approximately 9.738 ha, with a highly uneven distribution across the sub-districts. The two main sub-districts dominating the use of land for aquaculture are Cristo Rei and Dom Aleixo, contributing 4.693 ha (47.71%) and 4.607 ha (46.84%), respectively. Combined, these two sub-districts account for more than 94% of the total aquaculture land area in Dili District, indicating that fish farming activities are primarily concentrated in these area.

Meanwhile, the other three sub-districts—Metinaro, Nain Feto, and Vera Cruz—contribute only marginally. Metinaro has 0.107 ha (1.09%), Nain Feto has 0.13 ha (1.32%), and Vera Cruz has 0.201 ha (2.04%). The low proportion of aquaculture land in these three regions is likely due to limited space, unsuitable topographic characteristics, and high urbanization levels, particularly in central Dili District such as Nain Feto and Vera Cruz. The proportion of land used for aquaculture is shown in **Figure 10.6** and **Figure 10.7**.

This distribution suggests that aquaculture development in Dili District is still concentrated and not evenly distributed. Therefore, further studies on the potential of areas with low land proportions are necessary to identify opportunities for expansion or optimization of land suitable for aquaculture, both freshwater and brackish water. This approach is vital to support the diversification of coastal community economies and strengthen local food security based on aquaculture..

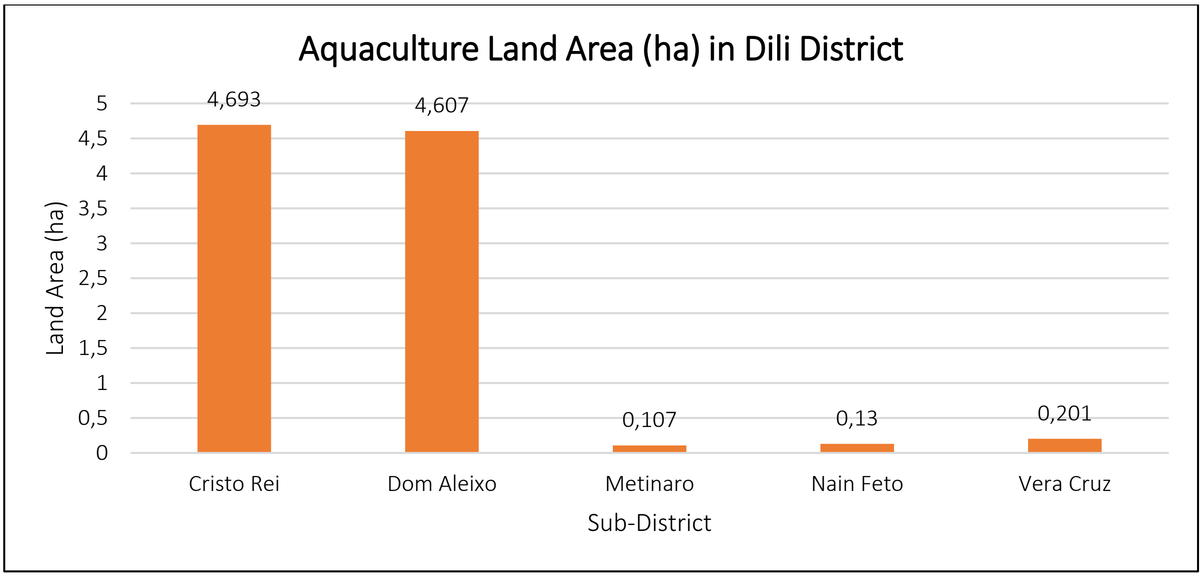


Figure 10.6 Aquaculture Land Area in Dili District
(Source: Timor-Leste Agriculture Census, 2019)

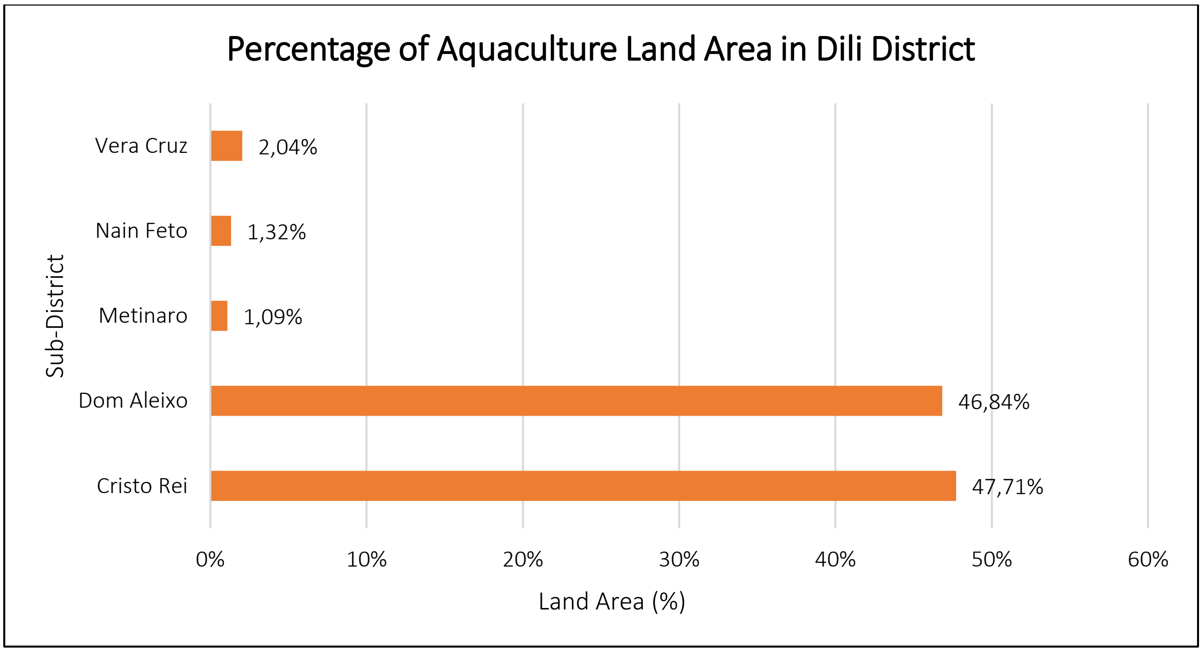


Figure 10.7 Percentage of Aquaculture Land in Dili District
(Source: Timor-Leste Agriculture Census, 2019)

2. Aquaculture Households

According to the collected data, there are 105 households involved in aquaculture activities in Dili District. The majority of these households are concentrated in Cristo Rei Sub-District, which recorded 37 households or about 35.24% of the total. This makes Cristo Rei the main center for aquaculture activities in Dili District, likely supported by sufficient land availability and better access to water resources and farming facilities.

Next, Dom Aleixo Sub-District contributes 30 households (28.57%), indicating a significant presence of aquaculture in this region. Meanwhile, the number of aquaculture households in other sub-districts is relatively small, with Vera Cruz recording 18 households (17.14%), Nain Feto with 11 households (10.48%), and Metinaro with only 9 households (8.57%). The distribution of households involved in aquaculture in Dili District is shown in **Figure 10.8** and **Figure 10.9**.

This distribution pattern indicates that aquaculture activities in Dili District are still limited and uneven, with a primary concentration in certain areas that have more favorable physical and social characteristics. Therefore, future development strategies need to be more inclusive and based on local potential, including capacity building for households in sub-districts with low participation, to promote economic diversification and strengthen food security based on aquaculture.

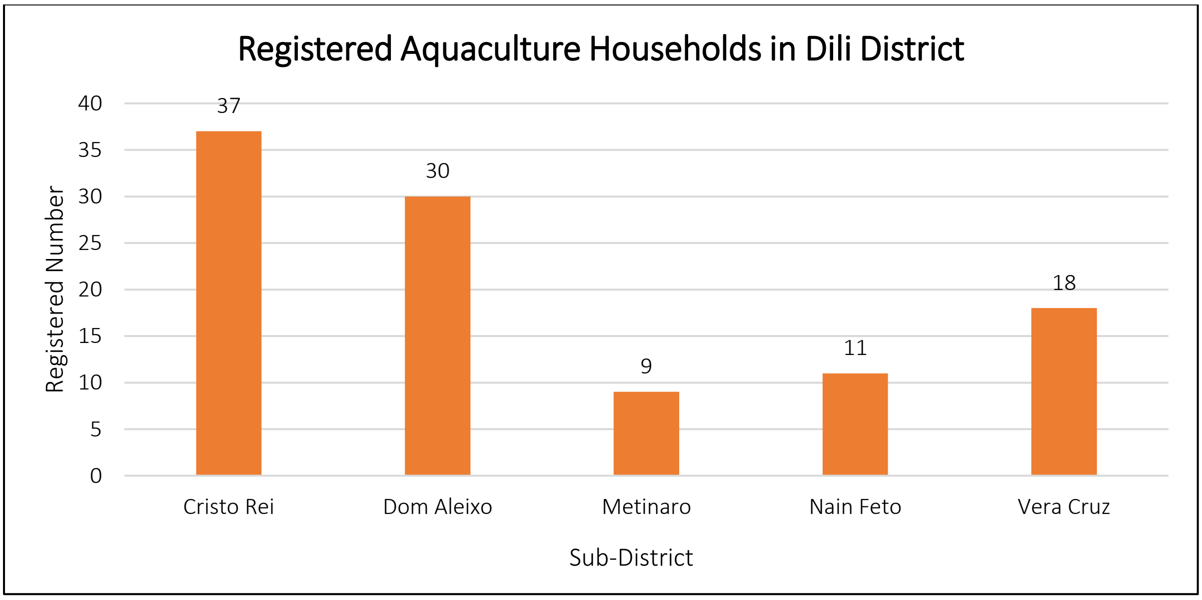


Figure 10.8 Aquaculture Households in Dili District
(Source: Timor-Leste Agriculture Census, 2019)

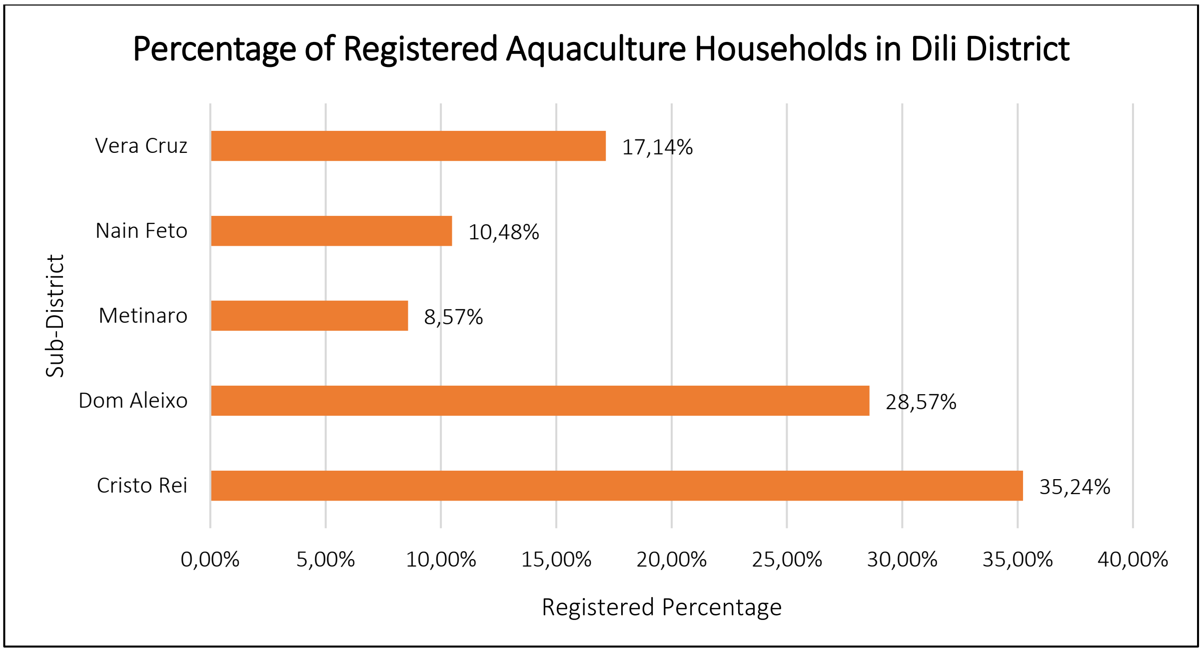


Figure 10.9 Percentage of Aquaculture Households in Dili District
(Source: Timor-Leste Agriculture Census, 2019)

3. Aquaculture Systems

The aquaculture systems currently developed in Dili District show a limited pattern focused on certain types. Of the total 129 aquaculture units recorded, the majority are dominated by fishpond systems, accounting for 118 units (91.47%) of all aquaculture systems. Meanwhile, fish shrimp ponds are only recorded as 11 units (8.53%), and no fish cages, rice-fish systems, or hatcheries are present in any of the sub-districts.

The distribution of fishpond systems is most commonly found in Cristo Rei Sub-District with 34 units (28.81%), followed by Metinaro Sub-District with 27 units (22.88%), Vera Cruz Sub-District with 26 units (22.03%), Dom Aleixo Sub-District with 19 units (16.10%), and Nain Feto Sub-District with 12 units (10.17%). This reflects that fishpond systems are the main approach in aquaculture activities in Dili District, both as household-based enterprises and small-scale activities.

Meanwhile, fish ponds are predominantly located in Metinaro Sub-District, contributing 72.73% of the total ponds in Dili District (8 out of 11 units), while the rest are scattered in Cristo Rei (2 units, 18.18%) and Dom Aleixo (1 unit, 9.09%). The concentration of shrimp ponds in Metinaro suggests the potential for broader brackish water aquaculture development in the region, particularly with technical and infrastructure support. The graph of facilities used for aquaculture in Dili District is shown in **Figure 10.10** and **Figure 10.11.**

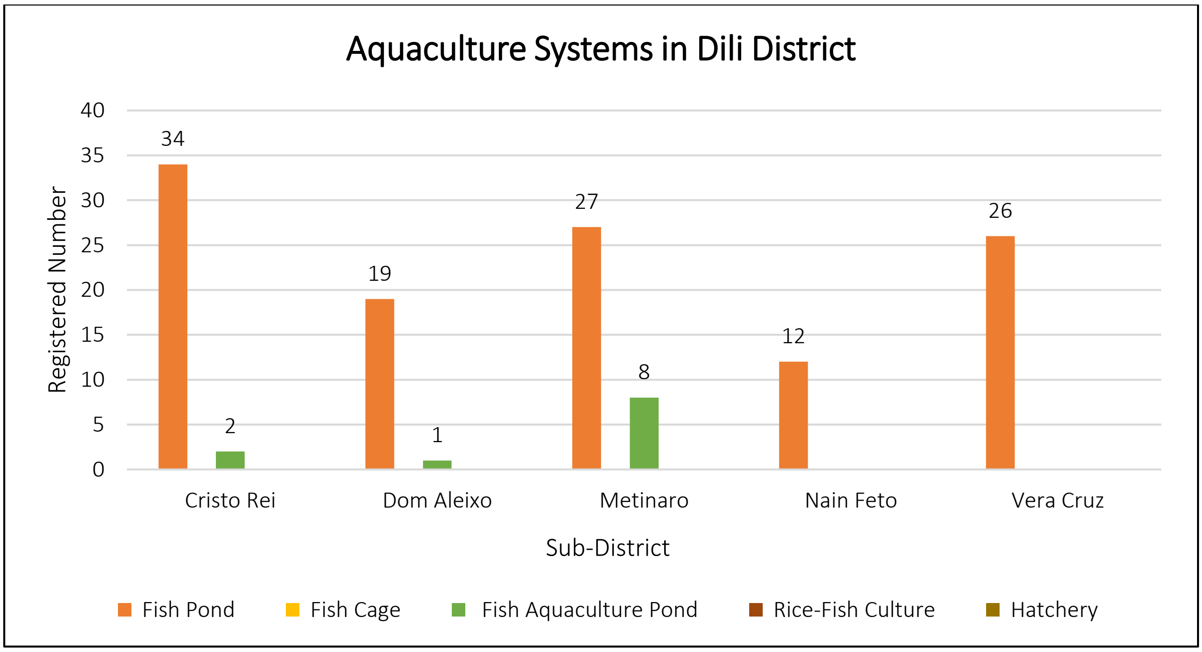


Figure 10.10 Aquaculture Systems in Dili District
(Source: Timor-Leste Agriculture Census, 2019)

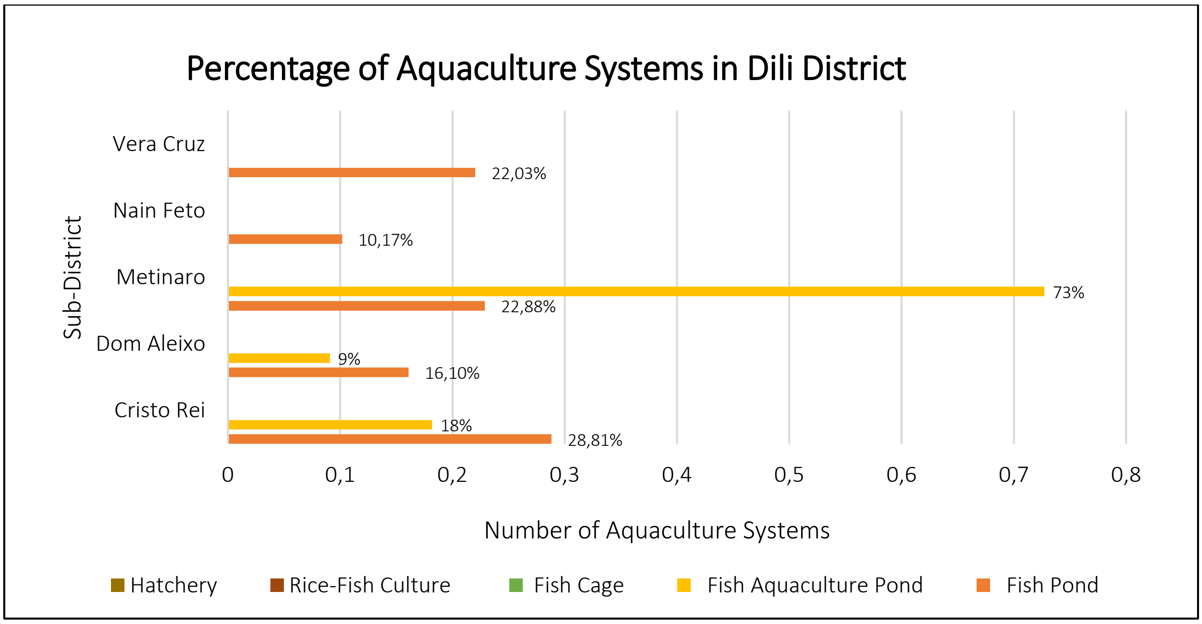


Figure 10.11 Percentage of Aquaculture Systems in Dili District
(Source: Timor-Leste Agriculture Census, 2019)

C. Field Observation Results

Dili District exhibits various forms of aquaculture ventures spread across the Cristo Rei administrative area. Each location shows distinct characteristics, including the scale of operations, management practices, cultivated commodities, as well as technical and environmental challenges, reflecting the potential for aquaculture development in this region.

One location is in Balibar Village, where aquaculture activities are conducted on a small scale by households. The farming facilities include a small lake known as Debu Metan, which serves as a natural pond for tilapia and carp, relying entirely on rainfall as the primary water source. The water level is highly seasonal, with the pond being fully filled during the rainy season but shrinking during the dry season, though not completely drying up. The farming activity at this site has not been intensively managed and remains subsistence-based. However, there is potential to develop this area int o an integrated aquaculture site based on recreation if supported by adequate infrastructure and technical assistance.

Figure 10.12 Debu Metan Fishpond in Balibar Village
(Source: Research Documentation, 2025)

In contrast to Balibar Village, aquaculture activities in Metinaro Village are run by a group of six farmers. They manage a pond located in a coastal area with mangrove vegetation. The water supply system at this location relies on a combination of tidal seawater and freshwater wells, which is channeled into the pond using hoses. The main commodities cultivated are milkfish and crab.

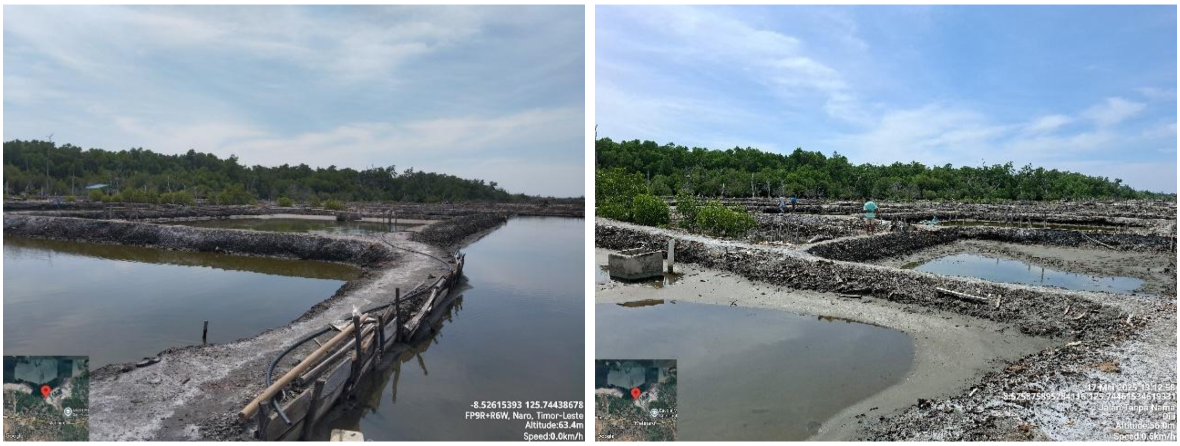


Figure 10.13 Aquaculture Pond in Metinaro Village
(Source: Research Documentation, 2025)

Although operations have begun, the farmers still face several challenges, particularly regarding seed supply, high feed costs, and low production certainty. Additionally, there was a mass fish death incident in certain ponds, with the cause still unknown. Field observations revealed the dominance of a type of mollusk in the affected ponds, indicating an ecological imbalance. This situation requires special attention, particularly in managing the farming environment and strengthening the production system through the provision of broodstock and more standardized facilities.

Figure 10.14 Mollusk Dominance in Aquaculture Pond in Metinaro Village
(Source: Research Documentation, 2025)

Meanwhile, in Hera Village, aquaculture activities are carried out under a public-private partnership (PPP) scheme. This unit is managed by eight staff members, most of whom have backgrounds in livestock farming, consisting of five men and three women. The main commodities farmed include tilapia and catfish (*Clarias sp.*). Compared to the previous two locations, the unit in Hera Village shows a more formal and organized management structure. The production unit is currently expanding, with a focus on increasing tilapia farming as the flagship commodity. The availability of trained human resources and the involvement of the private sector are key strengths in supporting the sustainability of this venture.

Figure 10.15 PPP Unit in Hera Village
(Source: Research Documentation, 2025)

Overall, the three observation locations in Dili District reflect a diversity of approaches and capacities in aquaculture management. From household-based systems utilizing local resources, group-based farming integrated with coastal ecosystems, to more structured cross-sectoral partnerships, all demonstrate potential for further development. These findings provide an essential foundation for formulating adaptive, inclusive, and sustainable aquaculture sector strategies in Dili District and its surrounding areas.

10.4 COMPREHENSIVE LAND SUITABILITY ANALYSIS FOR AQUACULTURE

A. Aquaculture Land Suitability in Dili District

Land suitability refers to the degree to which an area is suitable for a particular use, in this case, the aquaculture industry. The purpose of this assessment is to determine how the physical, chemical, and climatic characteristics of a land area can optimally and sustainably support the cultivation of aquatic commodities. Land suitability evaluation is conducted through two approaches: actual conditions (as they are) and potential conditions (after improvements have been made). The actual land suitability is determined based on field survey results that describe the land's capability in its natural state, without any interventions or improvement efforts. Therefore, this evaluation does not consider potential improvement actions or management strategies that could address constraints or limiting factors on each land unit.

The determination of the actual land suitability class is conducted by assessing each land quality based on existing limiting factors. This process is followed by scoring and calculating the final evaluation value, resulting in an objective overview of the land suitability level and its limiting factors for aquaculture commodities. Potential land suitability reflects the degree of suitability after improvements are made to the land. For example, land that is currently classified as marginally suitable (S3) due to certain constraints can be upgraded to moderately suitable (S2) or highly suitable (S1) through proper improvements such as topography modification or water quality adjustments. The potential suitability evaluation is carried out by considering feasible and realistic improvement actions, so the limiting land characteristics can be minimized, and the land suitability level is expected to increase.

With the application of proper management, land with a low suitability class (actual) can be improved to a higher class (potential). However, not all limiting factors can be addressed with available technology, or they may require very intensive management. In land use planning for aquaculture, the potential suitability evaluation becomes the main focus because it reflects the maximum potential of the land after improvements. This information is essential for designing effective and sustainable land utilization and determining the necessary improvement actions to achieve optimal results.

B. Results of Aquaculture Land Suitability Evaluation in Dili District

Land suitability analysis is a critical step in designing a sustainable resource management strategy for aquaculture. The evaluation is conducted through an integrated approach using geospatial data, field surveys, and physical and chemical analysis of water and soil in laboratories. This method allows for the identification of both the potential and limitations of land bio-physical characteristics for the development of various aquaculture commodities.

The obtained data is analyzed based on the growing requirements for each type of aquatic commodity in its actual state, as well as potential suitability after various land improvement efforts such as topography modification, water quality management, or the application of adaptive aquaculture techniques. This process generates comprehensive information to determine the priority of commodity development, identify limiting factors, and design relevant technical solutions. This scientific approach serves as the foundation for land suitability evaluation in Dili District.

The results of this analysis provide strategic guidance to maximize land productivity while maintaining the sustainability of aquatic resources in each area. The field and laboratory data used as the basis for land suitability assessment are presented in the relevant supporting documents. The land distribution map for aquaculture in Dili District is shown in **Figure 10.16.**

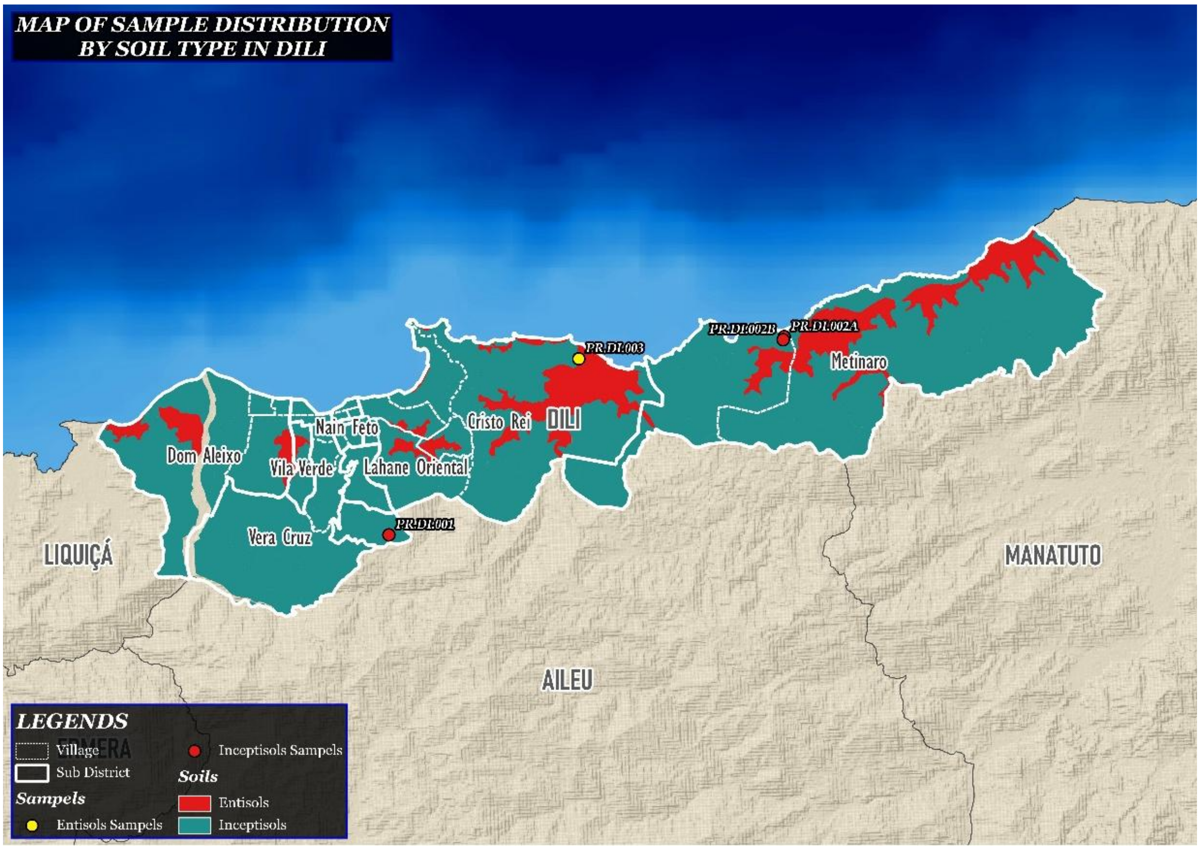


Figure 10.16 Map of Soil Distribution on Aquaculture Land in Dili District

a. Land Suitability Evaluation in Cristo Rei Sub-District

The land suitability analysis in Cristo Rei shows both potential and challenges for aquaculture development. For freshwater commodities such as gourami, catfish, carp, and tilapia, the main limiting factors are slope gradient and the dry season period. The slope gradient can be improved to S3 through a stepped pond system. However, the dry season remains unsuitable due to its difficulty in improvement, requiring strong water management strategies such as the construction of reservoirs or a recirculation system. Additionally, rainfall also serves as a limiting factor with an S3 category. Despite slight variations in the actual conditions, all freshwater commodities have the same final suitability potential value of 3.34, reflecting the intrinsic limitations of the location (Table 10.9).

In contrast, brackish water commodities such as milkfish, mangrove crab, and vannamei shrimp face much greater challenges. Besides slope and the dry season, the most critical constraint is low salinity. Technically, this issue can be addressed by mixing seawater, but the high logistical and operational costs make this option economically unfeasible in Cristo Rei. Even though mangrove crab has a higher suitability potential (3.46), this value becomes less relevant due to economic limitations (Table 10.9).

Based on these results, aquaculture development in Cristo Rei should focus on freshwater commodities. Through interventions such as topography management with stepped ponds and integrated water management to address the dry season, this area has the potential to optimize freshwater aquaculture to strengthen food security and create sustainable economic opportunities.

Table 10.9 Land Suitability Analysis for Aquaculture Commodities in Cristo Rei Sub-District

Commodity	Current Land Suitability Limiting Factors	Current Final Evaluation	Potential Land Suitability Limiting Factors	Potential Final Evaluation
Gourami (*Ospronemus gouramy*)	N: Slope gradient, dry months S3: Rainfall S2: Low temperature	3,17	N: Dry months S3: Rainfall, slope gradient	3,34
Catfish (*Clarias batrachus*)	N: Slope gradient, dry months S3: Rainfall	3,22	N: Dry months S3: Rainfall, slope gradient	3,34
Carp (*Cyprinus carpio*)	N: Slope gradient, dry months S3: Rainfall S2: pH	3,15	N: Dry months S3: Rainfall, slope gradient	3,34
Tilapia (*Oreochromis niloticus*)	N: Slope gradient, dry months S3: Rainfall S2: pH, low temperature	3,05	N: Dry months S3: Rainfall, slope gradient	3,34
Milkfish (*Chanos chanos*)	N: Slope gradient, dry months S3: Low salinity S2: Low temperature, pH, rainfall	2,96	N: Dry months S3: Rainfall, slope gradient	3,34
Mangrove crab (*Scylla serrata*)	N: Low salinity, slope gradient, dry months S2: Low temperature	2,99	N: Dry months S3: Slope gradient	3,46
Vannamei (*Litopenaeus vannamei*)	N: Slope gradient, dry months S3: Low salinity, rainfall S2: Low temperature, pH	2,90	N: Dry months S3: Rainfall, slope gradient	3,34

C. Aquaculture Land Improvement Efforts

The results of the actual land suitability evaluation in Dili District show various limiting factors that make most areas either unsuitable or only marginally suitable for aquaculture ventures. To improve the land suitability class, efforts to correct or improve these limiting factors are needed, as far as possible. Land improvement efforts in the context of aquaculture include technical interventions aimed at improving the bio-physical conditions of the land and water environment quality to better meet the optimal needs of the cultivated commodities. These improvements can involve habitat modification (such as improving the physical condition of ponds), water quality manipulation, or the provision of supporting infrastructure.

Based on **Table 10.10,** there are types of improvement efforts with varying levels of management difficulty. The management difficulty levels are divided into three categories: low, medium, and high. These levels then have assessment assumptions for improving actual land quality to potential quality, as shown in **Table 10.11.**

Table 10.10 Recommended Improvement Measures for Limiting Parameters

No	Parameter	Improvement Measures	Management Difficulty Level
1	Low Temperature	- Use of shallow ponds - Use of dark-colored ponds - Use of water heaters	- Low - Low - High
2	Low Salinity	- Conventional seawater mixing - Seawater mixing with pump systems	- Medium - High
3	Water pH	- Regular water changes - Use of zeolite	- Medium - High
4	Slope	- Use of terraced pond systems	- High
5	Rainfall	- Cannot be improved	
6	Dry Months	- Cannot be improved	

Description :

- *Low management difficulty: Can be carried out by farmers at a relatively low cost.*
- *Medium management difficulty: Can be carried out by intermediate-level farmers, requiring moderate capital and moderate aquaculture techniques.*
- *High management difficulty: Can only be carried out with relatively high capital, typically by the government or large to medium-sized companies.*

Table 10.11 Assumptions for Improving Actual Land Quality to Potential, Based on Management Difficulty Levels

No.	Land Quality/Characteristic	Management Level Low	Medium	High
1	**Topography**	-	-	+
	Slope Gradient			
2	**Soil Conditions**			
	- Clay Content	-	+	++
	- pH_F-pH_{FOX}	-	+	++
	- Organic Carbon	-	+	++
3	**Water Quality**			
	- Temperature	+	--	+++
	- Salinity	+	++	+++
	- pH	+	++	+++
	- Total Dissolved Solid (TDS)	+	++	+++
	- Ammonia	+	++	+++
	- Dissolved Oxygen (DO)	+	++	+++
4	**Climate**			
	- Annual Rainfall	-	-	-
	- Dry Months	-	-	-

Description :

- *Not feasible for improvement*

\+ *Improvement is possible, and the suitability class will increase by one level (S3 to S2)*

++ *Improvement will increase the suitability class by two levels (S3 to S1)*

+++ *Improvement will increase the suitability class by three levels (N to S1)*

XI. RECOMMENDATION

11.1 RECOMMENDATIONS FOR THE AGRICULTURAL SECTOR

1) Land Potential and Spatial Distribution

Dili District, as a center of national and international attention, possesses diverse land resources. Village Sabuli and Village Duyung (Metinaro Sub-District), Village Becora, Village Lahane Oriental, Village Lahane Ocidental, Village Balibar, Village Dare, and Village Macarenhas are suitable for dryland crop cultivation. Village Hera (Cristo Rei Sub-District) has potential for irrigated rice fields, while Village Becora (Cristo Rei Sub-District) is utilized as a grazing area with elephant grass (*Pennisetum purpureum*) and gamal (*Gliricidia sepium*) forage. This configuration requires selective and efficient agricultural land use planning amid the pressures of industry and coastal tourism.

2) Agricultural land use planning

The lowland areas will develop as industrial and urban centers. Agriculture will focus on urban farming in limited spaces (home gardens, vertical farming, rooftop gardening, household-community scale hydroponics) and selected smart farming practices. Steep slope zones will be designated as protected forests and agroforestry areas to preserve ecosystem services, control erosion, and act as buffers for microclimates.

3) Developed food and horticultural commodities

Cassava, corn, cowpea, taro, sweet potato, upland rice, and vegetables such as water spinach, spinach, chili, eggplant, caisim, cucumber, tomato, pakcoy, and pumpkin have been widely cultivated. Tropical fruits such as papaya, banana, mango, avocado, guava, soursop, custard apple, pineapple, rambutan, passion fruit, and jackfruit strengthen the opportunity for fresh supply to urban markets and tourism, provided they are supported by proper grading, packaging, and distribution.

4) Industrial crops and forestry vegetation as landscape support

Coconut, cacao, coffee, kapok, and sugarcane have potential as leading commodities based on local resources. Forestry vegetation such as pine, eucalyptus, jujube, sandalwood, teak, bamboo, palm, acacia, and betel nut are spread across Metinaro Sub-District, Cristo Rei Sub-District, Dom Alexio Sub-District, Nain Feto Sub-District, and Vera Cruz Sub-District. This cluster plays a role in preventing erosion, supplying organic material, and holds economic value if managed sustainably.

5) Urban farming and smart farming in Dili

Prioritize home gardens, vertical farming, hydroponics, and micro greenhouses in densely populated Villages; integrate drip irrigation, measured liquid fertilization, simple moisture sensors, and short planting schedules to ensure continuous harvesting. This model is suitable for supplying leafy vegetables, chili, tomatoes, and herbs to urban markets and hotels/restaurants.

6) Agroforestry based on ecotourism and agrotourism

Village Dare (Vera Cruz Sub-District), Village Lahane Oriental–Ocidental (Nain Feto Sub-District), and Village Balibar (Cristo Rei Sub-District) can develop agroforestry systems combining coffee, cacao, and fruit (orange, avocado, mango) with live fences made of leucaena, calliandra, and gamal as erosion barriers. Link this to educational ecotourism (model farms, conservation interpretive trails) to increase non-harvest income.

7) Soil and water conservation on sloped land

Develop stable terracing, contour-aligned planting strips, organic mulching, and legume strips. Implement functional field drainage to reduce runoff and topsoil loss, particularly on the slopes of Cristo Rei Sub-District and Vera Cruz Sub-District.

8) Water infrastructure and irrigation resilience

Strengthen water conservation with ponds, small reservoirs, wells, and rainwater reservoirs; rehabilitate small channels, and set up simple pipelines to irrigate rice fields and vegetable plots. Water-efficient irrigation models (drip/sprinkler) are a priority for urban and peri-urban farming, as well as fruit orchards on well-drained land.

9) Soil fertility improvement and fertilization SOP

Sustainable productivity requires balanced fertilization based on soil testing, addition of organic matter (compost, manure), and SOPs for application rates, timing, and methods that are easy to adopt. The limited follow-up fertilization must be addressed through demonstration plots, fertilizer recommendation cards, and intensive guidance.

10) Integrated crop protection and planting calendar

Coordinate simultaneous planting, use healthy seeds, conduct regular monitoring, and apply biological control. Limit chemical inputs to economically viable levels. For irrigated rice in Village Hera, focus on water management, balanced nitrogen fertilization, and land sanitation to ensure that intensification does not trigger pest outbreaks.

11) Grazing and feed bank

In Village Becora (Cristo Rei Sub-District), manage grazing with rotational paddocks, a cut-and-carry system in sensitive zones, and a feed bank based on elephant grass and gamal. Utilize livestock manure as compost for urban-periurban gardens.

12) Special case: 19 ha of orange orchards in Village Dare (Vera Cruz Sub-District)

Symptoms of decreased acidity (sourness) and plant death indicate nutrient-water issues. Recommendations: conduct soil and leaf testing, add organic matter and lime if pH is low, apply light fertigation or drip irrigation, use thick mulching to retain moisture, perform regular production pruning, and re-enter grafting on adaptive rootstocks. Implement legume groundcover rotation to increase nitrogen and suppress weeds.

13) Institutions, marketing, and supporting policies

Strengthen cooperatives in each Sub-District for input supply, product absorption, and access to financing. Improve simple post-harvest facilities (grading, packaging, communal cold boxes) to make urban vegetables and fruits more competitive. Targeted fertilizer subsidies and organic material incentives are crucial to maintain farming costs.

14) Commodity zoning and urban supply chains

Place fast-growing leafy vegetables and herbs in densely populated Village areas, fruits and tubers in peri-urban areas with good drainage, and irrigated rice in Village Hera with good water management. Link production with retail markets, horeca, and urban food programs to ensure stable absorption.

15) Implementation stages (quick wins to medium-term)

Quick wins: urban farming demonstration plots in Village Lahane Oriental–Ocidental and Village Becora, simple fertilization SOPs, mulching-legume strips on slopes, and household-scale rainwater harvesting. Medium-term: communal ponds, block-scale terracing, peri-urban greenhouses with drip irrigation, educational agroforestry in Village Dare–Balibar, and city market partnerships with supply contracts.

11.2 RECOMMENDATIONS FOR THE LIVESTOCK SECTOR

Based on the study, Dili is recommended to become a post-production livestock region. Policy directions should focus on strengthening supply chains and downstream industries. The development of logistical infrastructure such as slaughterhouses and cold storage facilities should be prioritized to facilitate the distribution of livestock from production centers. Additionally, investment in value-added product processing sectors such as sausage and cheese should be encouraged through incentives. This strategy positions Dili as a distribution and processing hub, playing a crucial role in meeting market demands and supporting sustainable livestock farming.

11.3 RECOMMENDATIONS FOR THE FISHERIES SECTOR

The fisheries sector can be summarized by noting that aquaculture activities in Dili District are currently dominated by Cristo Rei and Dom Aleixo Sub-Districts, which together account for more than 94% of the total aquaculture area. Among them, Cristo Rei holds a central position as the hub of aquaculture activities based on land area, the number of household fish farmers, and the number of active aquaculture units.

The aquaculture approach in Dili demonstrates diversity in systems and business scales, ranging from household pond systems based on local resources (Balibar Village), small coastal-based collaborative group systems (Metinaro Village), to formal partnerships with the private sector (Hera Village). Each reflects varying levels of capacity and technical approaches, but all indicate potential for further development.

The most common limiting factors identified are slope, dry months, and suboptimal temperature and pH conditions. Commodities such as tilapia, carp, and catfish are quite adaptive but still face significant seasonal and ecological challenges. On the other hand, commodities like milkfish, vannamei shrimp, and mud crabs show sensitivity to low salinity and instability in coastal environments, which, in the case of Metinaro Village, has led to mass mortality events and the dominance of invasive mollusks.

In terms of land suitability scores, all species showed an improvement from actual to potential suitability. The highest increase was observed in the mud crab commodity (from 2.99 to 3.46), indicating a significant potential for development if technical and environmental interventions are appropriately implemented.

Meanwhile, species like catfish, gourami, tilapia, and vannamei shrimp showed uniform potential values (3.34), indicating that ecologically, the area supports the diversification of commodities based on integrated pond and pond systems.

In efforts to improve productivity and sustainability in the aquaculture sector in coastal and rural areas, a location-based approach is crucial. Each area has distinct biophysical characteristics, operational challenges, and commodity potentials, so technical and strategic interventions must be contextually tailored. **Table 10.1** presents specific technical and strategic recommendations for Dili District.

Table 11.1 Specific Technical and Strategic Recommendations for Dili District

Location	Main Issues	Technical and Strategic Recommendations
Balibar Village	Dependence on rainfall; small-scale, non-intensive operations.	The development of Debu Metan Lake as an integrated aquaculture area based on ecotourism. This requires the provision of high-quality seed stocks and training for the intensification of fish farming, focusing on species such as carp, tilapia, and gourami.
Metinaro Sub-District	Salinity fluctuations; mass mortality; mollusk pests; limited seed supply.	Rehabilitation of the water circulation system (combining tidal flows and wells) with a biosecurity approach. Further research on dominant mollusk species is required, along with support for the provision of local seed stocks and training in mangrove-based pond ecosystem management. Key commodities: mud crabs and milkfish.
Hera Village	Challenges in increasing production capacity; non-fisheries human resources.	Focus on increasing the production scale of tilapia and catfish through mechanization, expansion of pond units, and training in production management based on CBIB (Good Aquaculture Practices). Strengthening synergy among stakeholders (PPP) is essential for replicating the model in other regions.

Pilot Project Location Determination

The recommended pilot project location for aquaculture in Dili District is Balibar Village, Cristo Rei Sub-District, specifically within the household communities surrounding Debu Metan Lake. This location was chosen based on several justifications, including the presence of a naturally stable lake year-round, high community participation, and the potential for developing a freshwater fisheries ecotourism model. Carp, tilapia, and gourami are the recommended species for cultivation.

Policy Recommendations for Local Government (City and Sub-District)

The development of a Fisheries Cultivation Zoning Plan (ZBP) for Dili City. The government needs to develop a spatially-based ZBP that refers to the results of land suitability evaluation and local characteristics, dividing Dili into zones for freshwater, brackish water, and conservation.

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Dili Municipality

Dili Municipality, as the national capital, plays a strategic role in agricultural sector development, with land-use proportions comprising irrigated rice fields (0.99 %), rainfed rice fields (14.65 %), dryland farming (22.98 %), grazing areas (9.89 %), and forestry zoning consisting of protected forests (49.45 %) and mangrove forest (2.04 %). The characteristics of this Municipality indicate a dominance of industrial crop development in lowland areas, alongside opportunities for implementing modern agricultural systems such as urban farming, LOT (smart farming), and the optimization of upland areas based on conservation principles. In addition, forest and mangrove ecosystems in Dili function as significant carbon reserves, supporting climate change mitigation and environmental conservation agendas.

Potential land-suitable commodities in Dili include food crops such as irrigated rice (particularly in Cristo Rei Administrative Post), rainfed rice, cassava, and corn; fruit horticulture such as pineapple, mango, and melon; vegetable horticulture such as caisim and cucumber; and spices and medicinal plants such as aromatic ginger and turmeric. Suitable industrial commodities for development include cotton and kapok, while the forestry sector shows potential for high-value species such as sandalwood, Eucalyptus, and teak. In the livestock sector, Dili has suitability for the development of pigs, cattle, and goats, supported by forage feed commodities including elephantgrass, setaria, and legumes.

Furthermore, the fisheries sector in Dili shows development prospects in Balibar Village (Cristo Rei Administrative Post), Sabuli Village (Metinaro Administrative Post), and Hera Village (Cristo Rei Administrative Post), with leading commodities including Nile tilapia, common carp, and gouramy. To strengthen food security and sustainable development, multisector integration strategies are directed through an integrated farming system based on the five key farming practices, livestock integration, and aquaculture intensification. Three Villages, namely Balibar, Sabuli, and Hera, are recommended as pilot projects for integrated agriculture, which are expected to serve as models for sustainable management while supporting Timor-Leste's position in the process of accession to ASEAN and strengthening the competitiveness of the agricultural sector at the regional level.