Land Suitability Evaluation & Regional Potential Mapping

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

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

PERSON IN CHARGE

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FOREWORD

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

With gratitude to God Almighty, we are proud to present the publication of the book titled *“Land Suitability Evaluation and Regional Potential Mapping for the Development of Agricultural, Livestock, Fisheries, and Forestry Commodities in Lautém District, Timor-Leste.”* This book represents a concrete outcome 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 region endowed with abundant natural resources, Lautém District faces significant challenges in optimizing land use, particularly amid resource constraints and the impacts of climate change. This book is prepared to offer structured and relevant solutions for land resource management in Lautém, with a focus on food security, environmental sustainability, and poverty alleviation.

The data-based approach used in this study has successfully mapped the potential of Lautém District for the development of key sectors, including food crops, plantation crops, horticulture, and forestry. Furthermore, the strategies formulated in this book are intended to support sustainable rural economic growth in Lautém while creating new employment opportunities that are relevant for local communities.

Encompassing six main Sub-District, namely Iliomar Sub-District, Lautém Sub-District, Lospalos Sub-District, Luro Sub-District, Lore Sub-District, and Tutuala Sub-District, this book offers a strategic guide for utilizing the dryland that dominates Lautém District. The proposed land suitability zoning approach provides solutions to the challenges of land degradation, erosion hazard, and declining soil fertility. Beyond that, the book emphasizes the importance of integrating environmental conservation and modern technology to support sustainable land productivity.

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

I invite all stakeholders, from government and academia to the broader community, to use this book as a reference for land resource management and agricultural sector development planning. Through strong synergy and close collaboration, we can ensure that agricultural development in Lautém District progresses in parallel with natural resource conservation, ecosystem sustainability, and the improvement of community well-being.

In closing, I would like to express my gratitude to all parties who have supported the completion of this book. May this work become an important milestone in Timor-Leste's journey toward robust food security, inclusive economic development, and a sustainable environment.

Respectfully,

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Minister of Agriculture, Livestock,
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EXECUTIVE SUMMARY

A. GENERAL OVERVIEW OF THE STUDY AREA

This chapter presents a general overview of Lautém District as essential background for evaluating land suitability and the development potential of agricultural, plantation, horticultural, and forestry commodities. The information covers demographics, soil types, land use, and existing field conditions, based on a detailed and comprehensive data-driven approach.

1. Demographics: Foundation of Human Resource Potential

Lautém District is dominated by dryland, which indicates strong potential for developing the agricultural sector as a backbone of national food security. This demographic condition makes the area a strategic candidate for strengthening national food security through the application of innovative agricultural technology.

2. Soil Types: Basis for Land Suitability Evaluation

Lautém District exhibits diverse soil types, including Inceptisols, Mollisols, Vertisols, Entisols, Alfisols and Ultisols, alluvial soils, and Histosols, which are known to be fertile and have high productivity potential when managed appropriately. This diversity reflects considerable opportunities for land-suitability-based agricultural development. However, soils that are susceptible to erosion, such as Vertisols, require particular attention. The implementation of intensive and targeted soil conservation strategies is therefore essential to sustain land productivity and support sustainable agriculture in the area.

3. Land Use: Dynamics of Ecosystems and Human Activities

Land use in Lautém District is dominated by forest areas (75.68 %), followed by unused dryland (10.42 %) and agricultural land (7.86 %). Forest areas dominate in Lautém, Lospalos, and Tutuala Sub-Districts, whereas agricultural land is distributed mainly in Luro, Iliomar, and Lautém Sub-Districts. This land use pattern indicates a balance between the ecological functions of forests and agricultural production potential, although integrated management is required to optimize its contribution to food security.

4. Slope Gradient: Risk and Potential

The topography of Lautém District is dominated by nearly level slopes with a slope gradient of 0 to 8 % and gently sloping terrain with a slope gradient of 8 to

15 %, which together cover more than half of the area. Steep to very steep slope classes with a slope gradient greater than 45 % are relatively limited in extent but are scattered throughout the district. These conditions create a high risk of erosion and limit land suitable for intensive agriculture; therefore, land management requires conservation approaches such as terracing, ground cover vegetation, and surface runoff control engineering.

5. Agroclimatic Zones: Regional Potential Grouping

Lautém District is dominated by agroclimatic zone E (40.56 %), which is characterized by a bimodal rainfall pattern. The stability of bimodal rainfall in this zone provides optimal opportunities for agricultural intensification with main crops such as lowland rice and corn. The next most extensive is zone B (35.15 %), characterized by a stable monomodal rainfall pattern, which allows intensification of primary food crops such as corn. These agroclimatic characteristics are suitable for agroforestry and seasonal dryland agriculture, although dependence on a single main rainy period requires strict adaptation strategies to climatic variability.

6. Field Conditions: Constraints and Potential

Lautém District has substantial potential that has not yet been fully utilized, including idle land that can be converted into productive land. Although vegetation growth is relatively good, the application of appropriate agricultural techniques, such as plant spacing and crop maintenance, remains limited. Several areas, such as Lospalos Sub-District, have potential for the development of rainfed and irrigated rice fields as well as livestock grazing that can support integrated farming systems. The main challenges in this area include difficult land access, limited water supply, and low adoption of efficient cultivation techniques. To optimize this potential, farmer training and support are needed, along with soil-conservation-based approaches to improve productivity and food security.

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

Chromolaena odorata, or siam weed, is an invasive weed that has spread widely in Timor-Leste since the 1980s. This plant threatens agriculture by forming dense thickets that compete for nutrients, and it is dangerous for livestock due to its content of toxic pyrrolizidine alkaloids. Ecologically, the invasion of this weed inhibits the regeneration of native vegetation and increases the risk of land fires. Nevertheless, *C. odorata* has potential uses, including as a source of traditional medicine, organic fertilizer, and vermicompost. An appropriate management approach is required to suppress its negative impacts while optimizing the added value of its biomass.

B. RESEARCH METHODS

This study employed a survey method, including field observation, interviews, and laboratory analysis, to evaluate land suitability comprehensively. The study used Homogeneous Land Units (HLU) as the basis for delineating the area, derived from thematic map data such as land use, soil type, geology, and slope gradient. Data analysis was supported by Geographic Information System (GIS) technology to produce accurate and informative map visualizations.

Research Procedure

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

    The physical and chemical soil parameters analyzed included:
    - Soil organic carbon (%) using the Walkley and Black method.
    - Total Nitrogen (%) using the Kjeldahl method.
    - Soil texture using the pipette method.
    - Soil pH potensiometer method (H2O at a 1:2.5)
    - Available Phosphorus and Available Potassium (ppm):
        - Bray-1 method for pH < 7 (converted to mg 100 g^-1).
        - Olsen method for pH > 7 (converted to mg 100 g^-1).
    - 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-:HClO4 digestion method.
    - Total Sulfur (ppm) and Available Sulfur (ppm) determined using the spectrophotometric method.
    - Salinity (dS m^-1) potensiometer method (H2O at a 1:2.5).
    - Cation exchange capacity (cmol/(mg/100g)) dan base saturation (%) determined using NH_4OAc 1N pH7.

- Soil fertility status classified according to the PPT (1995) method.
- Erosion hazard assessed through field observation and the Universal Soil Loss Equation (USLE).

3. Stages of Land Suitability Classification

- Actual Land Suitability:
  The initial classification was carried out to assess land suitability under existing conditions without improvement.
- Land Improvement Recommendations:
  Improvement measures were identified to address limiting factors, including input management such as fertilizer application and soil and water conservation techniques.
- Potential Land Suitability:
  Suitability evaluation was conducted after considering land improvements in order to maximize land potential.
- Zoning of Commodity Development Potential:
  Zoning was determined by integrating the Agro-Ecological Zones of Timor-Leste, based on land suitability and specific agroecosystem characteristics.

C. LAND CHARACTERISTICS FOR AGRICULTURE AND FORESTRY

1. Temperature

Air temperature is a primary parameter in land suitability evaluation, analyzed through the integration of field measurement data and the SRTM Digital Elevation Model (DEM) using the Braak approach. Lautém District is dominated by a warm temperature zone (24 to 26 °C). This range is an ideal condition for the growth of tropical crops such as rice, corn, and soybean and supports high productivity because it occurs in lowland areas with suitable humidity, making this district strategic for agricultural development.

2. Rainfall

Lautém District is dominated by annual rainfall of 1,000 to 1,500 mm/year. This amount is sufficient to support dryland farming activities and is suitable for crops such as horticulture. However, the variability in rainfall distribution requires appropriate water and land management strategies to sustain agricultural productivity in Lautém District.

3. Dry Month

Based on spatial distribution, the average duration of dry months in Lautém District ranges from 4 to 5 months per year. Areas such as Lospalos, Iliomar, and Tutuala tend to experience a shorter dry season (3 to 4 months), whereas Lautém and parts of Luro face a longer dry season (5 to 6 months). This variation in dry season duration requires adaptive strategies, such as crop diversification and the integration of agroforestry systems, to maintain ecosystem resilience and sustainable agricultural productivity.

4. Elevation

The average elevation of the district is 274.74 m above sea level, with variation from coastal areas to hilly terrain. Differences in elevation affect agroecological conditions, including microtemperature, humidity, and the types of soils that form. In low-lying areas, land potential is more suitable for annual crops, whereas at higher elevations there is greater opportunity for plantation crops. Elevation is therefore an important factor in land-use planning.

5. Drainage

Soil drainage conditions are generally poorly drained. The dominant clay content in this district results in smaller soil pores and slower water release, which further exacerbates natural drainage. In addition, the presence of developing layered subsoil horizons indicates additional limitations in the soil drainage system. These conditions need to be carefully considered in land-use planning so that they do not adversely affect productivity and the sustainability of grazing.

6. Coarse Fragments

Soils in this district have relatively low coarse fragment content. This indicates that most areas have fine-textured soils with minimal gravel or rock content, which tend to be more fertile and suitable for agriculture.

7. Effective Soil Depth

Effective soil depth is generally deep. This indicates that most land supports plant growth, especially perennial crops and species with deep root systems. Deep soils allow roots to develop more optimally, increase water-holding capacity and nutrient availability, and provide better physical stability for plant.

8. Surface Rock

The distribution of surface rock is quite variable, but is dominated by slightly stony conditions. This indicates that most land has very low surface rock content, thereby supporting agricultural activities through easier soil tillage and a large effective soil volume for root growth.

9. Rock Outcrop

The distribution of rock outcrops in Lautém District is dominated by the category with < 5 % rock outcrop. The low proportion of rock outcrops in this category indicates that most of the area is covered by soil, vegetation, or sediment. This condition results in a thick and fertile soil layer, which supports plant growth and agricultural activity because the soil is easier to cultivate and has a large effective volume for root development.

10. Flood Hazard

The level of flood hazard in this district is classified as high to very high. The flood hazard potential is driven by topography, land cover, and land use, which in turn affect agricultural activity. Therefore, water management and drainage channels are still required to anticipate land damage.

11.Soil Texture

Soil texture in Lautém District varies among sub-district. Iliomar, Lospalos, Luro, and Tutuala sub-district are dominated by clay texture, which has high water and nutrient retention but requires drainage management to maintain optimal aeration. Lautém Sub-District has clay loam texture with a balance between sand and clay, resulting in good drainage and water-holding capacity. Meanwhile, Lore Sub-District has loam texture with dominant sand, providing good drainage but lower water and nutrient retention. This variation in texture affects soil fertility and plant growth, so land management must be adjusted to support productivity and long-term soil sustainability.

12. Soil pH

Soil pH values in Lautém District fall within the neutral range. Under this condition, nutrients are optimally available and readily dissolved in water, making them easier for plant to absorb. Soil pH is very important because it provides an indication of soil fertility status.

13. Total Nitrogen

Total Nitrogen content in Lautém District ranges from low to high, with spatial variability among sub-district. Certain sub-district show higher nitrogen content, which is generally associated with biological activity and organic matter input. Conversely, in sub-district with sparse vegetation and high leaching, nitrogen content tends to be low. This variation highlights the importance of site-specific nitrogen fertilization management to improve soil fertility.

14. Available Phosphorus

Available Phosphorus in Lautém District shows significant differences among sub-district. Most sub-district have low Available Phosphorus due to the dominance of limestone formations, which fix phosphorus into forms that are not easily soluble and thus unavailable to plant. This condition can limit crop productivity. Therefore, appropriate phosphorus management strategies are required to support plant growth in this district.

15. Available Potassium

Available Potassium content in Lautém District generally varies among sub-district, with some area showing moderate values and others low. This difference is closely related to lithology and soil texture, which influence the capacity to supply potassium. In sub-district with finer-textured soil, potassium tends to be more strongly retained, so its availability is limited. This underlines the need for site-specific monitoring of soil potassium status to ensure sustainable agricultural productivity.

16. Electrical Conductivity / Toxicity

Electrical Conductivity values in Lautém District range from low to moderate and differ among sub-district. Elevated Electrical Conductivity in certain area can indicate potential salinity problems that affect water availability for plant. Thus, land management needs to consider sub-district-specific conditions to avoid the risk of toxicity and degradation of soil productivity.

D. SOIL FERTILITY STATUS

The soil fertility status in Lautém District is largely classified as low, accounting for 39.71 % (719.71 km²), followed by high at 35.53 % (643.97 km²), moderate at 17.55 % (318.16 km²), and very low at 7.21 % (130.71 km²). These categories are determined based on soil chemical parameters such as Cation Exchange Capacity (CEC). This condition indicates a limitation of the soil in supplying essential nutrients for plant, which has a direct implication for low agricultural land productivity.

This situation signals the need for effective soil management strategies, such as the use of organic fertilizer, soil conservation technique, and improved irrigation system to increase productivity. Optimising land with moderate and high fertility can support food security and community livelihood. Collaboration between farmer, academic institution, and government is crucial for designing land management solution in this district.

E. SOIL EROSION AND AGROFORESTRY-BASED CONSERVATION

1. Soil Erosion

Soil erosion plays an important role in land suitability evaluation and in the sustainability of land use. Soil erosion in Timor-Leste, including Lautém District, is influenced by key factors such as steep topography, unstable soil structure, limited vegetation cover, and land management practice that are not conservation-oriented. Analysis shows that more than 50 % of the area experiences severe to very severe erosion, which leads to the loss of fertile topsoil and a decline in soil productivity.

The main factors driving erosion in this area include:

- Topography: Dominance of steep slope, particularly in Luro Sub-District.
- Soil type: Dominant Inceptisols have clayey structure and texture that is susceptible to water scouring, which increases erosion risk.
- Rainfall: High rainfall intensity contributes to severe to very severe erosion.
- Limited vegetation cover: This condition contributes to the loss of topsoil due to surface runoff.
- Anthropogenic factor: Land management that does not follow conservation principle will accelerate erosion.

This condition underscores the need for conservation measure based on ecological approach to manage land and minimise soil degradation.

2. Agroforestry-Based Conservation

Agroforestry-based conservation is a key and effective approach to address soil erosion in Lautém District. Agroforestry integrates forest tree, food crop, and livestock on the same land to provide ecological benefit and sustainable land productivity. This approach focuses on:

- **Increasing vegetation cover** to reduce surface runoff and maintain soil moisture.
- **Improving soil fertility** through the contribution of organic matter from litter and root.

- **Managing water in a sustainable** way by retaining water in the soil profile through deep root system.

The main benefit of agroforestry for soil and water conservation include:

1. **Erosion mitigation:** Tree and crop act as natural barrier that protect soil from surface runoff.
2. **Improved water infiltration:** Root system of tree increases soil capacity to absorb water.
3. **Enhanced biodiversity:** Combination of food crop and tree creates a more diverse and stable ecosystem.
4. **Increased agricultural productivity:** Through a combination of agroforestry component that support diversified harvest.

Agroforestry Implementation in Lautém District

Agroforestry system implemented in Lautém District varies according to agro-ecological zone. Examples of effective agroforestry-based conservation system include:

- **Alley cropping:** Planting crop between row of tree on steep slope to reduce erosion.
- **Live hedge:** Using erosion-tolerant plant such as vetiver to stabilise slope.
- **Living stake system:** Using perennial plant such as *Leucaena* to control erosion, combined with pepper and other climbing crop.
- **Layered planting:** Combining tree, shrub, and ground cover plant to hold soil and reduce runoff.

Conservation Recommendation

1. Strengthen agroforestry practice in erosion-prone zone, such as Luro Sub-District.
2. Implement spatial data-based management to identify priority location for conservation intervention.
3. Enhance farmer capacity through training and adoption of modern agroforestry technique.
4. Strengthen soil conservation policy by integrating agroecology-based approach into regional land-use planning.

F. LAND SUITABILITY FOR AGRICULTURE

1. Land Suitability Evaluation

a) Lospalos Sub-District

- Potential development of food crop includes Upland Rice, Cassava, Corn, Peanut, and others.
- Vegetable horticulture commodity that can be developed includes Shallot, Green Beans, Chili, Eggplant, and Bitter Melon. Fruit horticulture such as Banana, Papaya, Orange, Rambutan, Avocado, and Mango, as well as floriculture such as Rose, Aster, and Sunflower, is suitable to be developed in Lospalos Sub-District.
- Spice and medicinal plant such as Aromatic Ginger and Vetiver Root can be developed.
- There is potential for development of industrial crop such as Robusta Coffee, which has already been developed on a small individual scale in Titilari, Fuiloro Village.
- Other potential commodity includes Cashew, Tobacco, and Sugarcane. Forestry species such as Melaleuca and other forest species become the focus in the forestry sector.

b) Iliomar Sub-District

- Food crop that can be developed includes Irrigated Rice, Upland Rice, Corn, Cassava, and Sweet Potato.
- Industrial crop that can be developed includes Robusta Coffee, Sugarcane, and Coconut.
- Horticultural crop that has potential to be developed includes Cucumber, Eggplant, Bitter Melon, Tomato Vegetable, Long Beans, Orange, Rambutan, Avocado, Durian, Mango, Rose, Aster, and Sunflower.
- Spice and medicinal plant that can be developed includes Vanilla and Pepper. Forestry species such as Agathis, Melaleuca, and Sandalwood can also be developed in Iliomar Sub-District.

c) Lautém Sub-District

- Forestry species that can be developed includes Agathis and Sandalwood.
- Food crop that has development potential includes Irrigated Rice, Upland Rice, Corn, and Soybean.
- Horticultural crop that has potential to be developed includes Shallot, Chili, Bitter Melon, Long Beans, Banana, Avocado, Rambutan, Snakefruit, Aster, Rose, and Sunflower.

- Spice and medicinal plant such as Ginger, Cinnamon, and Galangal can be developed.
- Industrial crop that can be developed includes Tobacco and Robusta Coffee.

d) Luro Sub-District

- Food crop that can be developed includes Cassava, Sweet Potato, and Corn.
- Horticultural crop includes Chili, Bell Pepper, Cucumber, Orange, Jackfruit, Soursop, and Pineapple. Industrial crop that has development potential includes Tobacco and Cashew.
- Forestry species that can be developed includes Melaleuca and Sandalwood, with land suitability class moderately suitable (S2).

e) Tutuala Sub-District

- Food crop that can be developed includes Cassava, Soybean, and Corn.
- Industrial crop that has development potential includes Coconut, Cacao, and Aromatic Ginger. Forestry species such as Melaleuca and Sandalwood have land suitability class moderately suitable (S2).
- Horticultural crop that has potential includes Caisim, Eggplant, Bitter Melon, Guava, Durian, and Pineapple, and flower crop such as Rose, Aster, and Sunflower.
- Spice crop that can be developed includes Lemongrass, Pepper, and Aromatic Ginger.

f) Lore Sub-District

- Forestry species that can be developed includes Sandalwood in coastal area.
- Horticultural crop that has potential to be developed includes Shallot, Chili, Bitter Melon, Long Beans, Banana, Avocado, Rambutan, Snakefruit, Aster, Rose, and Sunflower.
- Spice and medicinal plant such as Ginger, Cinnamon, and Galangal can be developed.
- Industrial crop that can be developed includes Tobacco and Robusta Coffee.

2. Zoning for Agricultural Commodity Development in Lautém District

This study aims to evaluate the potential and land suitability across various land-use categories in Lautém District, Timor-Leste, as a foundation for sustainable territorial planning. The analysis was conducted by examining biophysical characteristics, topography, soil types, and the ecological and economic functions associated with each land-use category.

a) **Forest,** Forest in Lautém District include agroforestry, protected forest, and mangrove. Nino Konis Santana National Park constitutes the largest protected forest area in Timor-Leste and is located spatially within this district. Forest serves as an asset for emission absorption as well as a carbon reserve asset for Timor-Leste.
b) **Jaco Island** is one of the key biodiversity area with dominance of perennial crop and the presence of an endemic species, the Timor deer, that needs to be conserved. The main problem in this area is the limited water reserve and forage availability for the Timor deer, so special attention from all stakeholder is required to address this issue.
c) **Agroforestry** covers 453.58 km² or about 25.02% of the total area, located at an elevation of 500–1,000 m above sea level with slope of 15–40%. Protected forest covers 860.81 km² (47.49%), located in mountainous area with slope ≥ 30% and functioning as an erosion buffer and water supplier. Mangrove covers only 45 km² or about 0.08% and plays a role in carbon storage, coastal protection against abrasion, and as coastal habitat.
d) **Dryland farming** covers 207.96 km² (11.47%) at an elevation of 20–700 m with gentle to moderately steep slope and Vertisol soil. Commodities include cassava, sweet potato, corn, soybean, horticulture, and industrial crop such as cacao and spice. Mixed cropping system, strip cropping, and crop rotation are recommended to maintain productivity and prevent erosion.
e) **Rainfed rice area** covers 132.94 km² (7.33%) and is distributed at an elevation of 0–500 m and higher. The main commodities are upland rice, corn, and legume. Productivity is strongly influenced by rainfall, so small reservoir, drought-tolerant variety, and efficient water use are required.
f) **Irrigated rice area** covers 6.48 km² (4.22%) and is distributed at an elevation < 100 m above sea level. Lospalos Sub-District is the most potential area for irrigated rice development because it has extensive lowland plain and water supply from the Mehara River.

g) **Grazing area** covers 79.30 km² (4.38%), dominated in Lospalos Sub-District. Although the extent is relatively small, it is important as a forage source for livestock. Management is directed through pasture rotation and integration with agroforestry. Elephantgrass, Setaria, and legume are the main forage to support livestock sustainability.

G. LIVESTOCK POTENTIAL

There are two strategic locations that become key focus area for livestock development in Lautém District, namely:

1. **KTS Pato Center,** In line with the national plan to develop Timor buffalo as a milk source, short-term recommendation focus on providing high-quality forage area, with the addition of species such as Setaria grass and legume (Gamal, Calliandra, *Indigofera*). The ideal feed composition is 60 % grass and 40 % legume, supported by supplementary feed such as rice bran or concentrate. Long-term recommendation include improving reproductive technology and providing staff training. This training is important to address reproductive constraints such as silent heat in buffalo. Training certification in Artificial Insemination (AI) is also encouraged so that KTS Pato Center is able to adopt modern livestock technology. With adequate facility, sexing method can be applied to increase the birth of female animal as milk producer and superior breeding stock.
2. **Seiraa, Mehara, Tutuala Sub-District,** are recommended as a pilot project for livestock area that is integrated with food crop and brackish-water aquaculture. Forage such as Setaria and legume including Calliandra, Gamal, and Leucaena for cattle and buffalo can be integrated with food crop such as tuber crop, tomato vegetable, and banana, and with freshwater aquaculture.

With an integrated approach that combines technical, social, and institutional aspect, livestock development in Lautém District has the potential to become an important pillar for improving community welfare and local food security in a sustainable manner.

H. FISHERIES AND AQUACULTURE POTENTIAL

A technical assessment of aquaculture constraints in Lautém District was conducted at the Village level to improve production effectiveness in priority areas. In Parlamento Village, the main challenges include high fish mortality during the dry season and pond leakage caused by soil texture. Recommended solutions include providing an additional backup water source and repairing ponds using tarpaulin or HDPE (High Density Polyethylene) lining.

In Fuiloro Village and Luro Village, issues related to feed efficiency and limited aeration can be addressed by installing simple aerators and providing training on feed management. Meanwhile, Souro Village faces inadequate infrastructure and unstable water supply, requiring improvements to water channels as well as training in production recording and water quality monitoring.

Parlamento Village has been designated as the pilot project site for aquaculture development, focusing on Nile Tilapia production, which has already reached a capacity of one million fish per year. Milkfish is proposed as an additional commodity for development in the coastal zone of Parlamento Village, given the strong potential and ease of replicating the production model in the area. However, infrastructure improvements remain essential to optimize cultivation outcomes.

Policy recommendations for the local government include providing grant funding for the construction of concrete ponds, water channels, and aeration systems; initiating pond revitalization programs to improve structural quality and water-use efficiency; and offering capital support and training to farmer groups for local seed production and commodity diversification. Furthermore, collaboration with research institutions and technical training centers is crucial to enhance local capacity and sustain long-term aquaculture development in Lautém District.

I. RESEARCH RECOMMENDATIONS

1. Agriculture

Agriculture in Lautém District should be directed toward the development of dryland food crops such as upland rice, corn, cassava, taro, sorghum, and legumes that are adapted to limited water availability, while wetland area is recommended for irrigated rice in Lospalos Sub-District. Horticulture has potential in all Sub-District, with priority in Lautém and Lospalos Sub-District, whereas industrial crop such as coffee, coconut, kapok, and cashew are suitable at mid-elevation. Spices and medicinal plant such as *Moringa oleifera*, tamarind, and candlenut need to be expanded in Lore, while forestry vegetation such as teak, Eucalyptus, bamboo, and mangrove should be directed toward conservation. Lospalos is also prioritized for livestock feed development. Tutuala is recommended to remain focused on forest commodity so that its ecosystems are preserved. Technical recommendations include soil and water conservation, rainwater harvesting, crop diversification, farmer capacity building, and infrastructure development.

2. Livestock

Livestock development is focused on large ruminant, with a demonstration site at KTS Pato. Suitable forage includes *Leucaena leucocephala* (lamtoro), elephantgrass, Setaria, and *Gliricidia sepium* (gamal), integrated with rotational grazing systems to maintain land fertility. The government is advised to provide feed grants, improved breeding stock, and training on community-based livestock management in order to increase productivity in a sustainable manner.

3. Fisheries

Aquaculture in Lautém District faces several major constraints, including limited water sources, particularly during the dry season; inadequate pond infrastructure with leakage problems; low feed-use efficiency; and limited production recording and water quality monitoring. To address these issues, technical improvements are required, such as adding backup water sources through rainwater harvesting or shallow wells, especially in Parlamento Village and Souro Village. Pond infrastructure needs to be improved by using impermeable materials such as tarpaulin or HDPE plastic to prevent leakage. Installation of simple aeration devices such as paddle wheels or manual blowers is essential to improve water quality in ponds, particularly in Fuiloro Village and Motalori Village, along with the application of siphon systems or alternating flow to maintain water circulation in concrete ponds. In addition, training on proper feed management and routine production recording should be provided to farmers to increase feed efficiency and culture productivity. Intensive extension support from local fisheries officers is also highly needed to strengthen better and more sustainable aquaculture management. With the implementation of these measures, aquaculture productivity and sustainability in Lautém District are expected to increase significantly.

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New Context: ASEAN, SDGs, and Development Challenges

The Democratic Republic of Timor-Leste is now officially part of the Association of Southeast Asian Nations (ASEAN). The announcement of Timor-Leste's accession was confirmed at the 47th ASEAN Summit held in Kuala Lumpur, Malaysia.

In this new era, Timor-Leste faces a dual challenge: achieving food self-sufficiency while simultaneously optimizing the sustainable management of its natural resources. With a growing population and increasing food demand, the country requires carefully designed and intelligent development strategies.

The achievement of the Sustainable Development Goals (SDGs), particularly food security (SDG 2), water management (SDG 6), and climate action (SDG 13), has become a strategic priority. In this context, Lautém District holds a highly unique and strategic role at the national level.

Meaning of the Regional Name: The Origin of Lautém

Like other districts in Timor-Leste, the name Lautém carries strong historical and cultural significance. The term "Lautém" originates from the Fataluku language and is a combination of two elements, namely "Lau" and "Tem/Teinu." In the oral traditions of ancestral communities, this area was formerly known as Lauteinu or Lauteira. Etymologically, the meaning of the name reflects local cultural identity, in which "Lau" refers to *tais* (traditional woven cloth), while "Teinu/Teira" signifies *lulik*, meaning something regarded as sacred or holy.

Regional Focus: Balancing Conservation and Production

Lautém District is an area with two remarkably contrasting yet complementary potentials.

1. **Conservation and Ecotourism Asset:** Lautém District is home to **Nino Konis Santana National Park,** the largest protected forest area in Timor-Leste. This area is a vital "carbon asset" for the country, contributing directly to climate change mitigation. The park, including the unique **Jaco Island** (known for its deer population) and coastal tourism area such as **Com Village,** is a key pillar for sustainable ecotourism development.

2. **Food Production Asset:** On the other hand, Lautém District has very high potential for agricultural production. Its topography is dominated by flat to gently sloping land (0–8 %), which accounts for **34.89 % of the total area.**

The main challenge in Lautém District is how to manage these two assets in harmony: protecting its ecological heritage while simultaneously optimizing its fertile land for food security.

Technical Basis: Fertile Soil Capital

The food production potential in Lautém District is strongly supported by highly fertile and diverse soil (edaphic) conditions. The dominance of three productive soil orders forms its primary asset:

- **Inceptisols (25.52 %), Mollisols (22.84 %),** and **Vertisols (21.49 %).** The combination of these three soil orders, covering nearly 70 % of the district, provides substantial opportunities for intensive agricultural development, particularly strategic food crops such as rice. Vertisols, with their high water-retention capacity, are especially ideal for irrigated rice fields.
- The presence of other soils such as **Entisols (16.08 %), Alfisols**, and **Ultisols (12.84 %)** further enriches the diversity and potential for agricultural diversification.

Integrated Sector Development Opportunities (Four Pillars)

The evaluation in Lautém District needs to encompass four development pillars in an integrated manner, balancing production potential and conservation:

- **Forestry:** The primary focus is the protection of Nino Konis Santana National Park as a national carbon asset and ecological buffer. Outside the protected area, the application of agroforestry on sloping land offers a dual benefit—supporting soil and water conservation while providing livelihood opportunities (Nair, 2011).
- **Agriculture:** With 34.89 % flat land and fertile soil, Lautém District has very high potential for intensive irrigated rice agriculture to support national food production.
- **Livestock:** The extensive flat land is also ideal for the optimal use of grazing land for cattle and goat farming, which are key commodities in Timor-Leste.
- **Fisheries (Freshwater and Brackish Water):** The coastal area of Lautém District, particularly along the southern coast, has strong potential for the

development of brackish water aquaculture (pond culture) using modern technologies such as biofloc, as well as freshwater fisheries in inland area.

Objective of the Evaluation in This Book

Therefore, the research underlying this book aims to evaluate land suitability and map the development potential in Lautém District. The focus covers four sectors: agriculture, livestock, fisheries (freshwater and brackish water), and forestry.

Through a comprehensive scientific approach, this book is expected to provide strategic recommendations for the government and other stakeholders. The objective is to design sustainable development policies that contribute to national food security while protecting the unique environmental and ecotourism assets of Lautém, in line with the challenges and opportunities faced by Timor-Leste in the new ASEAN era.

II. GENERAL OVERWIEW OF THE AREA

2.1 DEMOGRAPHY

Lautém District is one of the districts in Timor-Leste, located at the eastern tip of Timor Island. It is bordered by the Timor Sea and the Arafura Strait to the east, by the Wetar Strait to the north, by the Timor Sea to the south, and by Baucau and Viqueque Districts to the west. This district consists of six sub-districts: Lospalos, Lautém, Iliomar, Luro, Tutuala, and Loré, which include 34 villages and 151 aldeias. Geographically, Lautém District is located at latitudes 8.30° - 8.45° S and longitudes 126.45° - 127.15° E. The administrative map of Lautém District is presented in the figure below **(Figure 2.1)**.

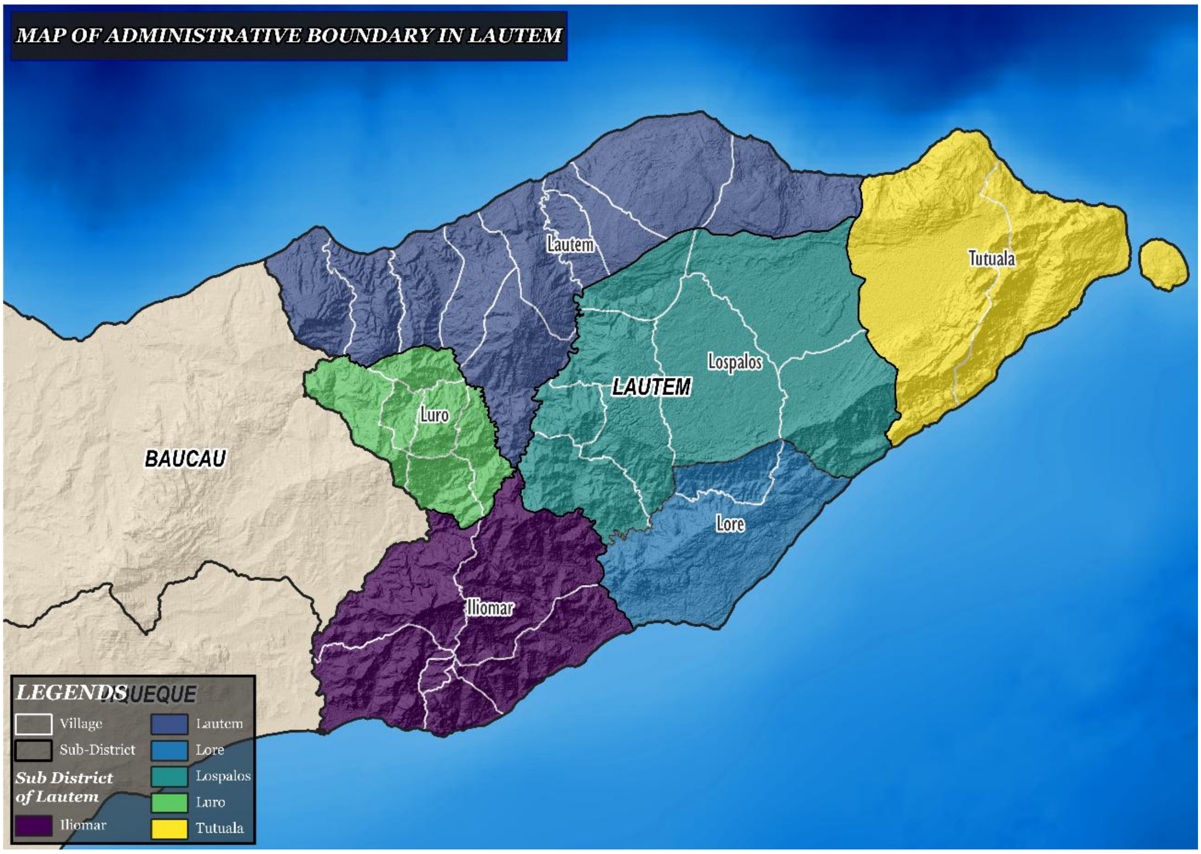


Figure 2. 1 Administrative Map of Lautém District

Like other districts, Lautém also has its own meaning for the name of the region. The word "Lautém" comes from the Fataluku language, formed from two words: "Lau" and "Tem/Teinu." According to historical accounts, the ancestors referred to this region as *Lauteinu* or *Lauteira*, where "Lau" means *tais* (traditional woven cloth), and "Teinu/Teira" means *lulik* (sacred or holy). Lautém

District has an area of approximately 1,814.60 km². Demographically, the district has a population of 94,161 people, with an average population density of 36.90 people/km². This data is presented in **Table 2.1**.

Table 2. 1 Area (ha) of Lautém District

Sub-District.	Area (ha)
Iliomar	30.090,90
Lautém	44.650,61
Lospalos	46.431,88
Luro	12.774,20
Tutuala	30.905,87
Lore	15.700,42

2.2 SOIL TYPE

The soil types in Lautém District have been classified according to the soil taxonomy (using the 1992 Soil Taxonomy key). This classification is made only up to the Great Group/Soil Type/Soil Group level. There are 7 soil orders, 16 suborders, and 22 great groups (soil types/soil groups).

Lautém District is dominated by the Inceptisols soil order, covering an area of 46,248 ha (25.52%) (Figure 2.2), which is spread across the entire study area (Figure 2.3). Next, the Mollisols order covers 41,400 ha (22.84%), the Vertisols order covers 38,953 ha (21.49%), the Entisols order covers 29,142 ha (16.08%), the Alfisols & Ultisols orders cover 23,270 ha (12.84%), the Alluvial order covers 1,573 ha (0.87%), and the Histosols order covers 670 ha (0.37%).

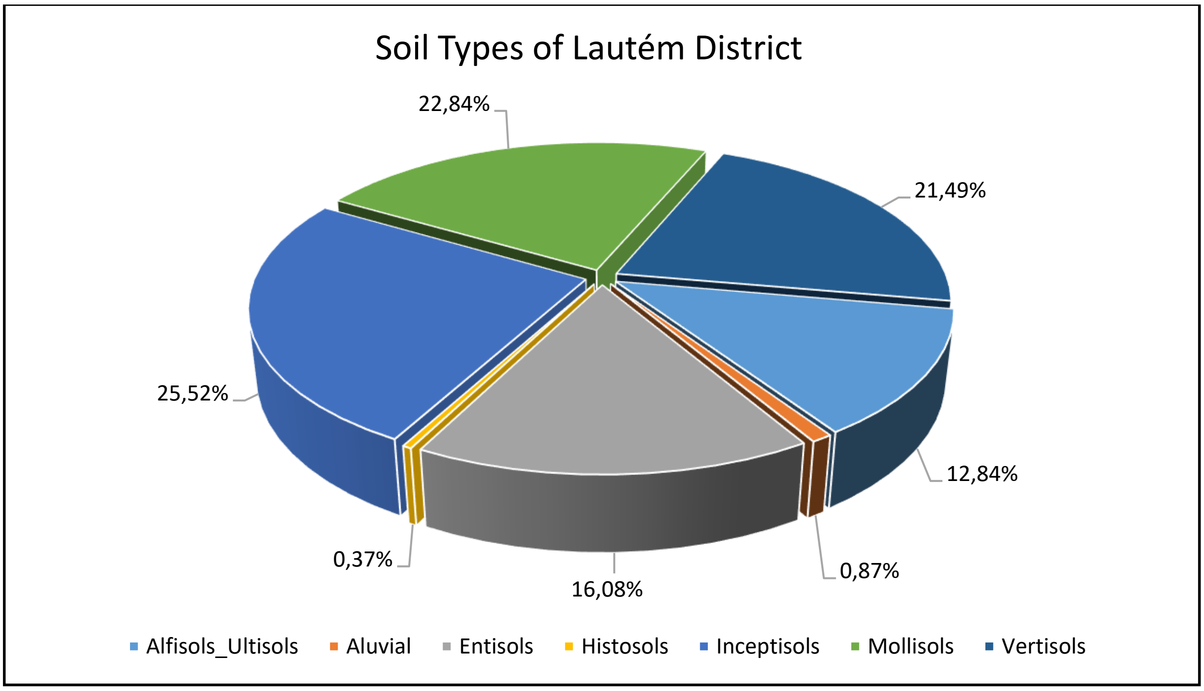
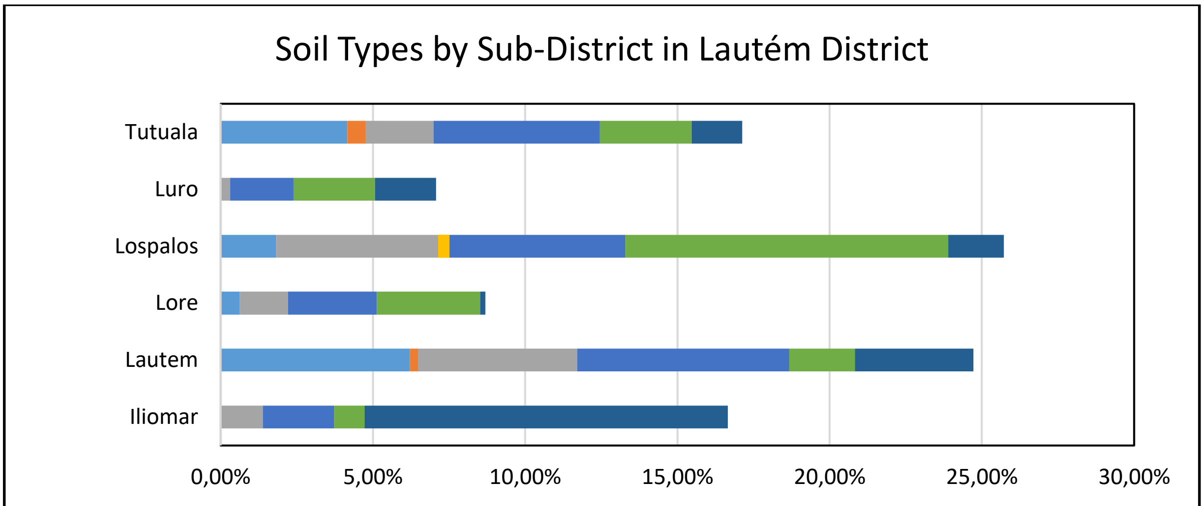


Figure 2. 2 Area Basen on Soil Types



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
Alfisols_Ultisols		6,22%	0,63%	1,83%		4,16%
Alluvial (Lake)		0,27%			0,00%	0,60%
Entisols	1,39%	5,23%	1,59%	5,32%	0,31%	2,24%
Histosols				0,37%		
Inceptisols	2,34%	6,96%	2,91%	5,77%	2,09%	5,45%
Mollisols	1,00%	2,15%	3,39%	10,61%	2,67%	3,02%
Vertisols	11,93%	3,90%	0,18%	1,83%	2,01%	1,66%

Figure 2. 3 Soil Types by Sub-District in Lautém District

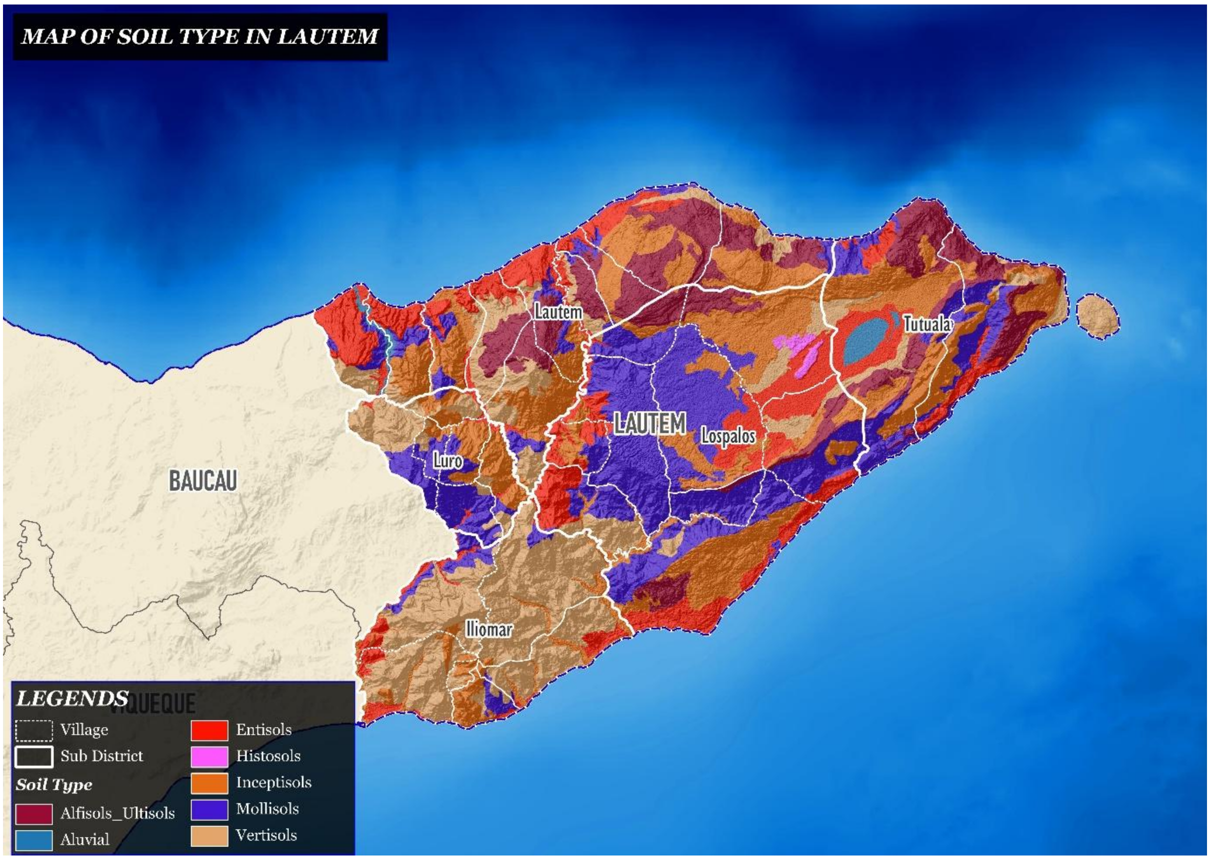


Figure 2. 4 Soil Types Map of Lautém District

2.3 GEOLOGICAL FORMATIONS

The distribution of geological formations in Lautém District shows a highly complex and significant geological diversity. Each geological formation contributes uniquely to the formation of soil characteristics and affects the potential and limitations of land for agricultural development. This analysis shows that the Surobeco Formation (34.64%) dominates the area, followed by the Aitutu Formation (15.86%), Bobonaro Formation (14.67%), Baucau Limestone (10.98%), Alluvial (7.70%), Cribas Formation (5.80%), Suai Formation (3.38%), Viqueque Formation (2.68%), Alluvial Deposits (1.57%), Maubisse Formation (1.44%), Borolalo Formation (1.04%), Cablaci Limestone (0.15%), and Aileu Formation (0.09%), as shown in **Figures 2.5, 2.6, and 2.7.**

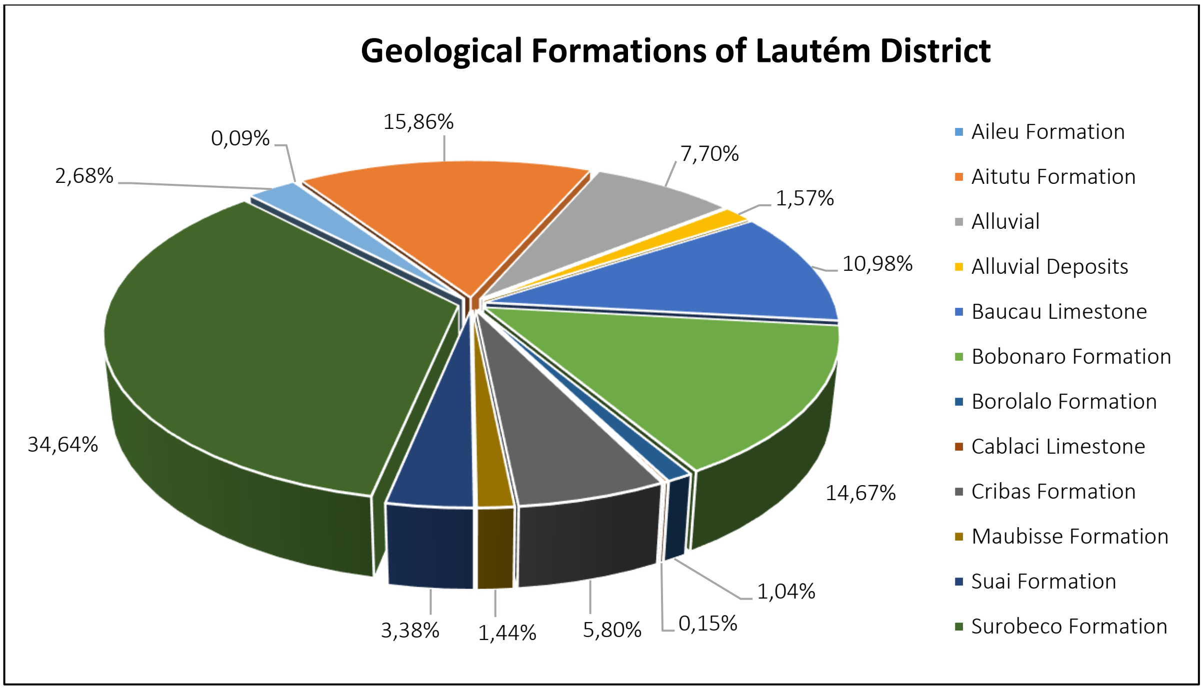


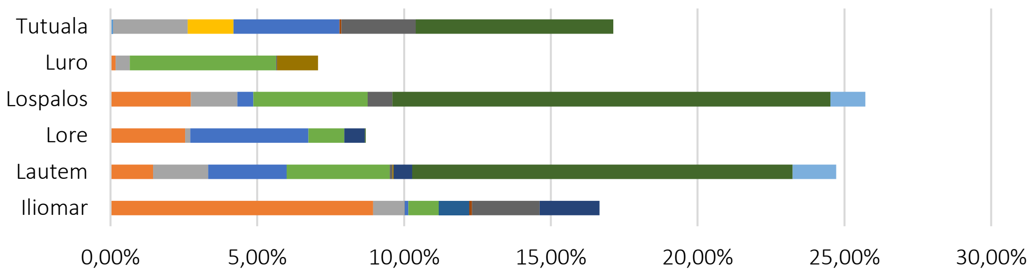
Figure 2. 5 Geological Formations in Lautém District

The Surobeco Formation, covering 34.64% of the area, has a lithology consisting of limestone. This rock is formed through sedimentary processes. This lithology can be used to determine land use potential, as the porosity of limestone can influence the soil's ability to retain water, which is relevant in irrigation planning.

The Aitutu Formation, covering 15.86% of the area, reflects a shallow marine sedimentary environment with lithologies such as calcilutite and marl. This lithology supports the formation of soils with high mineral content, which is important for supporting plant growth. Meanwhile, the Viqueque Formation (0.09%) contributes to soil formation in flat areas and gentle slopes, providing significant opportunities for integrated land development.

The Bobonaro Formation, covering 14.67% of the area, consists of fragments of rock blocks arranged randomly in a matrix of clayey shale. This formation is composed of a mixture of irregular and random materials of various sizes scattered without a clear pattern in the clay matrix.

Geological Formation Data by Sub-District in Lautém District



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
Aileu Formation	0,00%	0,00%	0,00%	0,00%	0,00%	0,09%
Aitutu Formation	8,95%	1,45%	2,54%	2,74%	0,17%	0,00%
Alluvial	1,06%	1,87%	0,17%	1,58%	0,48%	2,54%
Alluvial Deposits	0,01%	0,00%	0,00%	0,00%	0,00%	1,57%
Baucau Limestone	0,13%	2,67%	4,03%	0,54%	0,00%	3,61%
Bobonaro Formation	1,04%	3,52%	1,22%	3,90%	4,98%	0,00%
Borolalo Fornation	1,04%	0,00%	0,00%	0,00%	0,00%	0,00%
Cablaci Limestone	0,09%	0,00%	0,00%	0,00%	0,00%	0,06%
Cribas Formation	2,30%	0,09%	0,00%	0,84%	0,04%	2,54%
Maubisse Formation	0,00%	0,04%	0,00%	0,00%	1,40%	0,00%
Suai Formation	2,05%	0,63%	0,70%	0,00%	0,00%	0,00%
Surobeco Formation	0,00%	12,96%	0,03%	14,92%	0,00%	6,72%
Viqueque Formation	0,00%	1,49%	0,00%	1,19%	0,00%	0,00%

Figure 2. 6 Geological Formations by Sub-District in Lautém District

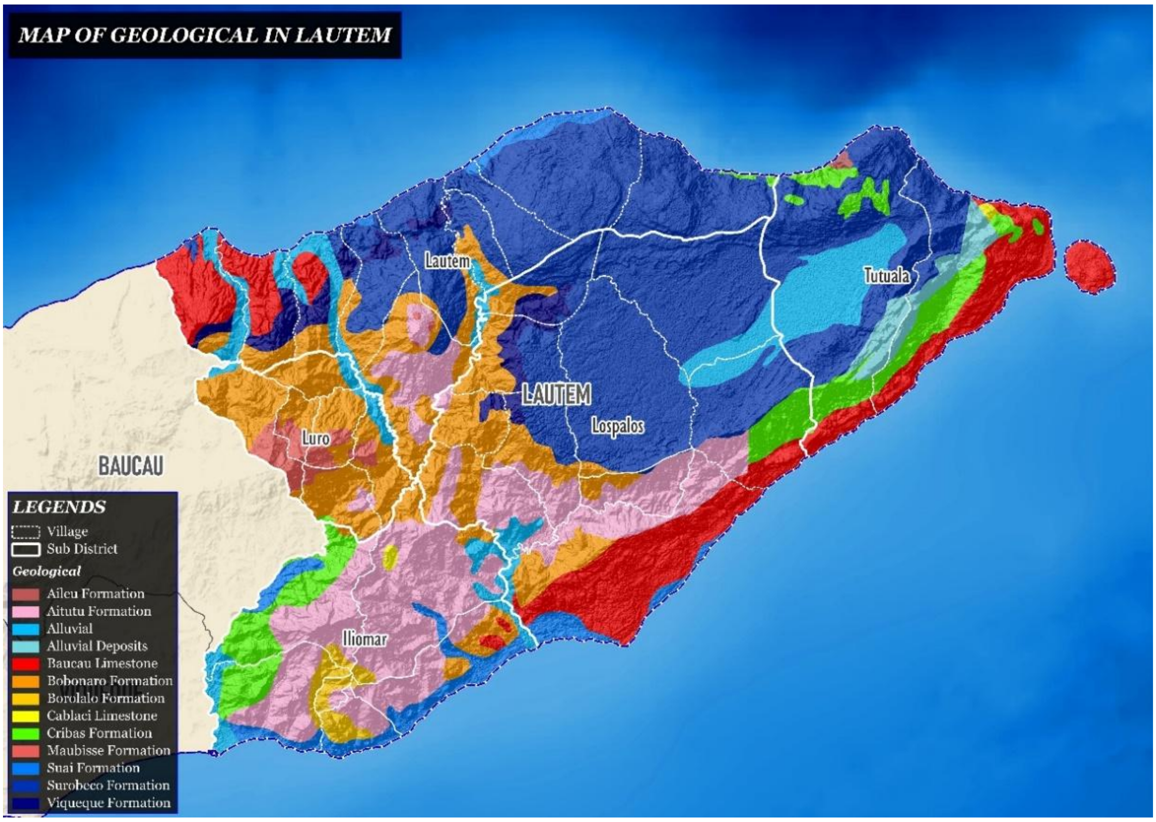


Figure 2. 7 Geological Map of Lautém District

The Baucau Limestone Formation (10.98%) also plays an important role in soil formation in the study area. With a lithology of reefal limesto ne, this formation supports good drainage but requires moisture management to optimize soil productivity. Similarly, the Cablaci Limestone Formation (0.15%) and Aileu Formation (0.09%) provide variations in soil characteristics that are relevant for agricultural management in areas with different environmental conditions.

The diversity of these geological formations forms an important basis for land suitability evaluation. Each formation has a direct influence on soil physical and chemical properties, such as texture, structure, water retention capacity, and susceptibility to erosion (Brady & Weil, 2017; Lal, 2019). As stated by Brady and Weil (2017), geological formations directly affect soil characteristics, which ultimately determine land use potential.

2.4 LAND USE

The area of Lautém District, Timor-Leste, has a diverse range of land uses that provide an important basis for the development of agricultural and forestry commodities. The predominant land use in Lautém District is forest land, covering 137,170 ha (75.68%), followed by uncultivated dryland areas covering 18,890 ha (10.42%), agricultural land covering 14,246 ha (7.86%), and river land covering 6,471 ha (3.57%). This is followed by rural settlement land covering 3,512 ha (1.94%) and residential and industrial land use covering 965 ha (0.53%). The data on land area based on land use types is presented in **Figure 2.8**.

The majority of land in Iliomar Sub-District consists of protected forests, covering 8.28%, humid-lowland forests with sparse vegetation covering 3.95%, humid-lowland forests with dense vegetation covering 2.18%, dryland for food crops covering 1.83%, rice fields areas covering 0.25%, while rivers occupy a small portion of 0.10%. Mangrove areas are less frequent in this region, covering 0.07%. Lautém Sub-District has an area of mixed dry-lowland forests, covering 12.57%. Additionally, there is lowland forest with single species covering 5.07%. Agricultural land in this sub-district includes rice fields covering 0.27% and dryland for food crops covering 1.48%. Protected forests also cover a significant area in this region (3.18%).

Lospalos Sub-District shows a higher diversity of land use. Protected forests dominate this area, covering 9.38%, followed by humid-lowland forests with sparse vegetation covering 7.60%. In addition, grasslands cover 3.01%. This sub-district also has settlements, including urban and larger rural settlements, covering 0.36%, and mixed villages and gardens covering 1.12%. Rice fields in Lospalos cover 0.54%, and grazing areas cover 2.47%.

Lore Sub-District is dominated by protected forests, covering 8.33%, followed by humid-lowland forests covering 0.37%. Luro Sub-District is dominated by lowland forests with single species, covering 2.25%. Agricultural land for dry food crops is relatively large, covering 1.73%, while rice fields cover 0.53%. This sub-district also has rural settlements covering 0.03%. Tutuala Sub-District has protected forests covering 17.13%, and rivers covering 2.29%. The rice field area in Tutuala is relatively smaller compared to other sub-districts, covering 0.14% **(Figure 2.10)**.

Overall, land use in Lautém District presents both challenges and significant opportunities. The dominance of forest land provides an opportunity to develop sustainable forest commodities, while the scattered agricultural land calls for strategies for sustainable intensification.

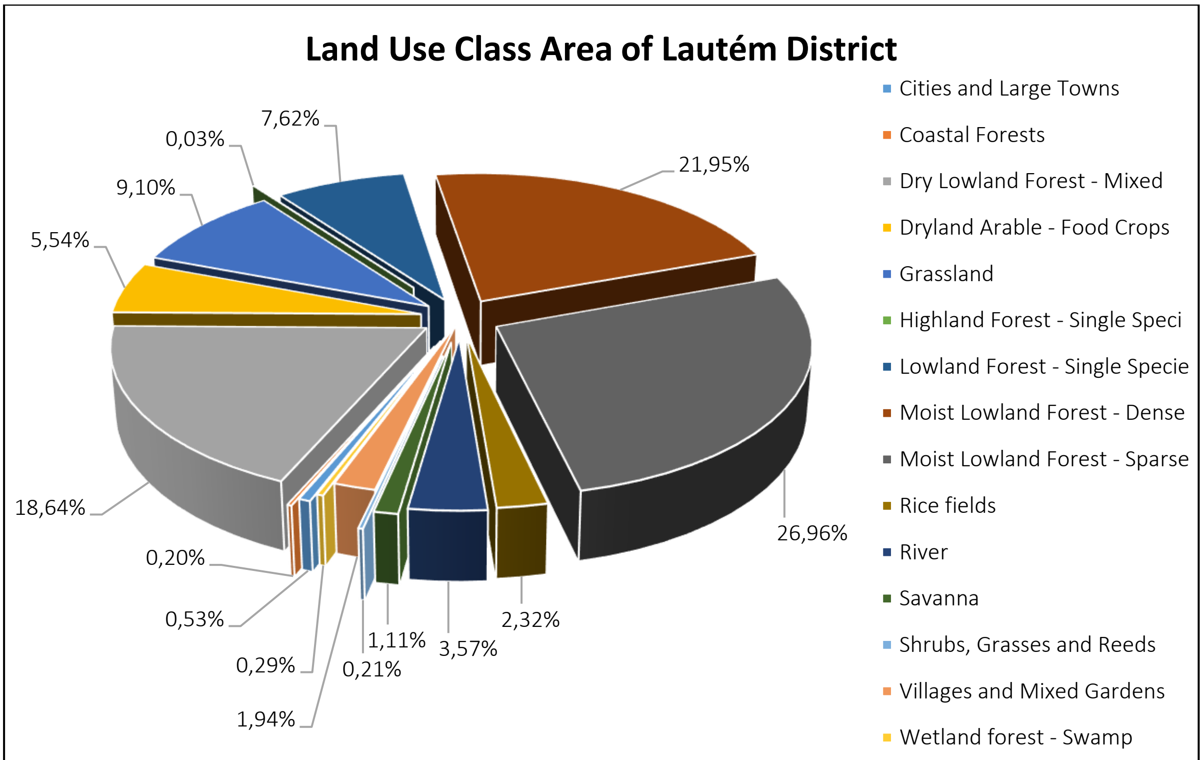
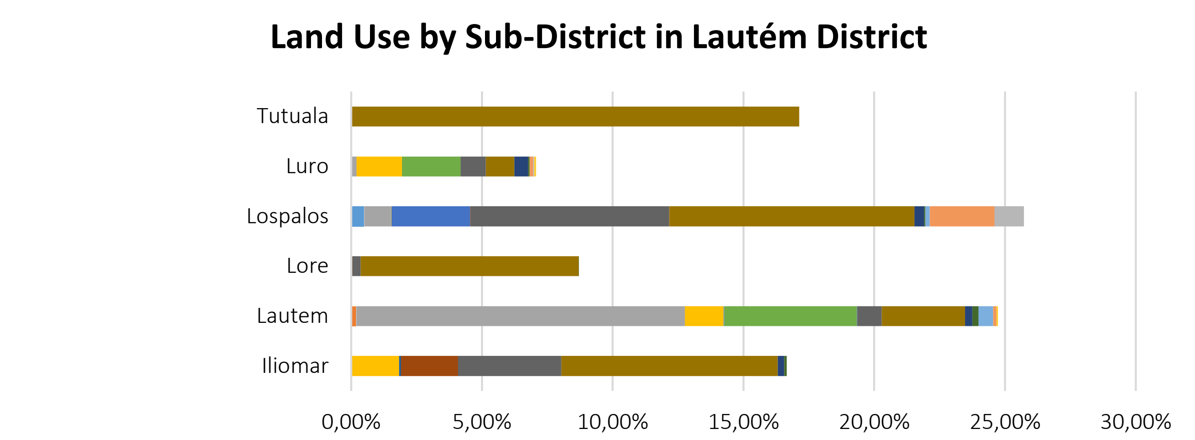


Figure 2. 8 Area of Each Land Use Type Class in Lautém District



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
Cities and Large Towns	0,00%	0,00%	0,00%	0,49%	0,00%	0,00%
Coastal Forests	0,00%	0,19%	0,00%	0,00%	0,00%	0,00%
Dry Lowland Forest - Mixed	0,00%	12,57%	0,00%	1,03%	0,20%	0,00%
Dryland Arable - Food Crops	1,83%	1,48%	0,00%	0,01%	1,73%	0,00%
Grassland	0,00%	0,02%	0,00%	3,01%	0,00%	0,00%
Lowland Forest - Single Specie	0,00%	5,07%	0,00%	0,00%	2,25%	0,00%
Mangrove	0,07%	0,01%	0,00%	0,00%	0,00%	0,00%
Moist Lowland Forest - Dense	2,18%	0,00%	0,05%	0,01%	0,00%	0,00%
Moist Lowland Forest - Sparse	3,95%	0,95%	0,32%	7,60%	0,96%	0,00%
Protected Forest	8,28%	3,18%	8,33%	9,38%	1,08%	17,13%
Rice fields	0,25%	0,27%	0,00%	0,36%	0,53%	0,00%
River	0,10%	0,24%	0,00%	0,04%	0,06%	0,00%
Savanna	0,00%	0,57%	0,00%	0,18%	0,00%	0,00%
Savanna/ Grazing area	0,00%	0,12%	0,00%	2,47%	0,14%	0,00%
Villages and Mixed Gardens	0,00%	0,00%	0,00%	1,12%	0,03%	0,00%
Wetland Arable	0,00%	0,06%	0,00%	0,00%	0,07%	0,00%

Figure 2. 9 Land Use by Sub-District in Lautém District

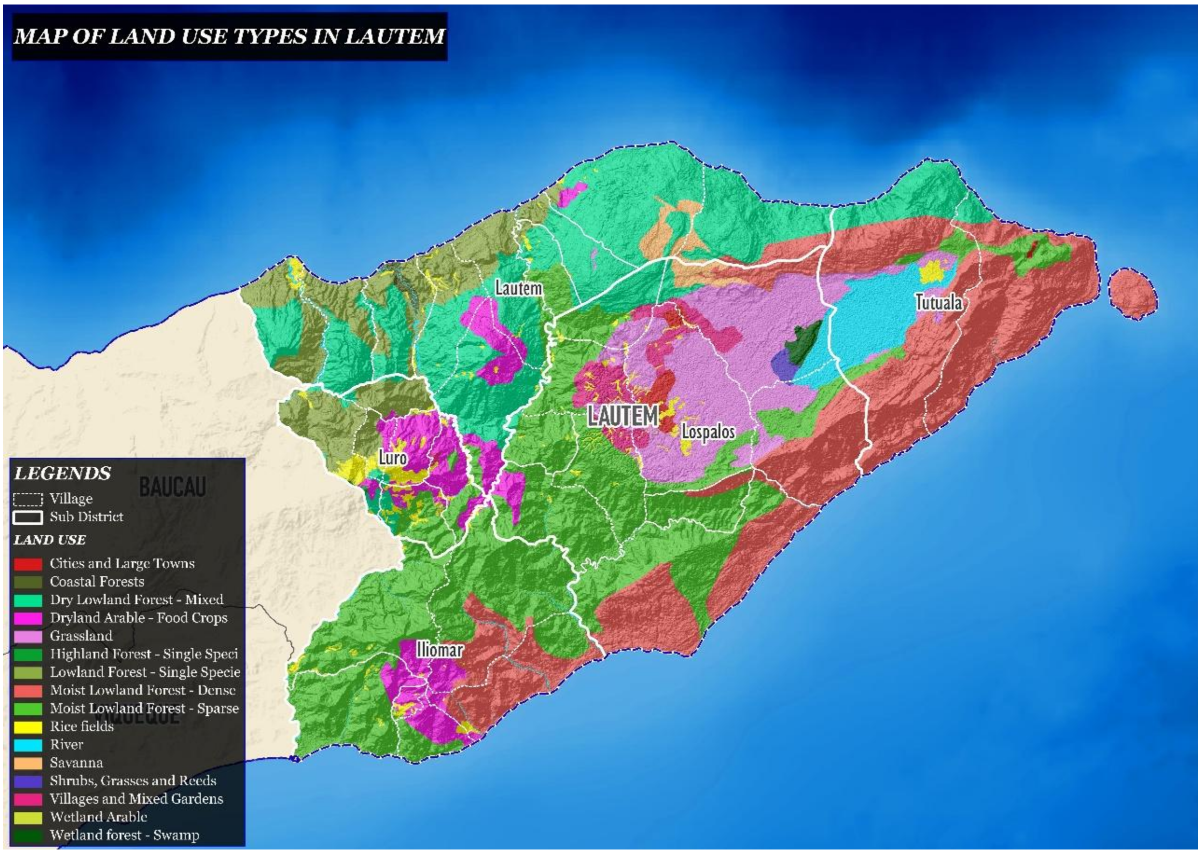


Figure 2. 10 Land Use Map of Lautém District

2.5 SLOPE GRADIENT

The distribution data of slope gradient classes in Lautém District provides an overview of the region's topography, which influences land management strategies, erosion risks, and natural resource conservation efforts. The slope categories consist of flat (0-8%), gentle (8-15%), moderately steep (15-25%), steep (25-45%), and very steep (>45%). This variation in slope reflects the complexity of the area, which plays a role in determining the potential and challenges of land management for agricultural purposes **(Figures 2.11 and 2.12)**.

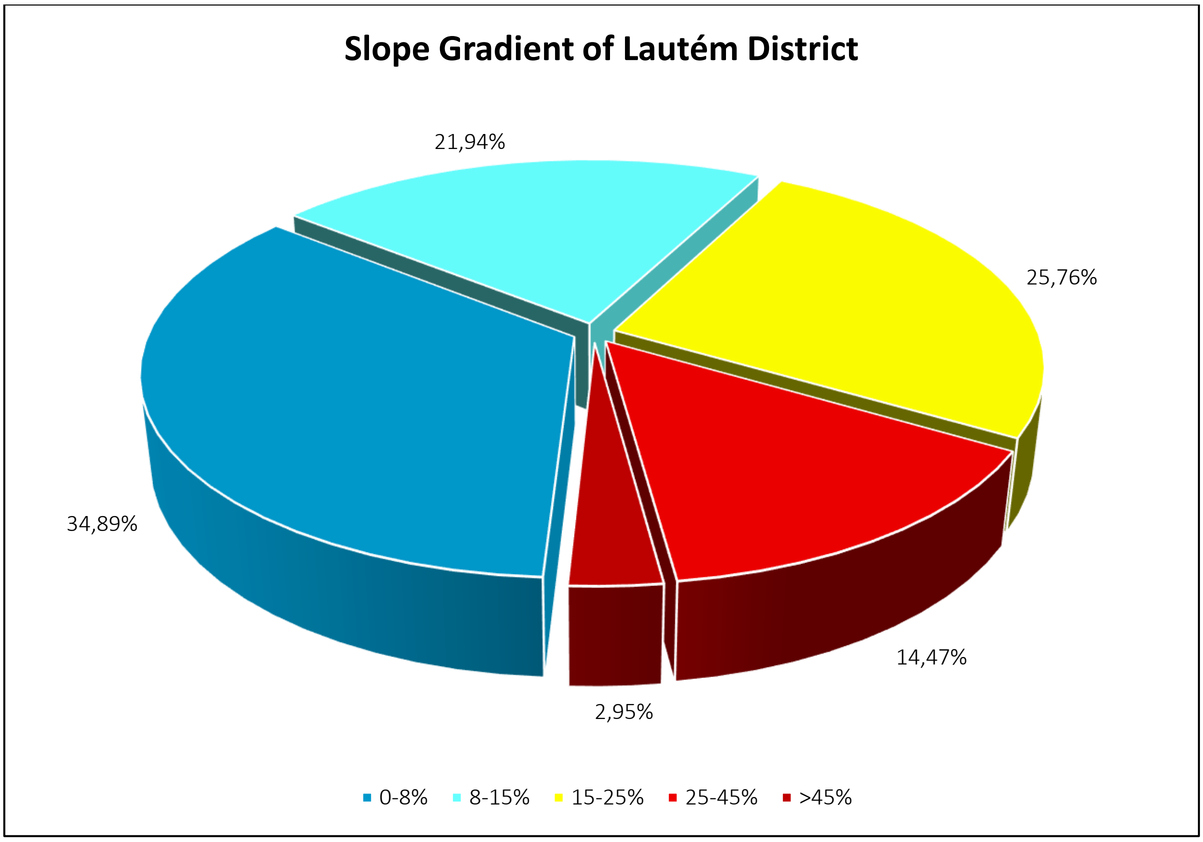
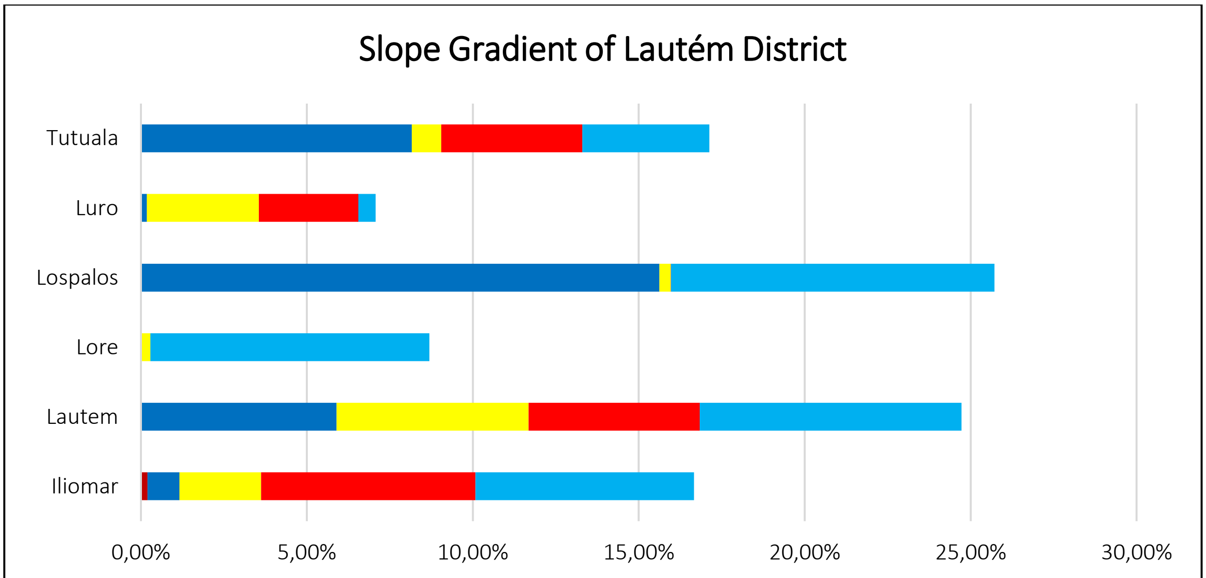


Figure 2. 11 Slope Gradient of Lautém District



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
>45%	0,20%	0,00%	0,00%	0,00%	0,03%	0,00%
0-8%	0,96%	5,90%	0,00%	15,62%	0,15%	8,16%
15-25%	2,46%	5,79%	0,29%	0,34%	3,38%	0,89%
25-45%	6,46%	5,16%	0,00%	0,01%	2,99%	4,25%
8-15%	6,58%	7,88%	8,41%	9,75%	0,52%	3,83%

Figure 2. 12 Slope Gradient by Sub-District in Lautém District

The flat slope class (0-8%) covers areas with low gradient and dominates much of the area in certain sub-districts, particularly in Lospalos, with an area of 310.54 km². This topography is ideal for intensive agricultural activities, settlement development, and infrastructure due to its high accessibility. Lautém Sub-District also shows a significant area in this category, covering 151.89 km², followed by Tutuala with 118.83 km². Iliomar and Luro Sub-Districts have smaller contributions, covering 40.85 km² and 10.33 km², respectively, but are still important as potential productive land. This region is highly relevant for development that requires soil stability.

The gentle slope class (8-15%) provides a balance between stability and land availability for productive activities. Lospalos again has a significant coverage of 130.60 km², showing that this region not only supports agriculture but also multifunctional use. Lautém contributes 115.17 km², while Luro and Iliomar cover 24.34 km² and 65.67 km², respectively. Tutuala, with a coverage of 61.69 km², adds to the complexity of land management in the area. This land offers flexibility for various uses, including settlements and other economic activities.

The moderately steep slope class (15-25%) stands out as a dominant area in Lospalos and Lautém, covering 129.00 km² and 116.45 km², respectively. This characteristic shows sufficient topographical stability for conservation-based agriculture. Iliomar covers 107.21 km², enhancing the diversity of land use in the area. Tutuala Sub-District, with 62.37 km², and Luro Sub-District, with 51.69 km², show potential for conservative management in productive activities. These areas, though steeper, can still be utilized with appropriate agricultural interventions.

The steep slope class (25-45%) reflects regions with higher topographical challenges. Iliomar Sub-District has the largest contribution in this class, covering 71.46 km², followed by Lautém with 58.42 km². Lospalos covers 50.54 km², while Tutuala and Luro cover 46.18 km² and 35.54 km², respectively. However, these regions have significant opportunities for conservation functions, such as reforestation, as well as natural resource management with an environmental focus.

The very steep slope class (>45%) has limitations in terms of direct utilization for development or intensive agriculture. However, this area is crucial for conservation and ecosystem protection functions. Iliomar has the largest coverage in this category, with 16.63 km², followed by Tutuala with 21.42 km² and Luro with 6.23 km². Lautém covers 6.06 km², while Lospalos has the smallest contribution at 3.04 km². This topographical characteristic emphasizes the importance of conservation-based management to minimize erosion and protect environmental sustainability.

The distribution of slope gradients serves as an important guide in location-based land management. Flat to gentle areas have potential for intensive agriculture and infrastructure, while steeper areas require soil conservation to prevent erosion. High erosion risks on steep slopes prioritize protective measures such as ground cover vegetation and terracing. This information is also relevant for selecting crops suitable for each slope class, supporting sustainable land management in Lautém District.

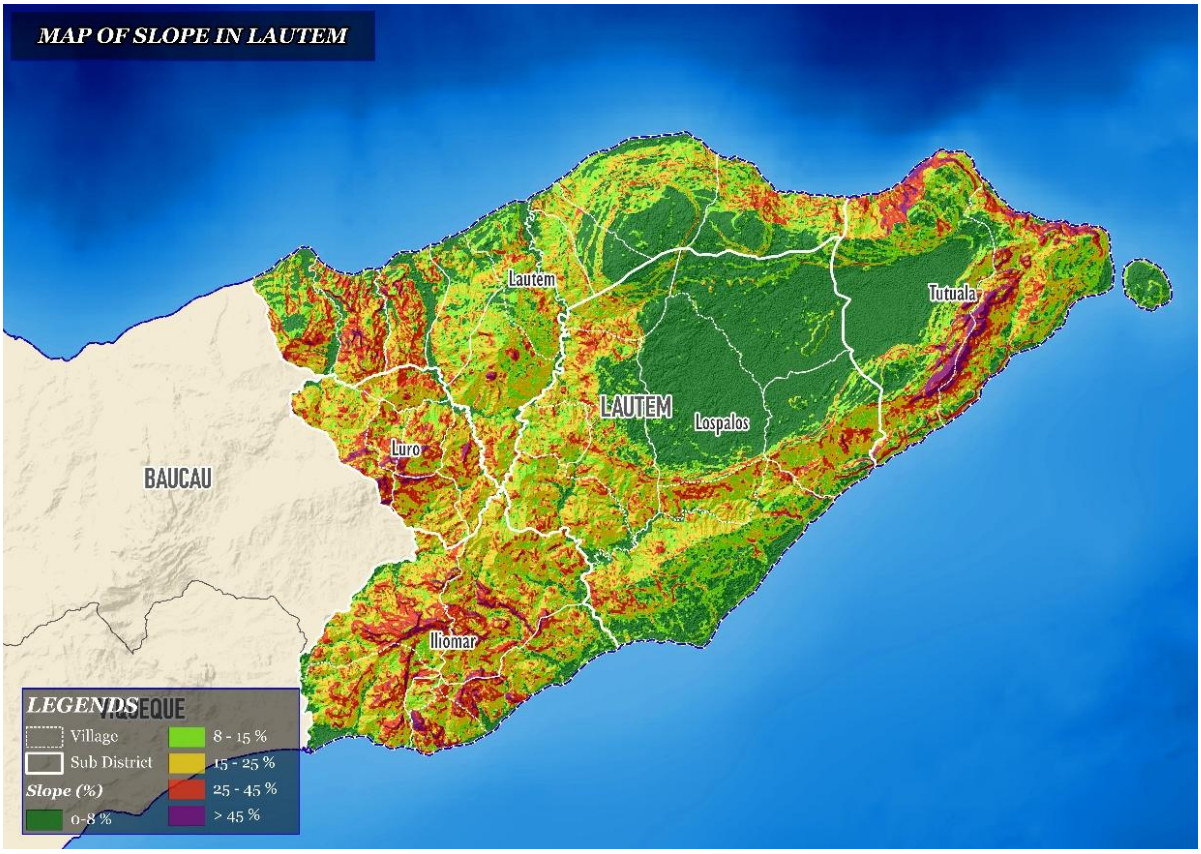


Figure 2. 13 Slope Gradient Map of Lautém District

2.6 AGROCLIMATE ZONES

The agroclimatic zones in Lautém District are classified based on elevation and rainfall patterns, as summarized in the Agriculture Land Use Information System (ALGIS), which refers to the theory of Fox (2003). The region is divided into six main agroclimatic zones, each with characteristics related to rainfall patterns, elevation, commodity types, and livestock potential. Information on the total area of each agroclimatic zone in Lautém District is presented in **Figure 2.14**, while the division of agroclimatic zones by sub-district is shown in **Figure 2.15**. This approach is relevant for natural resource management and serves as a scientific framework for sustainable land suitability evaluation (Molyneux *et al*., 2013; Williams *et al*., 2017).

Zone A covers an area of 142.85 km², which reflects 7.88% of the total area of Lautém District. The monomodal rainfall pattern in this zone provides opportunities for developing drought-resistant crops such as legumes and cassava. The largest distribution is in Lautém Sub-District, with an area of 125.74 km², equivalent to 6.94% of the total area of Lautém District. Tutuala Sub-District covers 9.47 km² (0.52%), followed by Luro with 4.16 km² (0.23%) and Lospalos with 3.48 km² (0.19%). Iliomar Sub-District has no area in this zone.

Zone B covers 637.10 km², or 35.15% of the total area of Lautém District. The stable monomodal rainfall pattern allows for the intensification of major food crops such as corn. Lautém Sub-District dominates with an area of 269.52 km², or 14.87% of the total area of Lautém District. Next, Lospalos covers 208.54 km² (11.50%), followed by Luro with 80.04 km² (4.42%) and Tutuala with 73.39 km² (4.05%). Iliomar Sub-District has the smallest contribution with 5.61 km² (0.31%).

Zone C covers 91.36 km², or 5.04% of the total area of Lautém District. This zone offers potential for horticultural management with the support of adaptive irrigation technology. Lautém Sub-District contributes the largest area with 52.92 km², followed by Luro with 19.94 km² (1.10%), Tutuala with 11.02 km² (0.38%), and Lospalos with 6.89 km² (0.61%). Iliomar Sub-District records only 0.58 km², or 0.03% of the total area of Lautém District.

Zone D covers an area of 44.97 km², or 2.48% of the total area of Lautém District. The bimodal rainfall pattern provides stability in water supply, supporting crop rotation systems. Iliomar Sub-District dominates with 20.21 km², or 1.11% of Lautém District. Tutuala records 13.72 km², or 0.76%, Luro contributes 7.49 km² (0.41%), and Lospalos covers 3.55 km² (0.20%). Lautém Sub-District has no area in this zone.

Zone E is the largest zone, covering 735.13 km², or 40.56% of the total area of Lautém District. The stability of bimodal rainfall in this zone provides optimal opportunities for agricultural intensification with major crops such as irrigated rice and corn. Lospalos Sub-District has the largest area, covering 340.65 km², or

18.79% of the total area of Lautém District. Iliomar contributes 210.59 km² (11.62%), followed by Tutuala with 167.33 km² (9.23%) and Luro with 16.56 km² (0.91%). Lautém Sub-District has no area in this zone.

Zone F covers 161.22 km², or 8.89% of the total area of Lautém District. The bimodal rainfall pattern in this zone supports vegetation conservation and adaptive crop management to improve environmental carrying capacity. Iliomar Sub-District records the largest area in this zone, covering 65.00 km², or 3.59% of Lautém District. Lospalos contributes 60.71 km² (3.35%), while Tutuala covers 35.51 km² (1.96%). Lautém and Luro Sub-Districts have no area in this zone.

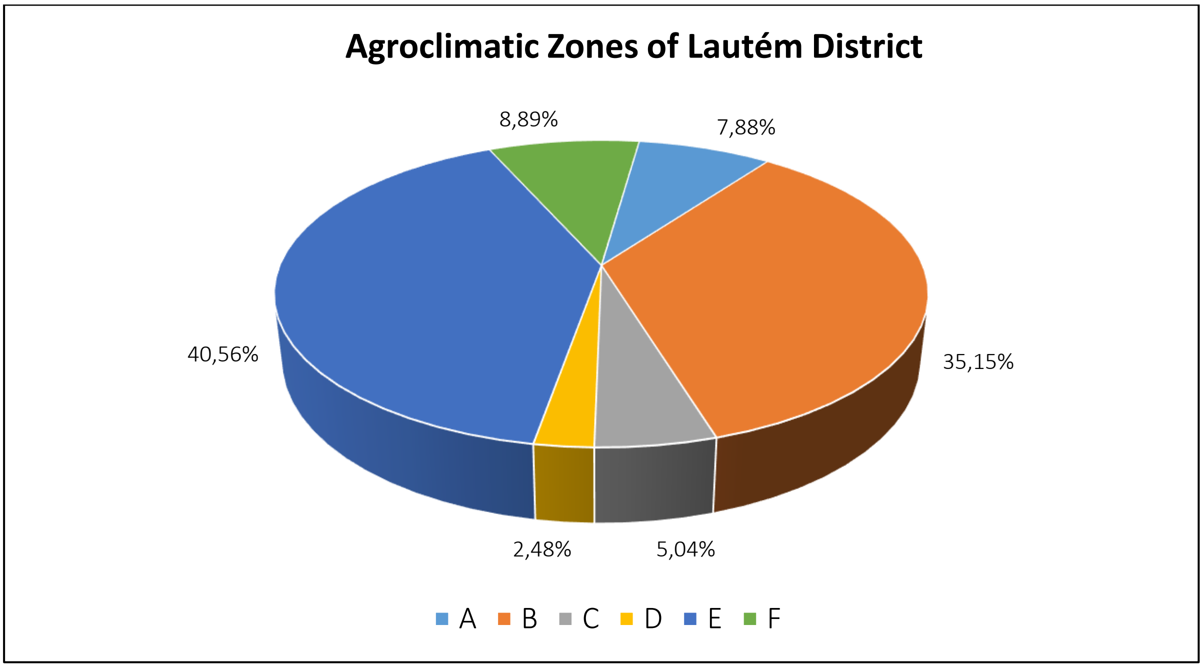
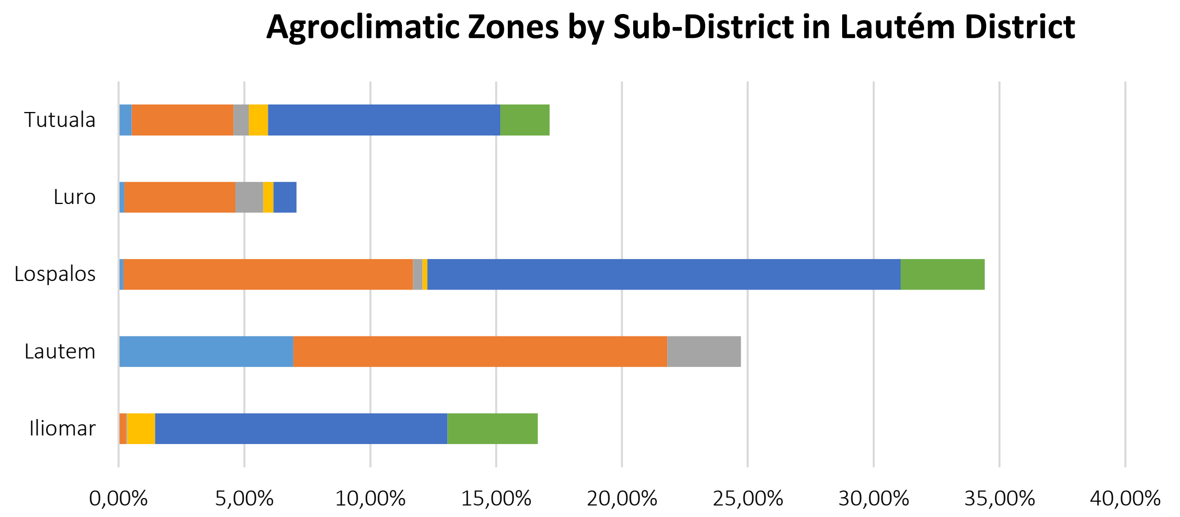


Figure 2. 14 Agroclimatic Zones of Lautém District



	Iliomar	Lautem	Lospalos	Luro	Tutuala
A	0,00%	6,94%	0,19%	0,23%	0,52%
B	0,31%	14,87%	11,50%	4,42%	4,05%
C	0,03%	2,92%	0,38%	1,10%	0,61%
D	1,11%	0,00%	0,20%	0,41%	0,76%
E	11,62%	0,00%	18,79%	0,91%	9,23%
F	3,59%	0,00%	3,35%	0,00%	1,96%

Figure 2. 15 Agroclimatic Zones by Sub-District in Lautém District

The agroclimatic zones identified in Lautém District provide a scientific framework for exploring land potential, including in the agriculture, livestock, and fisheries sectors. This information serves as the foundation for a more in-depth land suitability evaluation, involving the integration of thematic maps such as rainfall, geology, soil types, and land use, along with field observations and laboratory analyses. The results of this evaluation are then aligned with the growth requirements of various food crops, horticulture, plantations, forestry, and grazing areas. With this comprehensive approach, land resource management can be directed to support food security and the sustainable preservation of ecosystems. The agroclimatic zone map of Lautém District is presented in **Figure 2.16.**

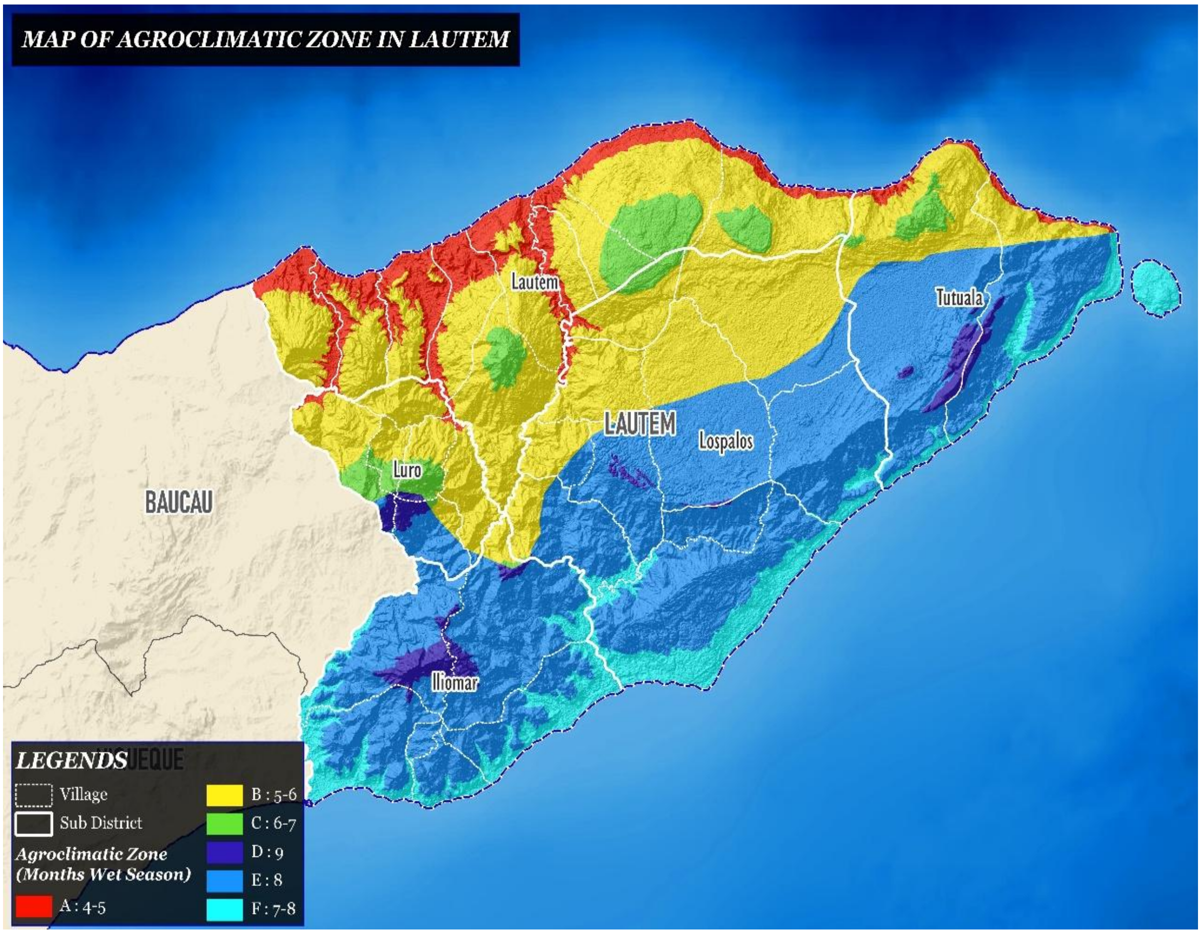


Figure 2.16 Agroclimatic Zone Map of Lautém District

2.7 EXISTING FIELD CONDITIONS

Field observations indicate that there are many idle lands (lands that are not being utilized) but with significant potential to be developed into productive land. In general, the vegetation growth in Lautém District shows fairly good fertility. However, there is still a lack of adequate technical cultural practices, such as plant spacing, crop combinations, and plant maintenance practices like pruning, weeding, and fertilization (organic, inorganic, or biological). The lack of these techniques is evident across all current land use types.

Figure 2.17 Condition of Mixed Garden Land in Lautém District
(Source: Researcher Documentation, 2025)

In Lospalos Sub-District, there are vast areas with potential to be developed as rainfed rice fields, livestock grazing areas, and centers for planting animal feed **(Figure 2.18)**. Animal manure from these areas can be used as organic fertilizer, providing additional benefits for agriculture in the region. The availability of this land serves as a fundamental asset in planning the development of integrated agricultural systems.

Figure 2.18 Grazing Area in Lospalos Sub-District
(Source: Researcher Documentation, 2025)

Suco Com has significant coastal tourism potential, opening opportunities for the development of agriculture-based agrotourism. The integration of the agriculture and tourism sectors in this region is expected to produce high-quality horticultural products and serve as an agricultural tourism education medium. This area also has several irrigation rice centers with a considerable land area **(Figure 2.19)**. This potential allows the region to contribute substantially to food availability for the district. However, its utilization and management are still not optimal, so land productivity has not reached its maximum capacity.

Figure 2. 19 Irrigated Rice Fields in Lautém Sub-District
(Source: Researcher Documentation, 2025)

The land in the surrounding area has a shallow solum, which only supports the growth of perennial vegetation. Therefore, a technical study is needed on the potential and availability of groundwater to support the sustainability of vegetation and drought-resistant agriculture. Areas without vegetation in Tutuala Sub-District also have potential to be developed as deer grazing fields. This aligns with the characteristics of the local ecosystem and offers economic opportunities based on wildlife, managed sustainably.

Field observations found a large area of former rice fields in Lore Sub-District, but this land remains abandoned and has not been optimally utilized **(Figure 2.20)**. The local government plans to restore the land's function as rice fields if the supporting infrastructure is available. The development of coffee and horticultural commodities has also been suggested by the local sub-district head as a strategy for revitalizing the area's economy. This land has the potential to be returned to productive rice fields, considering the soil conditions that are still supportive and the availability of spring water. With proper management, this land could increase agricultural production and support food security in the region.

Figure 2. 20 Former Rice Fields in Lore Sub-District
(Source: Researcher Documentation, 2025)

Industrial crop commodities such as teak, mahogany, and coconut dominate several areas of Lautém District. On the other hand, PAM Lautém has initiated a program to establish 1-hectare agricultural demonstration plots per village as part of the support for the national free lunch program. This initiative is expected to serve as a model for replication in other regions.

Lautém District faces several significant challenges in the agricultural sector, particularly difficult access to potential land due to extreme terrain, which hinders farmers and development. Additionally, the limited water supply in most areas makes agricultural activities dependent on rainfall, causing fluctuations in agricultural production, with land cultivation only possible during the rainy season. In general, land management practices applied by farmers in this district are still very minimal. Some indicators of this condition include:

1. Lack of adequate production inputs, such as superior seeds, resulting in low crop production.

2. Low use of fertilizers, both organic and inorganic, which impacts the quality and yield of crops.
3. Insufficient application of proper cultivation techniques, including plant spacing, effective planting methods, and poorly organized plant arrangements.
4. Minimal attention to plant care, pruning, and orchard cleanliness, all of which contribute to suboptimal production results.

The lack of efforts to improve these practices indicates the need for additional training and support for farmers to manage their land more effectively and increase agricultural yields.

2.8 *Chromolaena odorata*

Chromolaena odorata (Siam weed) is a flowering weed from the Asteraceae family that thrives in tropical and subtropical regions. This plant originates from North America, Mexico, and the Caribbean before spreading to various regions in Asia, Africa, and Australia due to human activity and natural phenomena (Day *et al.*, 2013). The spread of this plant, particularly in developing countries such as Timor-Leste, has a significant impact on both the ecosystem and the local economy.

Figure 2.21 *C. odorata* Plant
(Source: Researcher Documentation, 2025)

In tropical Asia, *C. odorata* is commonly found in lowland areas up to an elevation of 500 meters above sea level, particularly in open areas such as coconut and rubber plantations, home gardens, and grazing fields (Peniwiratri & Arbiwati, 2021). This plant has striking morphology, with a cylindrical, hairy stem, single serrated leaves, and composite flowers that are bluish in color when young and turn brown as they mature. In terms of its chemical composition, *C. odorata* contains active compounds such as flavonoids, tannins, alkaloids, saponins, and essential oils (Jamatia *et al*., 2024). The presence of these compounds gives this plant great potential as a raw material for traditional medicine to treat various diseases such as diabetes, burns, hypertension, and skin infections (Jamatia *et al*., 2024).

In Timor-Leste, *C. odorata* was first recorded in the 1980s and spread rapidly due to slash-and-burn practices and the dry tropical climate that supports its growth (Day *et al*., 2013). This plant has the ability to grow in various soil types, including marginal, less fertile land, with an optimal elevation between 500 and 2,000 meters above sea level (Westaway *et al*., 2018). Its rapid invasive growth reflects its exceptional ability to adapt to new environments, but it also poses a serious threat to the sustainability of productive land.

Figure 2. 22 Leaf and Flower Structure of *Chromolaena odorata*

The threat posed by *Chromolaena odorata* to various sectors, including agriculture, livestock, and ecosystems, is significant and requires serious attention. In the agricultural sector, *C. odorata* is known to form dense thickets that inhibit the growth of crops such as corn, coffee, and various horticultural plants. This weed aggressively invades land newly cleared for subsistence farming, which is the main livelihood source for rural communities. Its ability to absorb soil nutrients more rapidly than cultivated crops, due to a deep and extensively branched root system, creates detrimental nutrient competition. As a result, agricultural productivity decreases drastically, which ultimately affects local food security.

Negative impacts are also felt in the livestock sector. The leaves of *C. odorata* contain pyrrolizidine alkaloids, which are hepatotoxic and can cause liver damage in livestock such as cattle and goats if consumed in large amounts. Additionally, the spread of this weed in grazing fields reduces the availability of forage, decreases grazing capacity, and negatively impacts the economy of livestock farmers, particularly in areas like Timor-Leste.

Ecologically, the invasion of *C. odorata* disrupts ecosystem balance by dominating native vegetation and hindering the regeneration of trees and local plants that are important for biodiversity. The plant's dry biomass also increases the risk of land fires during the dry season, which is a serious threat in tropical regions. Repeated fires not only accelerate land degradation but also degrade environmental quality, including the loss of soil microbial content that plays a role in maintaining soil fertility. Thus, the presence of *C. odorata* threatens not only the agricultural and livestock sectors but also contributes to broader ecological issues.

Although often regarded as a harmful weed, *Chromolaena odorata* has several potential uses, particularly in agriculture, traditional medicine, and biomass management. As an indicator of soil fertility, it plays a role in increasing nutrient content, particularly phosphorus, in sandy soils when its biomass is mixed with manure. Research has shown that this combination supports the growth of crops such as shallots. Additionally, the high organic content in *C. odorata* makes it a potential material for producing environmentally friendly organic fertilizers.

In traditional medicine, this plant has long been used for its healing properties, including treating burns, managing diabetes, hypertension, and skin infections. Its flavonoid and phenolic compounds provide strong antioxidant, anti-inflammatory, and antibacterial properties. In various countries, its uses are diverse; 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.

Moreover, the biomass of *C. odorata* can be processed into high-quality vermicompost through biodegradation with the help of earthworms (*Eisenia fetida*). Research has shown that the resulting vermicompost contains significant macro-nutrients such as nitrogen, phosphorus, and potassium. This makes *C.*

odorata an alternative material with the potential to support sustainable agricultural practices through more efficient organic fertilizer production.

III. RESEARCH METHODS

This research was conducted in Lautém District, Timor-Leste, with the main objective of evaluating land suitability for the development of the agricultural sector. Data were collected through field surveys, laboratory analyses, and the use of geospatial information systems. The study was carried out from May to June 2025, with the main activities including direct field observations, soil sampling, interviews with local farmers, and Geographic Information System (GIS)-based mapping. All stages of the research were systematically organized to produce accurate information that can be used as a foundation for sustainable land management planning.

3.1 RESEARCH DESIGN

A. Methodological Approach

This research applies both quantitative and qualitative approaches. The quantitative approach aims to obtain numerical data, which is then statistically analyzed, while the qualitative approach is used to explore the experiences and perceptions of farmers regarding agricultural practices in the study area (Trigunasih, 2016). The research methods include field observations and laboratory analyses, including soil sampling and interviews with local communities.

B. Sample Point Determination

The research sample points were determined using a suco-based approach, considering various factors such as land use practices, agricultural traditions, and community dynamics. This approach was designed to represent homogeneous land units in the region, providing relevant results that accurately reflect the field conditions. Soil samples were randomly and compositely collected using a soil boring method. Each land unit was represented by a composite soil sample, collected at a depth of 0-30 cm for annual crops and 30-60 cm for perennial crops. Each soil sample weighed 1 kg and was sent for further analysis in the laboratory.

C. Soil Morphological Observations

During the soil sampling process, environmental conditions around the sample sites were observed and recorded using a soil observation form. The parameters observed include soil color, texture, structure, consistency, and drainage condition. For more in-depth analysis, ring samples were used to collect intact soil samples to measure bulk density (BD) and soil porosity, which are crucial for determining soil fertility levels and water retention capacity (Sukarman *et al.*, 2017).

D. Interviews and Questionnaires

In conjunction with the field survey, interviews and systematic questionnaire filling were conducted with farmers using purposive sampling or judgmental sampling methods, considering the respondents' experience and expertise in the agricultural sector (Sekaran & Bougie, 2013). The data collected included planting patterns, agricultural constraints, and the land use systems in place in the study area.

E. Land Suitability Evaluation

The results from the field survey, climate data, and laboratory analysis were then tabulated and evaluated using an agroecosystem land suitability rating system based on the criteria outlined by Ritung *et al.* (2011). The classification method used refers to the FAO (1976) system with a matching approach, where land characteristics are matched with the growth requirements of the plants being studied. The agricultural commodities evaluated in this research include food crops, horticulture, industrial crops, livestock feed, and grazing.

3.2 RESEARCH PROCEDURE

A. Literature Review

The literature review phase was conducted to gather relevant secondary data to support this research. The collected data includes administrative maps of the study area, geographical conditions, agricultural land area, and agricultural commodity production data. The climate data analyzed includes temperature, rainfall, dry months, and humidity. Additionally, various previous studies relevant to land suitability evaluation were also reviewed to strengthen the theoretical foundation of this research.

B. Homogeneous Land Unit (SLH) Analysis

The SLH analysis aims to determine the land unit as a basis for field observation planning. The homogeneous land units obtained are used as references for soil sampling and the preparation of land suitability maps. The SLH analysis process includes:

a. Interpretation of the Digital Elevation Model (DEM) map to analyze landforms and slope gradients.
b. Satellite image analysis to verify the actual land use patterns, especially in areas that have undergone land conversion, such as rice fields, settlements, and other infrastructure.
c. Utilization of supporting data, including slope gradient maps, geological maps, and soil type maps, to strengthen the delineation of land units.
d. Overlaying various thematic maps to generate homogeneous land units, which will serve as the basis for soil sampling.

C. Field Survey

The field survey is conducted to verify the suitability of the sample points against the actual conditions on the ground. If discrepancies are found between the results of land use analysis from satellite images and the field reality, adjustments are made by creating new sample points. The determination of sample points is based on satellite image analysis and the most current field conditions.

In addition, interviews with local farmers are conducted to obtain additional information about agricultural practices and the challenges faced in land management. Observations are made on various environmental factors affecting agricultural productivity, such as soil drainage, effective depth, erosion risks, flood risks, and surface rock content (Ritung *et al*., 2011).

Soil samples are collected using the boring method to a depth of 0-30 cm for annual crops and 30-60 cm for perennial crops. The collected soil samples are then further analyzed in the laboratory to identify the physical and chemical properties of the soil that influence land fertility. Climate data, such as temperature, rainfall, and humidity, are obtained from local climate observation stations and presented in tabular form. The results of the land suitability evaluation and the characteristics of each land unit are presented in **Table 3.1**, while the land suitability distribution map is shown in **Figure 3.1**

Table 3. 1 Relationship of Parameters, Data Collection, and Data Sources

No	Parameter	Data Collection		Data Source
		Primary	Secondary	
1	Temperature (tc)		√	Remote Sensing/Climatology Timor-Leste
2	Rainfall		√	Remote Sensing/Climatology Timor-Leste
3	Dry Months		√	Remote Sensing/Climatology Timor-Leste
4	Humidity		√	Remote Sensing/Climatology Timor-Leste
5	Drainage	√		Field Survey
6	Texture	√		Laboratory Results
7	Coarse Materials	√		Field Survey
8	Soil Depth	√		Field Survey
9	Cation Exchange Capacity (CEC)	√		Laboratory Results
10	Base Saturation	√		Laboratory Results
11	Soil pH	√		Laboratory Results
12	Organic Carbon (C-organic)	√		Laboratory Results
13	Total Nitrogen	√		Laboratory Results
14	Phosphorus (P_2O_5)	√		Laboratory Results
15	Pottasium (K_2O)	√		Laboratory Results
16	Salinity	√		Laboratory Results
17	Alkalinity	√		Laboratory Results
18	Slope Gradient	√		Field Survey
19	Erosion Hazard (eh)	√		Field Survey
20	Flood Hazard (fh)	√		Field Survey
21	Surface Rocks	√		Field Survey
22	Rock Outcrops	√		Field Survey

D. Soil Analysis in the Laboratory

The parameters used to determine the properties or characteristics of the soil samples analyzed in the laboratory are as follows:

a. Organic Carbon (C-organic) using the Walkley and Black method (%).
b. Total Nitrogen (N-total) using the Kjeldahl method (%).
c. Soil Texture using the pipette method.
d. Soil pH using the potentiometer method (H_2O 1:2.5).
e. Available Phosphorus (P-available) (ppm) and Available Potassium (K-available) (ppm) using the Bray-1 method if soil pH is below 7, and the Olsen method if soil pH is above 7, with unit conversion (mg/100 g).
f. Total Phosphorus (mg/100 g) and Total Potassium (mg/100 g) determined using the 25 % HCl method.
g. Total Zinc (ppm) determined using the DTPA extraction method and Available Zinc (ppm) determined using the HNO3-:HClO4 digestion method.
h. Total Sulfur (ppm) and Available Sulfur (ppm) determined using the spectrophotometric method.
i. Salinity (dS/m) using the potentiometer method (H_2O 1:2.5).
j. Cation Exchange Capacity (CEC) (cmol) and Base Saturation (BS) (%) using NH_4OAc 1N at pH 7 extraction
k. Soil Fertility Status determined based on the method (PPT, 1995).
l. Erosion Hazard using the Universal Soil Loss Equation (USLE).

E. Land Suitability Analysis

Field observations and laboratory analysis results were then tabulated into data on the characteristics/quality of the agroecosystem land. The agroecosystem land suitability analysis was conducted by matching (matching) the land characteristics/quality data with the growth requirements of crops such as bamboo, teak, mahogany, pine, coffee, cocoa, and coconut, thereby determining the land suitability class based on the criteria of Ritung *et al*. (2011). Land suitability classification was analyzed down to the land unit level.

The land suitability class is divided into actual and potential land suitability. The actual land suitability for each homogeneous land unit is determined by using the matching method between land characteristics/quality and the growth requirements of plants, without any improvement to limiting factors. Potential land suitability is obtained by considering inputs and management actions given to each homogeneous land unit, assuming that improvements have been made to the limiting factors.

F. Agricultural Commodity Development Planning

The planning of agricultural commodities is based on the evaluation of potential land suitability for the commodities being developed, with the highest land suitability for each crop as the main parameter. Other parameters include the primary land use for each homogeneous land unit and the feasibility of farming activities.

G. Land Use Recommendations

Land use recommendations are made at the land unit level, based on the results of the highest land suitability assessment followed by lower suitability levels, addressing limiting factors and improvement efforts for each homogeneous land unit across the 6 sub-districts in Lautém District. The creation of digital maps using geographic information systems (GIS) greatly facilitates the interpretation of information. The information includes agroecosystem land suitability, land use recommendations, and zoning of agricultural commodities. The creation of land suitability maps is based on homogeneous land units and the results of agroecosystem land suitability classification.

The results of the land suitability classification for each commodity are mapped for the crop commodity groups evaluated. The land suitability for crop commodities is presented in agricultural commodity zoning maps, while the land use planning is presented in land use recommendation maps. The research flowchart is presented in **Figure 3.1.**

H. Data Analysis Using Geographic Information System Technology

The land suitability information system consists of spatial data (homogeneous land unit maps) and attribute data (land suitability classes). The integration of these two components results in an information system using the QGIS 3.10 application, where the provided information includes the land suitability classes for food crops, horticulture, and plantations based on their suitability evaluation. The land suitability maps, along with the database and resource information based on the land data and suitability criteria, are designed to reflect the development of land use, such as crop varieties, cultivation technologies, and land management.

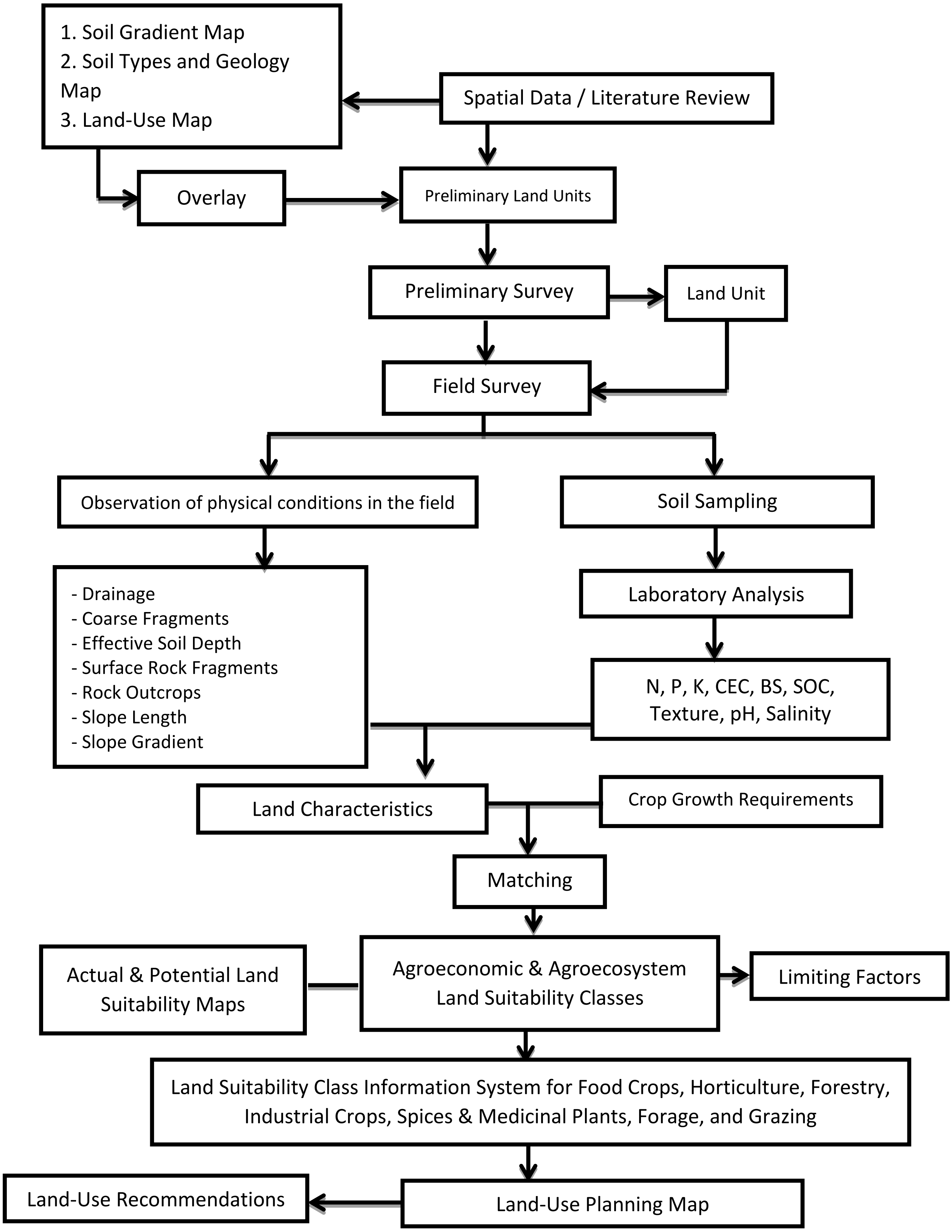


Figure 3. 1 Research Process Flowchart

The land use planning map is obtained based on the land suitability classification and commodity zoning. The land use planning map is a thematic digital map that provides information on land use recommendations for various crop commodities, horticulture, and plantations. The digital map is the result of converting primary and secondary data and information from raster and analog forms into digital data. The advantages of digital map data include the ease of correcting errors, its easy replication, long-term storage, and the ability to measure distance and area on-screen without the need for time-consuming and costly field measurements (Nugroho and Yarianto SBS, 2010). The resulting map is available in digital form as an analog or hard copy in *.jpeg format that can be printed, and a digital map in *.dbf or *.shp shape file format, which is integrated, easy to copy, and informative. The map's edge information displays the map name, followed by the creator's name, scale, and a legend box showing homogeneous land units, study area, soil type, slope, and land use, as well as the source, coordinates of latitude and longitude, and the datum system used.

3.3 GEOGRAPHIC INFORMATION SYSTEM (GIS) TECHNOLOGY

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

1. Collecting, storing, and displaying information based on spatial location.
2. Identifying locations in a particular area that meet the established criteria.
3. Exploring relationships between various datasets in a specific area.
4. Facilitating the selection and distribution of data for specific analytical application models that can predict the impact of alternatives for specific regional conditions.
5. Presenting specific areas graphically and numerically, both before and after analysis (Murai, 2006).

From various definitions of GIS, there are several common keywords, including: geographically referenced data, data analysis (spatial and attribute) to generate information, and specific purposes. Therefore, it can be concluded that, compared to other systems, GIS has the ability to handle data and information in a geographical perspective. This relevance is particularly noticeable in development planning because planning is carried out within a specific regional (area) context.

The term "Geographic" is part of spatial (spatial) terminology. These two terms are often used interchangeably, leading to the third term, "geospatial." These three terms have the same meaning in the context of GIS. The use of the word "Geographic" refers to issues related to the Earth: a two- or three-dimensional surface (Prahasta, 2005).

The term "Geographic Information" refers to information about places located on the Earth's surface, knowledge about the position of an object located on the Earth's surface, and information about the attributes present on the Earth's surface whose positions are given or known (Prahasta, 2005).

GIS is a formal system that consists of various physical resources related to objects found on the Earth's surface. Thus, GIS is also a type of software used for input, storage, manipulation, display, and output of geographic information and its attributes (Prahasta, 2005). Figure 3.2 shows the components that make up GIS.

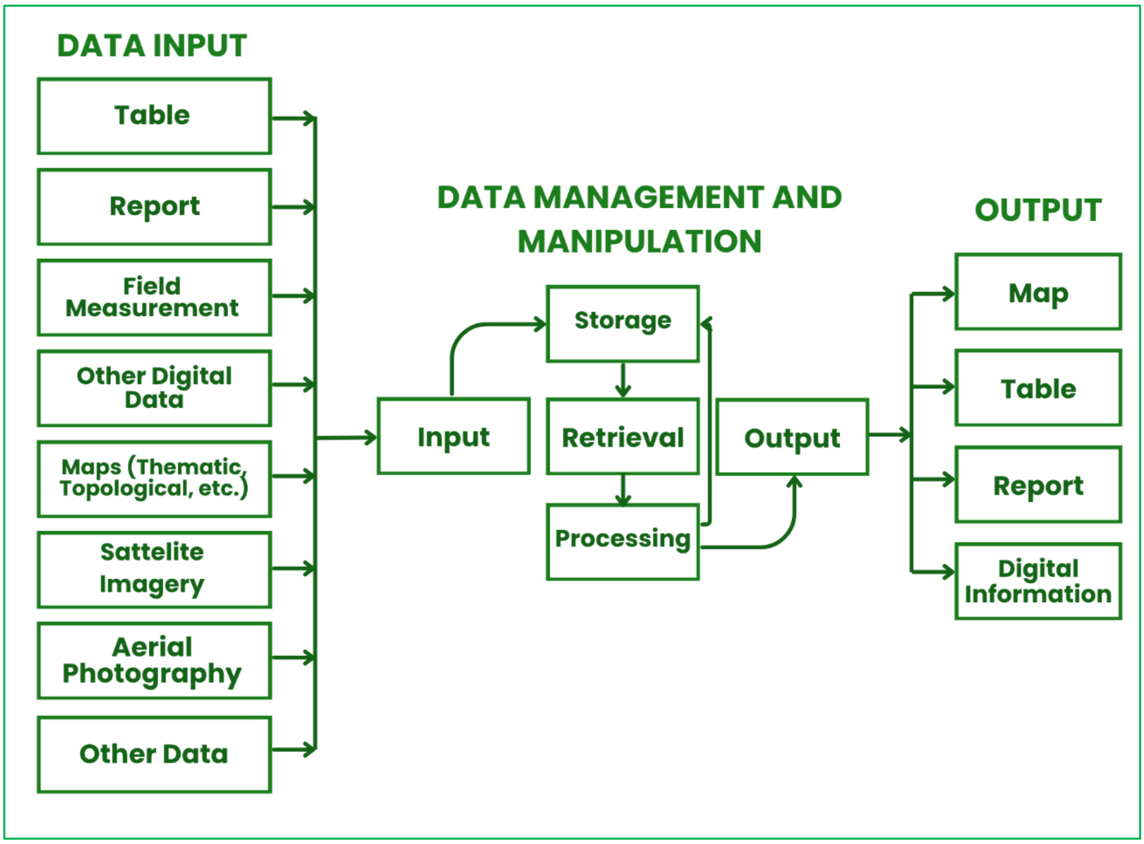


Figure 3. 2 Components Constituting of GIS
(Source: Prahasta, 2005)

Geographic Information Systems (GIS) can be applied in various fields. Some of the capabilities of this system are (Prahasta, 2005):

1. Cartographic Capability

With this capability, GIS users can effectively and efficiently create maps and technical drawings. The cartographic capability includes digitization, graphical visualization, interactive line manipulation, and plotting.

2. Data Management Capability

GIS has the ability to store, process, and manipulate geographically referenced data. This management capability also includes the ability to process attribute data, which involves storing and displaying specific attribute data related to specific geographic images.

3. Analysis Capability

The analysis capability is the ability to interpret and study the data and information that has been collected for specific purposes. This analytical capability includes: engineering function analysis, prediction/forecasting, computation operations, demographic analysis, socio-cultural analysis, analysis of various regions and districts, graphical and tabular presentation, overlay analysis, logical analysis, and selection analysis.

4. GIS and Multimedia Integration

The ability to integrate GIS and multimedia is one of the creative results of local innovation in Bali. By integrating multimedia systems with GIS, the final output from GIS analysis becomes more attractive and easier to read and understand.

A. GIS Process and Components

GIS essentially performs six processes (Prahasta, 2005):

1. Data Input

Before geographic data can be used in GIS, it must be converted into a digital format. This process is called digitization. In this study, digitization was performed on-screen, where data conversion can be carried out using scanning technology.

2. Data Transformation

The type of data used in GIS may need to be transformed or manipulated in several ways to fit the system. For example, there may be differences in scale, so before being entered and integrated, it must first be transformed into the same scale. This transformation can be temporary for display purposes or permanent for analysis processes.

3. *Editing*

The editing stage is the digital correction stage. Corrections can involve adding or removing arcs or features, such as editing excessive (overshoot) or missing (undershoot) arcs. Editing is also done to manually add arcs, such as creating polygons, lines, or points.

4. Data Management

Once spatial data is entered, the next process is the management of descriptive data, which includes annotation (adding text to coverage), labeling (adding information to the corresponding map), and attributing, where each labeled ID from the labeling process is given additional attributes that provide information about the polygons or arcs it represents.

5. *Query and Analysis*

A query in GIS is fundamentally an analysis process but done in a tabular format. Spatial analysis is the core analysis in GIS. GIS has many advantages in spatial analysis, but two important ones are:

a) Proximity Analysis

   A geographic analysis based on the distance between layers. Questions like "How many houses are located in a watershed?" In proximity analysis, GIS uses a process called buffering (creating a supporting layer around a layer at a certain distance) to determine the closeness of relationships between different parts.

b) Overlay Analysis

   The process of integrating data from different layers is called overlay. In simple terms, it is a visual operation, but this operation requires more than one layer to be physically merged. For example, overlay or spatial join is the integration of soil data, slope, vegetation, or land ownership with estimated tax values.

6. Visualization

For certain types of geographic operations, the best final output is represented in a map or graph. Maps are highly effective for storing and presenting geographic information.

B. GIS Components

In general, GIS operates based on the integration of five components: hardware, software, data, humans, and methods, which can be described as follows (Budianto, 2010):

1. Hardware

Hardware is the computer on which the GIS operates. Currently, GIS can work on a wide range of hardware types, from centralized server computers to desktop computers used as stand-alone or network configurations.

2. Software

GIS software provides the necessary functions and tools for creating, processing, analyzing, and displaying geographic information, such as:

a. Tools for data input and manipulation.
b. A database management system (DBMS)
c. Tools that support queries, analysis, and geographic visualization
d. A Graphical User Interface (GUI) for accessing tools.

3. Data

A crucial component in GIS is data. Fundamentally, GIS works with two types of geographic data models: vector data models and raster data models. The vector data model represents, places, and stores spatial data using points, lines, or curves, or polygons along with their attributes. The raster data model represents, places, and stores spatial data using a matrix structure or pixels that form a grid. Each pixel or cell has its own attribute, including its unique coordinates (at the corner of the grid, center, or other locations). The accuracy of this data model depends on the resolution or pixel size (grid cell) on the Earth's surface.

4. Humans

GIS technology would not be useful without the people who manage the system and develop plans that can be applied to real-world conditions. Similar to other information systems, GIS users range from technical specialists who design and maintain the system to end-users who use GIS to assist with their daily work.

5. Methods

A good GIS has consistency between a well-designed plan and real-world rules. The methods, models, and implementations vary for each problem.

C. Data Processing in GIS

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

1. Map Digitization

Map digitization is performed on the Indonesian Rupabumi map at a 1:25,000 scale, which will later serve as the basis for conducting surveys and digitizing maps, including data updating (map updating). The data conversion into a digital format is carried out layer by layer, complete with topology.

2. Data Import

Data import is carried out on satellite imagery that has a different format from the processing software. This format conversion process is a common first step in image processing tasks.

3. Image Geometry Correction

Geometry correction of the image is necessary so that satellite imagery has a reference or map coordinate system. This geometric correction can be done using three methods: image-to-image (corrected images), image-to-ground (where map coordinates are directly measured in the field using GPS), and image-to-map.

4. Digital Image Processing

Satellite imagery will be processed digitally to enhance the standard spatial resolution of 25 m in multispectral channels to 15 m in color. This process is carried out using a digital image fusion model (image data fusion) with the Brovey Transform method. This process is done for visual interpretation of planimetric objects, such as transportation networks, rivers, and other planimetric objects in the area.

5. Satellite Image Classification

Another process involves performing digital classification supported by a knowledge base approach for extracting spatial information on land use. This classification process will be conducted using supervised classification and filtering methods. The digital classification model, which has much more accurate grouping accuracy than human vision, will be accompanied by visual interpretation of data from the Brovey Transform. The digital classification model is performed by grouping recognized object arrangements as samples (sampling area). The image processing software will automatically search for pixel arrangements similar to the sample area, forming distinct classes. The classified image is then field-tested to detect deviations and identify questionable pixels. Deviations from the field test should not exceed 3% of the test area. The results of this clarification are used for updating the Indonesian Rupabumi map that has been digitized using the digital light table effect and raster-vector overlay methods.

6. Spatial Information Updating

Spatial information updates of the map will be carried out using the raster-vector overlay method, supported by the light table effect for interpretation and analysis of spatial information on land use. Spatial information updates for planimetric data will be conducted with raster-vector overlay. This integration model is performed using the digital image classification model and visual image interpretation for obtaining accurate updated spatial data. Specific objects that are considered important for mapping and not clearly visible on the image will be mapped using GPS during field survey work. The final result of the updating process is digital spatial data on land use in GIS.

7. Field Survey

Field surveys are conducted to correct errors in interpretation in the laboratory, to gather spatial information on objects that are questionable on the image, and to plot the positions of important objects that cannot be directly extracted from the image.

8. Re-interpretation and Editing

This work is carried out to correct the inaccurate interpretation of the image based on the results of the fieldwork. This work will be performed digitally in the laboratory to obtain final updated spatial information.

9. Edge Matching

Edge matching will be done to ensure that the consistency between adjacent map sheets can be formed. This process will be done digitally across all layers that are adjacent to each other.

10. Digital Cartography and Map Production

Cartographic processes will be fully digital for obtaining standard map layouts that comply with established cartographic principles. The cartographic model used in this work will refer to the thematic map cartographic model issued by the Geospatial Information Agency.

11. Database Structuring and Modeling

Database structuring will be performed on all spatial GIS data formats resulting from the work, which includes spatial data on land use, attribute data, and the generated thematic maps.

IV. LAND CHARACTERISTICS

4.1 TEMPERATURE

Air temperature is one of the main factors in land suitability evaluation, as it significantly affects the sustainability of natural resource management and regional development potential. In this study, the temperature distribution was analyzed using the integration of field measurement data and geospatial data based on the Digital Elevation Model (DEM) Shuttle Radar Topography Mission (SRTM) with the Braak formula approach: the higher the elevation, the lower the average air temperature (Ritung *et al.*, 2011). This analysis provides a comprehensive view of temperature variability that reflects the complexity of topography, elevation, and microclimates in Timor-Leste. The results of the air temperature analysis in Lautém District show that this area is dominated by warm to hot temperatures **(Figure 4.1)**.

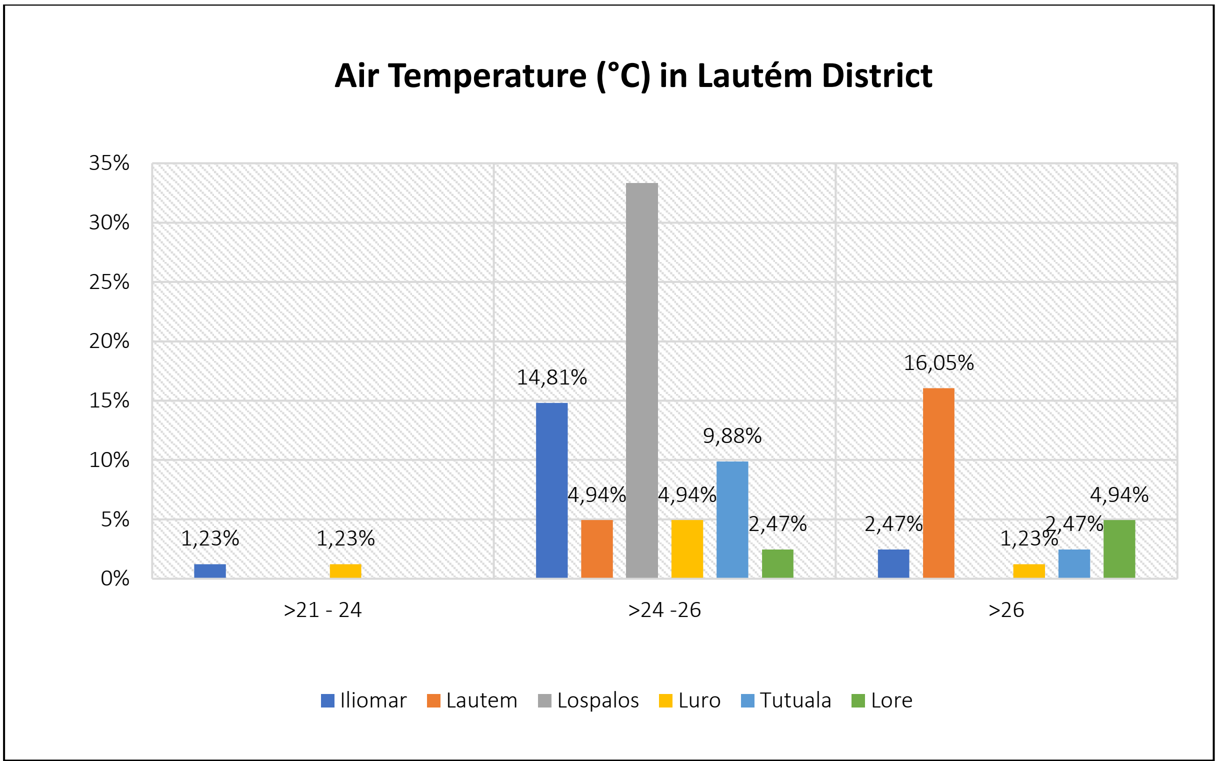


Figure 4.1 Temperature Data (°C) for Lautém District

Temperatures in the range of >24–26°C dominate the Lautém District. This indicates that most of the area is located in lowland regions, making it fall within the moderate temperature zone, which is ideal for the growth of various tropical plants. The distribution of this temperature is most significant in Lospalos Sub-

District, while the lowest proportion is found in Lautém and Luro Sub-Districts. Such temperature conditions are very beneficial for crop cultivation, as the combination of optimal temperatures and appropriate humidity makes this zone strategic for increasing agricultural production.

The next temperature range, >26°C, which has a large proportion, is spread across all sub-districts, with the highest intensity in Lautém Sub-District, followed by Lospalos Sub-District. The lowest distribution is found in Luro Sub-District. This condition can lead to an increase in evaporation rates and a higher water demand in the agricultural system, especially in areas like Lautém and Lospalos, which have a significant contribution to this category.

The lower temperature category, 21–24°C, is found to be limited to areas like Iliomar and Luro, which are regions with higher elevation and denser vegetation. This reflects that areas with relatively cool temperatures are very limited in this region. Lower temperatures generally correlate with elevation and land cover that is still natural, which helps reduce surface temperatures through shading and humidity effects.

4.2 RAINFALL

Based on field observations of rainfall, the region shows characteristics of variable rainfall with two main groups based on the annual rainfall range distributed across the area **(Figure 4.2).** The rainfall category of 1000–1500 mm/year dominates the entire Lautém District, particularly in Lospalos and followed by Lautém. These areas are generally coastal or lowland regions that are more exposed to the effects of dry winds and tropical air circulation, which does not always bring high humidity throughout the year. Additionally, the uneven presence of monsoon winds can cause some areas to experience consistently lower rainfall (Saragih *et al*., 2025).

Meanwhile, the rainfall category of 1500–2000 mm/year has the largest concentration in Iliomar Sub-District and a smaller portion in Tutuala Sub-District. These areas tend to have higher elevation and are within the rainfall catchment zone of moist winds coming from the east or southeast, which generate higher precipitation through orographic processes. This polarization of rainfall aligns with the agroclimatic zoning concept developed by Oldeman (1975), which states that the amount and distribution of annual rainfall are crucial in determining planting patterns, the types of commodities that can be cultivated, and the agronomic technologies needed to support the success of the agricultural system.

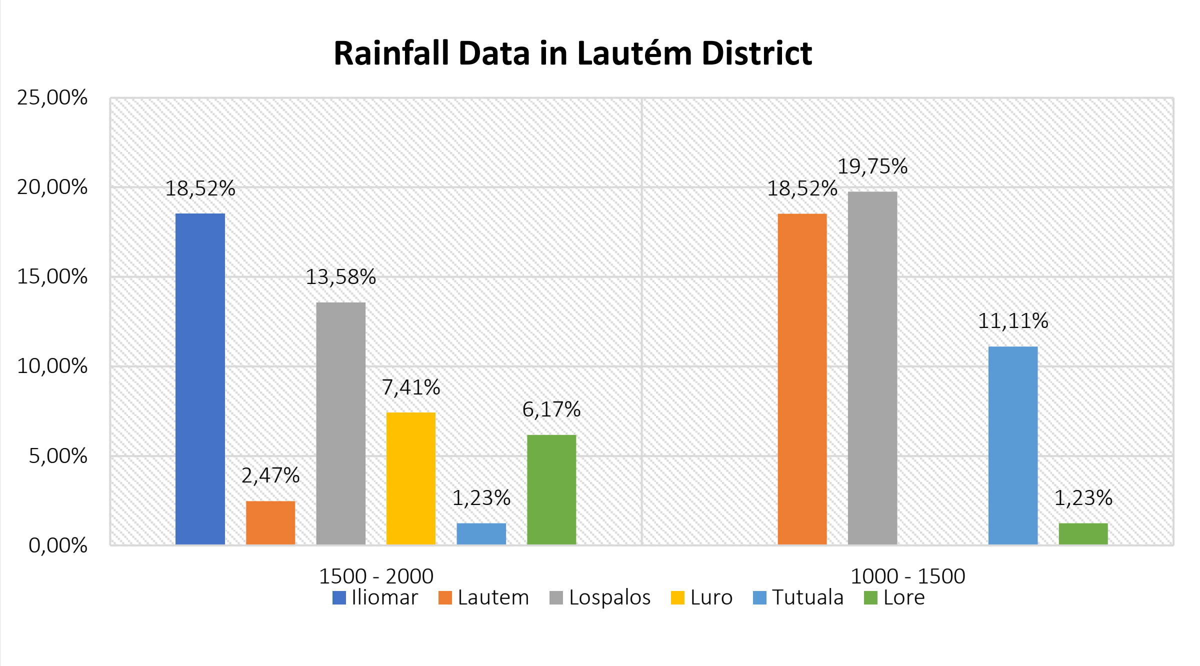


Figure 4.2 Rainfall Data in Lautém District

Based on this approach, areas with high rainfall generally fall into zones with two main planting seasons for food commodities and are suitable for cultivating crops that require a stable water supply, such as irrigated rice and horticultural commodities. However, these areas also carry potential risks, such as erosion, waterlogging, and land degradation, which necessitate the implementation of an integrated soil and water conservation system, including the creation of terraces, planting cover crops, and developing micro-drainage systems. In contrast, areas with lower rainfall tend to have more limited planting seasons, requiring a more adaptive agricultural approach to the climatic conditions.

4.3 DRY MONTHS

The distribution of dry months in Lautém District shows significant spatial variation across the sub-districts **(Figure 4.3)**. Based on the analysis, the 3–4 dry months category is the most dominant in this region, particularly in Lospalos Sub-District, followed by Iliomar and Tutuala, with smaller portions found in Lore and Luro. This condition indicates that these areas experience a relatively short dry season, allowing for the implementation of two planting seasons with the support of adequate irrigation systems. The next dry month range with a large proportion, after the dominant category, is the >6 months category, with the largest concentration in Lautém Sub-District, followed by Lospalos Sub-District, and the lowest distribution in Tutuala Sub-District.

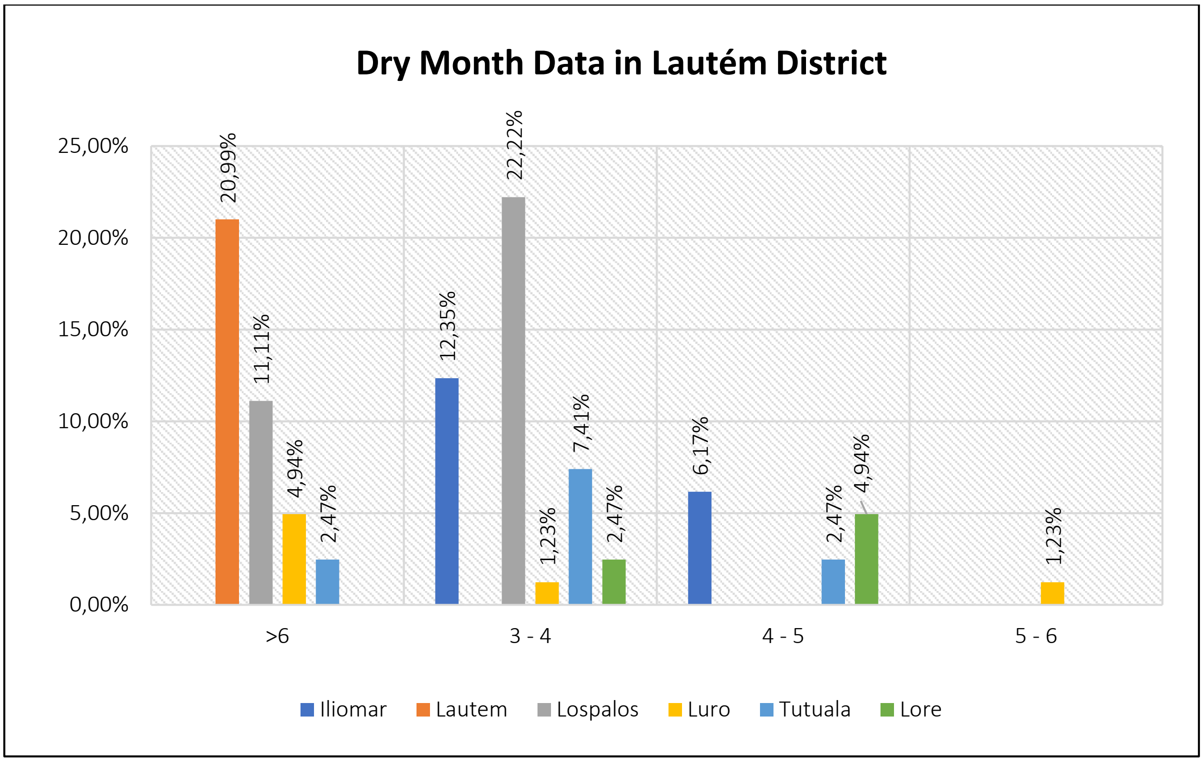


Figure 4.3 Dry Month Graph for Lautém District

The category with a dry season duration of 4–5 months is most dominantly distributed in the Lore Sub-District. Meanwhile, the 5–6 months dry season category is relatively small and is only found in the Luro Sub-District. This condition reflects a transition zone that requires a dynamic management approach in terms of crop selection and cultivation technology. The distribution of dry months is consistent with agroecological principles, which state that the duration and intensity of the dry season are critical factors in determining a sustainable agricultural production system. Shorter dry seasons offer opportunities for production intensification, particularly for food crops that require a stable water supply. Conversely, areas with prolonged dry seasons demand crop diversification and agroforestry system integration to enhance ecosystem resilience and reduce the risk of crop failure.

4.4 ELEVATION

The distribution of elevation in Lautém District shows a varied pattern, with dominance in the 0–400 meters above sea level (m asl) class **(Figure 4.4).** This class is primarily found in Lospalos Sub-District, followed by Lautém Sub-District, indicating that most of the administrative area is in the lowland to foothill zones. This elevation zone is ecologically associated with relatively high air temperatures, easier accessibility, and higher human activity intensity, including settlements and agriculture. This condition aligns with the findings of Molyneux *et al.* (2012), which showed that lowland areas in Timor-Leste generally become population centers and are vulnerable to land degradation if not managed with conservation practices (Molyneux *et al*., 2012).

In the 400-700 m asl elevation category, Lospalos Sub-District dominates, followed by Luro and Iliomar Sub-Districts. This area reflects the presence of medium-level plains or slopes that are still suitable for agricultural activities.

In contrast, the >700 m asl category, found only in Iliomar Sub-District, represents the smallest elevation class but plays a vital role in soil and water resources. In the montane zone, the rate of water infiltration is usually higher due to relatively higher rainfall and lower temperatures, making this area essential as a recharge zone that supports water availability in the lowlands. Additionally, the soil condition at higher elevations tends to have more organic material due to slow decomposition, which can potentially increase soil fertility for crops that are adapted to cooler temperatures. This supports the view of BirdLife International (2018), which states that, although limited in area, the montane areas >700 m asl in Lautém play a crucial role in water regulation and soil fertility for agriculture in the areas below them (BirdLife International, 2018).

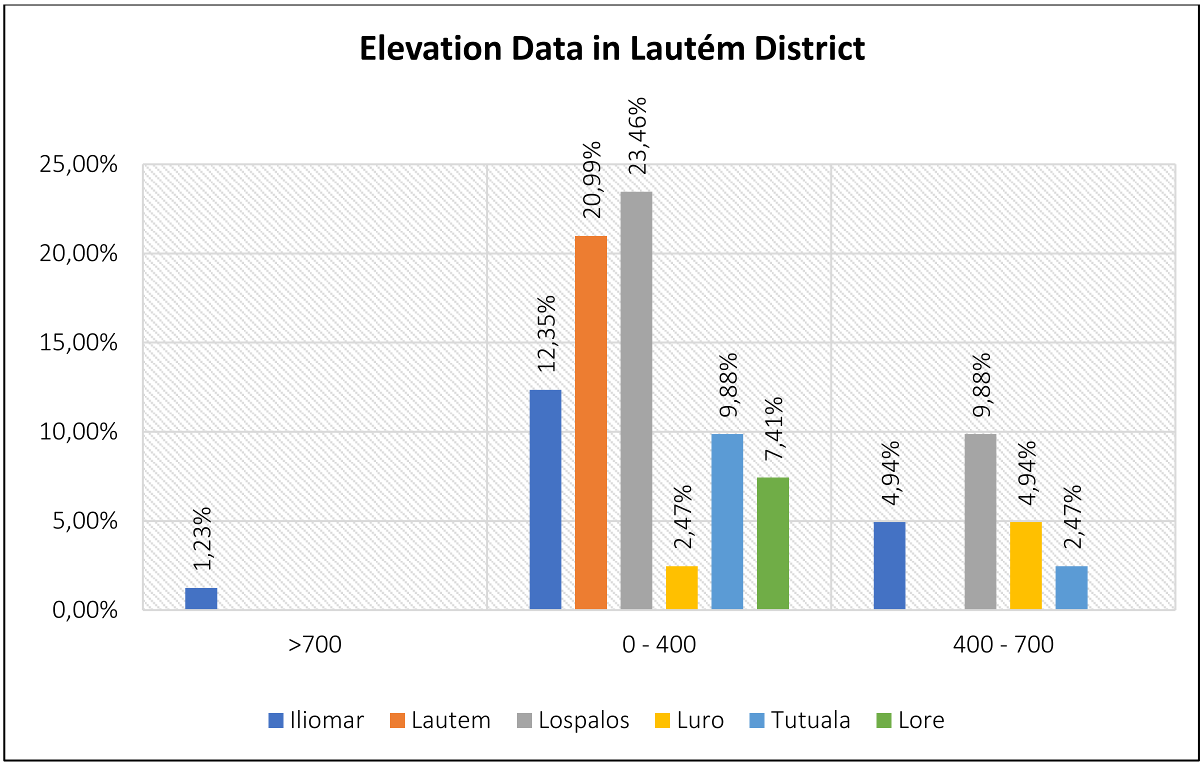


Figure 4.4 Elevation Data in Lautém District

4.5 DRAINAGE

Based on the percentage data on drainage conditions in Lautém District **(Figure 4.5)**, there is significant variation in dominance across the sub-districts in each drainage category. In the Excessively Drained category, dominance is only shown by Luro Sub-District, although the proportion of this category is generally relatively low. This is due to the dominance of natural forest land use, which ecologically has dense vegetation cover and deep root systems. This vegetation plays an important role in increasing the infiltration rate and reducing surface runoff, thus supporting the formation of rapid drainage conditions.

In the Well Drained category, the highest dominance is recorded in Lautém Sub-District, where most of the area is dominated by unused dry land and forested areas. Dry land with a high proportion of sand fraction has higher porosity and permeability, which accelerates water infiltration into the soil and reduces surface water accumulation. Additionally, because of minimal disruption from anthropogenic activities, the soil structure in these areas tends to be stable, supporting optimal infiltration processes. Well-drained soil is essential for supporting plant growth, particularly in providing adequate aeration for the roots to efficiently absorb nutrients (Wirosoedarmo *et al*., 2011).

The Moderately Drained category shows relatively even distribution across the sub-districts, with the highest dominance in Lospalos Sub-District. Moderately drained conditions indicate the ability of the soil to drain water that is between the well-drained and poorly drained categories. This condition is generally found in soils with fine to medium texture, which have medium porosity, and in areas with low slopes and less dense vegetation cover.

In the Somewhat Poorly Drained category, the highest dominance is found in Lautém Sub-District. This area is dominated by Inceptisols, Entisols, and Alfisols–Ultisols soils, which generally have underdeveloped soil structures and low infiltration capacity (Septiaji *et al.*, 2024). These characteristics cause water to remain on the surface and slow down the flow rate, resulting in somewhat poor drainage conditions.

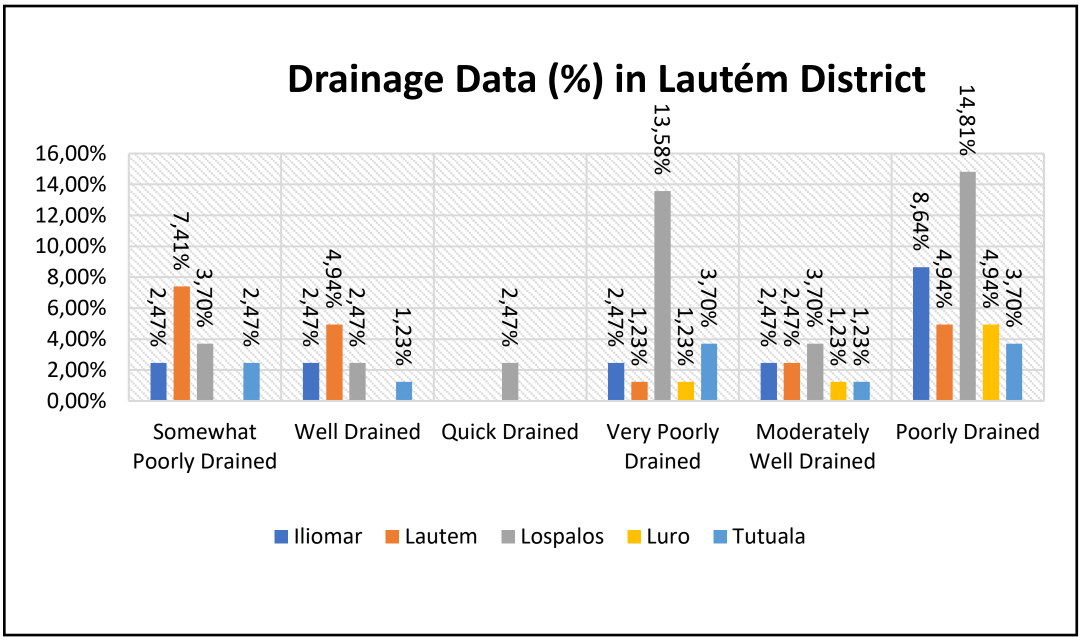


Figure 4.5 Drainage Data (%) in Lautém District

Next, in the Poorly Drained and Extremely Poorly Drained categories, Lospalos Sub-District again shows the highest dominance. This condition is closely related to land use as grazing areas, which, based on field observations, generally have shallow soil solum, locations near rivers, and clayey soil texture. The high clay fraction causes smaller soil pores, leading to slower water drainage, thereby worsening drainage conditions. In contrast, soils with a dominant sand fraction generally have faster drainage capabilities. Additionally, the presence of a developing subsoil horizon also serves as an additional indicator of drainage limitations (De Feudis *et al.*, 2021).

4.6 COARSE FRAGMENT

The characteristics of coarse materials in the soil are an important factor in determining land suitability for agriculture, as coarse materials affect the soil's ability to store water, manage infiltration, and support plant roots. The results of the coarse material percentage analysis in Lautém District show that this area has a diverse soil texture distribution **(Figure 4.6).** In the <3% coarse material category, Lospalos Sub-District dominates with the highest percentage, followed by Lautém and Iliomar. This indicates that most of these areas have fine-textured soils with minimal gravel or rock content, making them more fertile and suitable for agriculture.

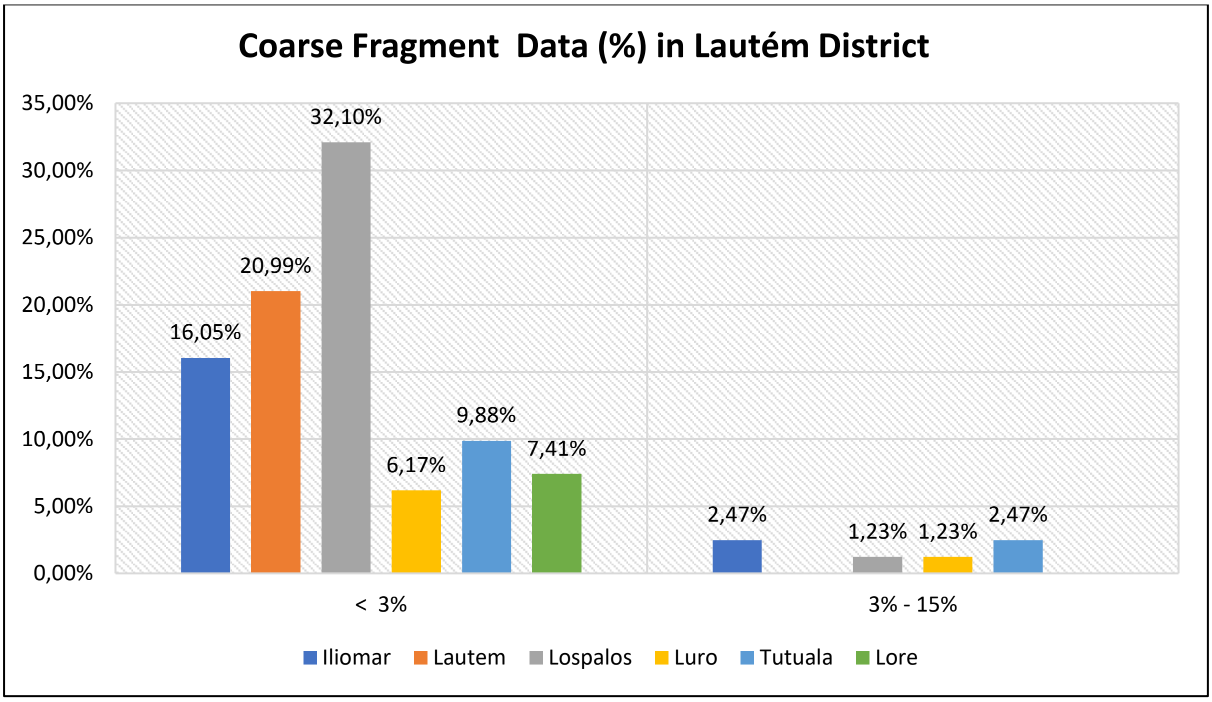


Figure 4.6 Coarse Fragment Data (%) in Lautém District

In contrast, in the 3%–15% coarse material category, the highest proportion is recorded in Iliomar and Tutuala. This area shows an increase in coarse material content, which is usually associated with more varied topography and the beginning of active erosion processes, although it remains within manageable limits for agriculture and other land uses. This distribution has implications for the agricultural sector in Lautém District. Areas with low coarse material content have high potential for food crop cultivation, such as rice, corn, and horticultural crops, because the soil tends to be more fertile and capable of retaining water well.

4.7 EFFECTIVE DEPTH

Based on the effective soil depth data in Lautém District **(Figure 4.7),** there are two depth categories: 60–90 cm and 90–120 cm. In the 60–90 cm soil depth category, this is only found in Lautém Sub-District. Meanwhile, in the 90–120 cm soil depth category, Lospalos Sub-District dominates this category. This dominance indicates that most of the land in Lospalos has deep soil, which is very supportive of plant growth, especially for perennial crops and those with deep root systems. Deep soil allows plant roots to develop more optimally, increases water retention capacity and nutrient availability, and provides better physical stability for plants (Suriadi, 2016).

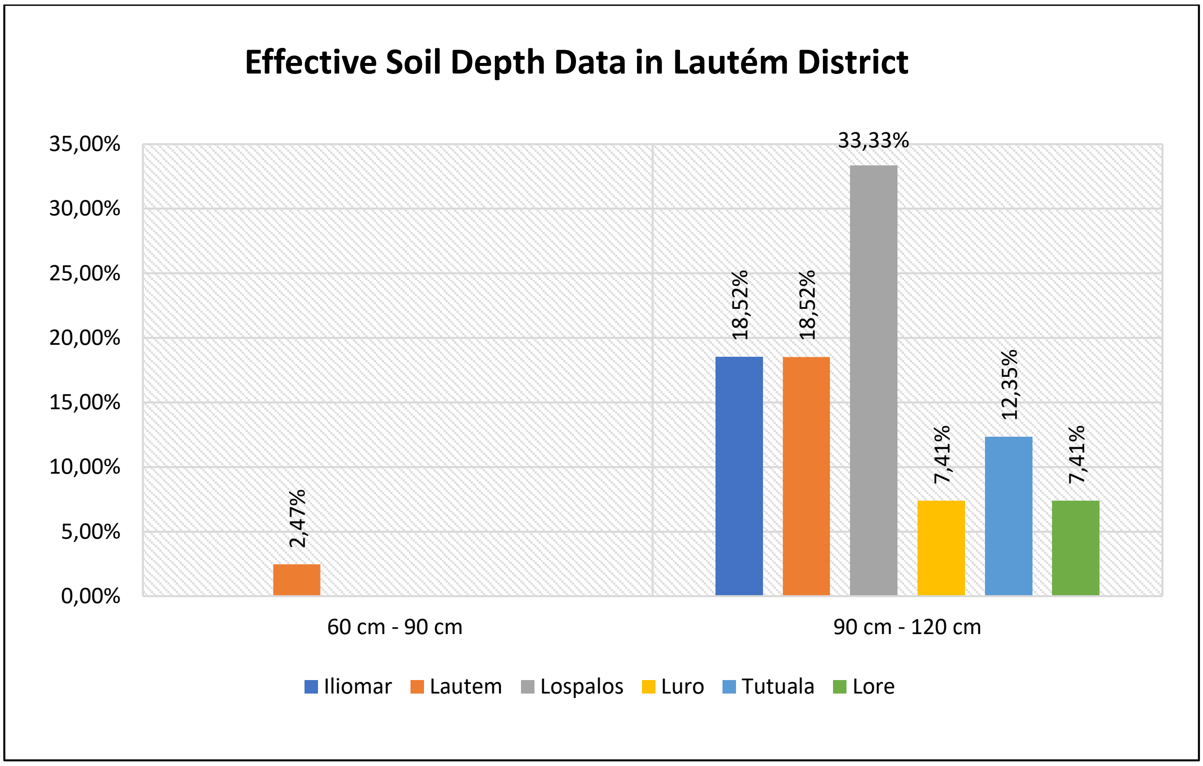


Figure 4.7 Effective Soil Depth Data in Lautém District

Meanwhile, Lautém and Iliomar Sub-Districts also have a fairly large proportion in this category. This condition suggests that these areas still have good potential for agricultural development, although not as optimal as Lospalos. On the other hand, Luro and Tutuala Sub-Districts have a lower percentage. The shallower soil depth in these two areas may be caused by steeper topography, more active erosion processes, or the presence of surface rock outcrops, which limits soil layer development (Supriadi *et al.,* 2018).

Scientifically, effective soil depth is greatly influenced by the soil formation process, parent rock weathering, as well as erosion and deposition activities. Areas with flat topography and intensive weathering processes tend to have deeper and more fertile soils, while regions with steep slopes or high erosion typically have shallower soils (Ramadhan & Adji, 2020). Sufficient soil depth is one of the main indicators in determining agricultural land potential, as it directly affects the soil's capacity to store water and nutrients, as well as its ability to support optimal plant root growth.

4.8 SURFACE ROCK

Surface rock conditions are one of the key parameters in assessing land potential and management challenges. The presence of surface rocks affects land suitability for agriculture, as high surface rock content can hinder soil cultivation activities and reduce soil fertility. Based on surface rock data in Lautém District, each sub-district shows different characteristics related to the percentage distribution of surface rocks, which generally indicate better suitability for agricultural land use **(Figure 4.8).**

The distribution of surface rocks in Lautém District is dominated by the category with less than 5% surface rock, which indicates that most of the land has very low surface rock content, thus supporting agricultural activities through easier soil processing and a larger effective soil volume for plant root growth. Lospalos Sub-District has the largest coverage in this category, followed by Lautém and Iliomar, while Luro records the smallest area. In the 5–15% category, Lospalos, Iliomar, and Lore show the highest proportions, indicating a slightly higher surface rock content but still allowing for agricultural management with technical adjustments. The 15–40% category, which reflects significant limitations for soil cultivation and water absorption, is predominantly found in Iliomar and Lautém, while Luro has no area in this category. The surface rock category of >40% is most commonly found in Luro and Tutuala, indicating high limitations for intensive agriculture, while Iliomar, Lautém, and Lospalos have no areas in this category. Overall, the distribution of surface rocks shows high agricultural potential in most of Lautém District, although a small portion of the land requires special management to address soil physical limitations

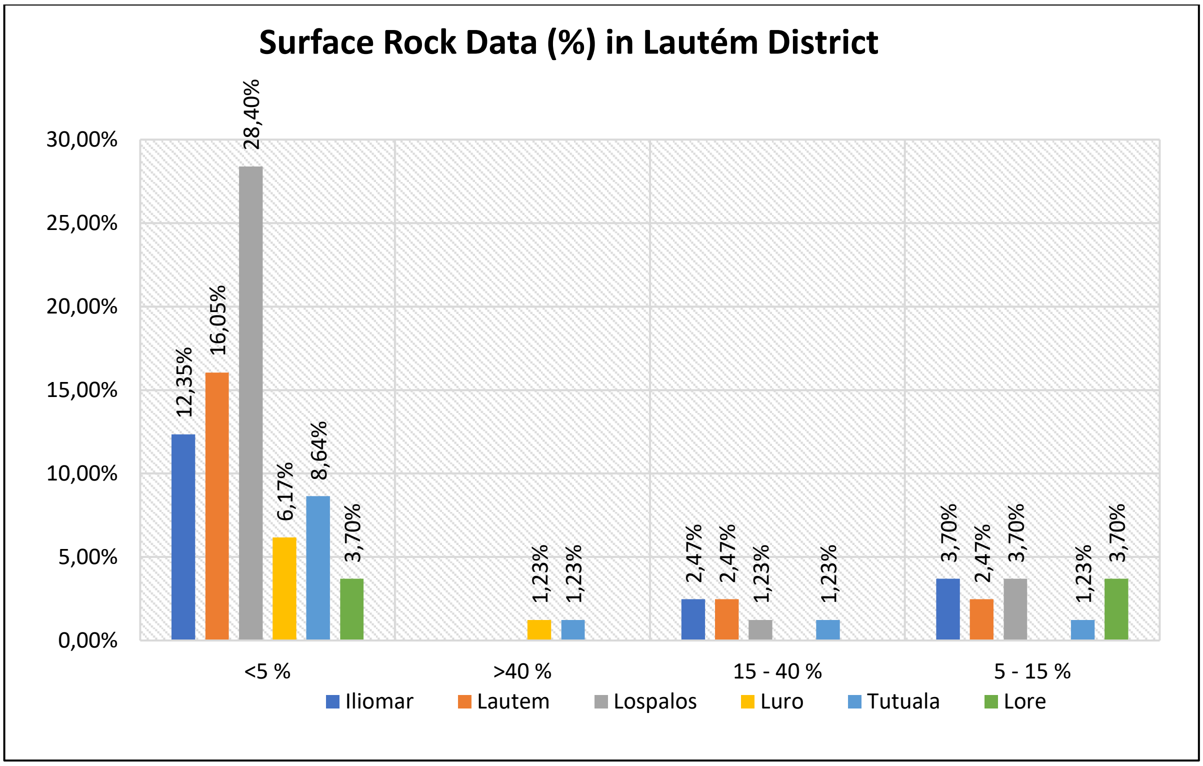


Figure 4.8 Surface Rock Data (%) in Lautém District

Scientifically, the distribution of surface rocks is influenced by geological factors and sedimentation processes, which are affected by tectonic conditions, parent rock weathering, and the level of erosion related to rainfall and topography (Sari et al., 2024; Wahyudi *et al*., 2020). High surface rock content can hinder the penetration of plant roots, reduce soil water retention capacity, and complicate land cultivation, thereby negatively impacting agricultural productivity (Wahyudi *et al*., 2020). Therefore, understanding the distribution of surface rocks is crucial in land use planning and agricultural development in areas with complex geological and geomorphological characteristics, such as Lautém District.

4.9 ROCK OUTCROPS

Rock outcrops are an important indicator in assessing geological conditions and land suitability. The presence of rock outcrops can influence soil physical properties, water storage capacity, and erosion levels. The results of the rock outcrop percentage analysis in Lautém District show that most of the area has a low level of rock outcrops **(Figure 4.9).**

The distribution of rock outcrops in Lautém District is dominated by the category with less than 5% rock outcrops, with the widest distribution in Lospalos Sub-District and the smallest in Lore. The low percentage of rock outcrops in this category indicates that most of the area is covered by soil layers, vegetation, or sediments. This condition results in thick and fertile soil layers, supporting plant growth and agricultural activities because the soil is easier to cultivate and has a large effective volume for plant root development (Supriadi *et al*., 2018; Suriadi, 2016).

In the 5–15% rock outcrop category, Iliomar and Lore Sub-Districts have the largest distribution. This zone is a transition area that begins to show more exposure of the parent rock due to thinning soil layers and decreased weathering intensity, as well as slightly more varied topography. This condition increases the risk of erosion and requires adjustments in land management techniques, such as soil conservation and the selection of tolerant crops (Ramadhan & Adji, 2020).

The 15–25% rock outcrop category is found only in Iliomar, Lautém, and Lospalos, marking areas with steeper slopes and significant erosion processes, where the parent rock is more widely exposed. The increased exposure of rock in these areas limits effective soil depth and water retention capacity, affecting agricultural productivity and requiring more careful land management (Hasanah *et al*., 2017). The >25% rock outcrop category is the least widespread, with the highest distribution in Tutuala, while Lautém and Lospalos have no areas in this category. Areas with high rock outcrops are very vulnerable to land degradation, such as erosion and landslides, and have significant physical limitations for intensive agriculture due to shallow soil depth and limited availability of water and nutrients (Ramadhan & Adji, 2020).

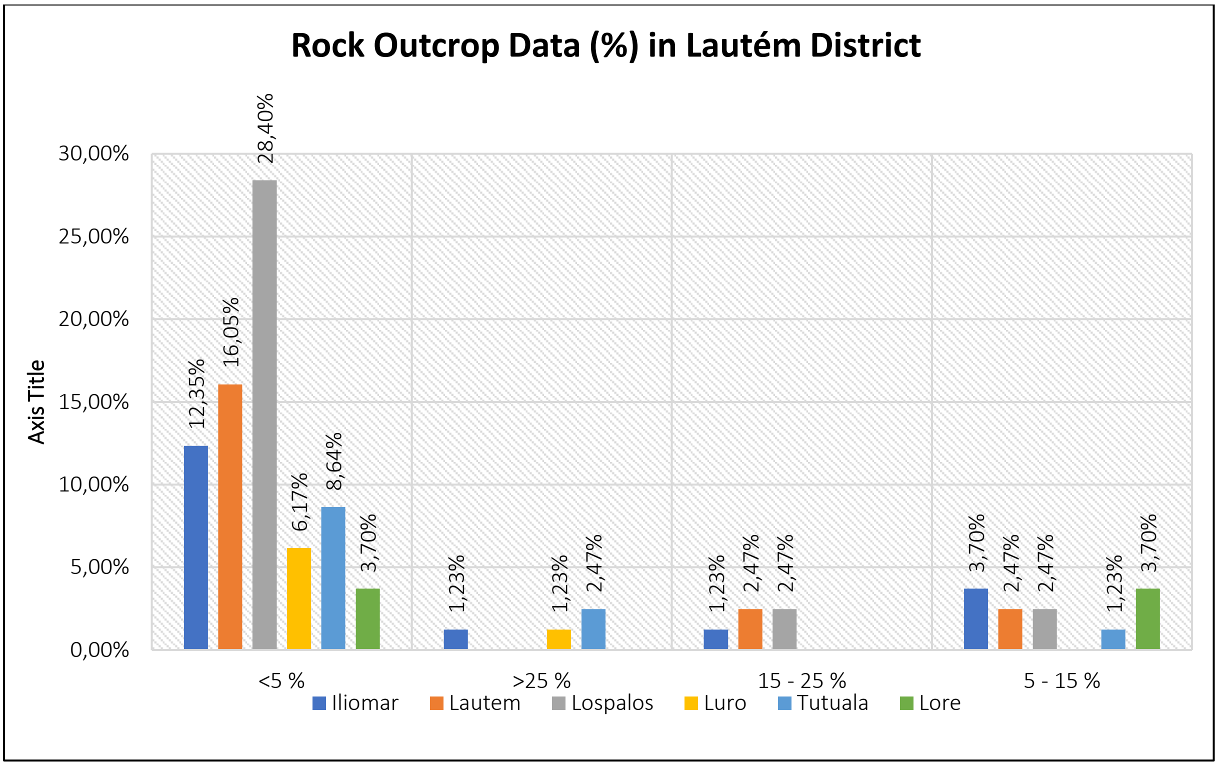


Figure 4.9 Rock Outcrop Data (%) in Lautém District

Overall, the distribution of rock outcrops in Lautém District is heavily influenced by geological factors, weathering processes, and varied topography. The higher the percentage of rock outcrops, the more limited the potential for intensive agriculture due to soil physical limitations and land degradation risks. Therefore, a deep understanding of the distribution of rock outcrops is crucial in land use planning and sustainable agricultural development in this area.

4.10 FLOOD HAZARD

Based on flood hazard potential data in Lautém District **(Figure 4.10),** Lospalos Sub-District has the highest flood risk, particularly in the very high hazard category. This makes Lospalos the area with the largest contribution to the total flood hazard potential in the district. In contrast, the Luro area shows no potential for flooding in the high or very high hazard categories, indicating that it is relatively safe from flood threats. Field observations show that flooding in agricultural land, particularly in the Lospalos area and its surroundings, is caused by poor drainage systems in some land use types. The worse the drainage system in an area, the less the soil's ability to absorb water.

In the no flood category, Iliomar Sub-District is the most dominant, followed by Lospalos and Luro Sub-Districts. This condition is due to the fact that most areas in these regions have sandy soil textures, which support good drainage systems. Sandy soil texture allows water to infiltrate more quickly into the soil layers, thus reducing the potential for waterlogging and flood risks. This makes these areas suitable for agricultural development, especially for crops that require good soil aeration conditions. Additionally, the differences in flood hazard potential across the areas are likely influenced by topographical factors, land cover, and variations in land use in each region.

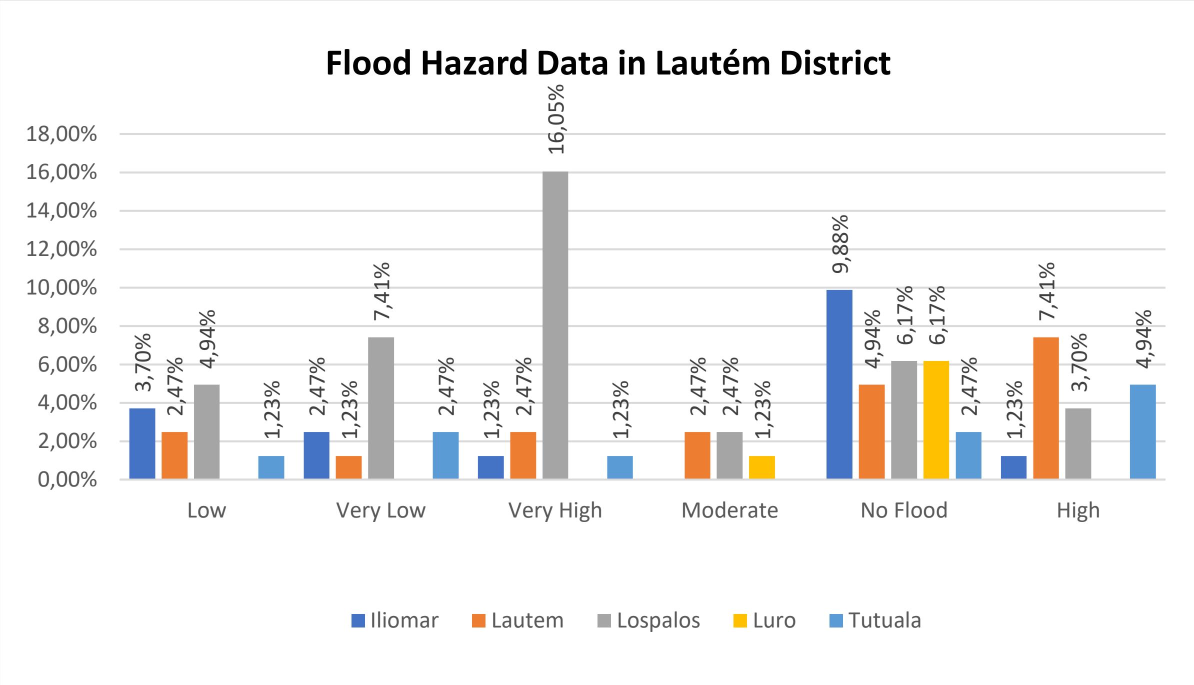
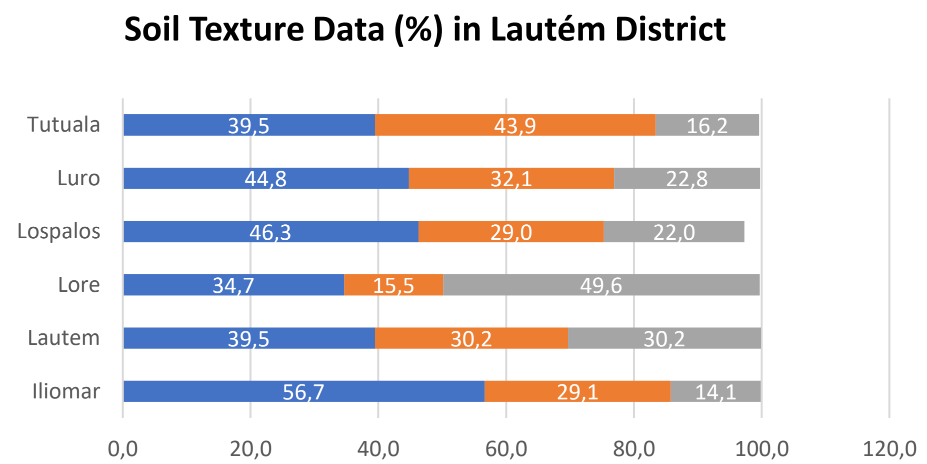


Figure 4.10 Flood Hazard Data in Lautém District

4.11 SOIL TEXTURE

Soil texture characteristics in each area of Lautém District show variations in different classes **(Figure 4.11)**. In Iliomar, Lospalos, Luro, and Tutuala Sub-Districts, the soil texture is dominated by the clay fraction, making the soil in these areas have high water and nutrient retention capacities. However, this condition also requires good drainage management to maintain optimal soil aeration and prevent hindrance to root development. In contrast, in Lautém Sub-District, the soil texture is classified as clay loam, with a balance between clay and sand fractions. This results in soil with more balanced physical properties, offering adequate water retention and relatively good drainage. Meanwhile, Lore Sub-District has clay soil with a dominant sand fraction, making the soil in this location more permeable and having good drainage, although its capacity to retain water and nutrients is relatively lower compared to the other sub-districts.

The variations in soil texture found across the sub-districts reflect differences in physical properties that directly affect soil fertility and plant growth potential. Therefore, land management must be adjusted according to the soil texture characteristics in each sub-district to support productivity and maintain soil sustainability. Soil texture plays a crucial role in determining the physical properties of soil that are directly related to plant growth. Fine textures, such as clay, have a higher ability to retain water and store organic matter but often limit aeration and root movement. In contrast, coarse textures like sand provide better aeration and drainage but are less capable of retaining water.



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
Clay (%)	56,7	39,5	34,7	46,3	44,8	39,5
Silt (%)	29,1	30,2	15,5	29,0	32,1	43,9
Sand (%)	14,1	30,2	49,6	22,0	22,8	16,2

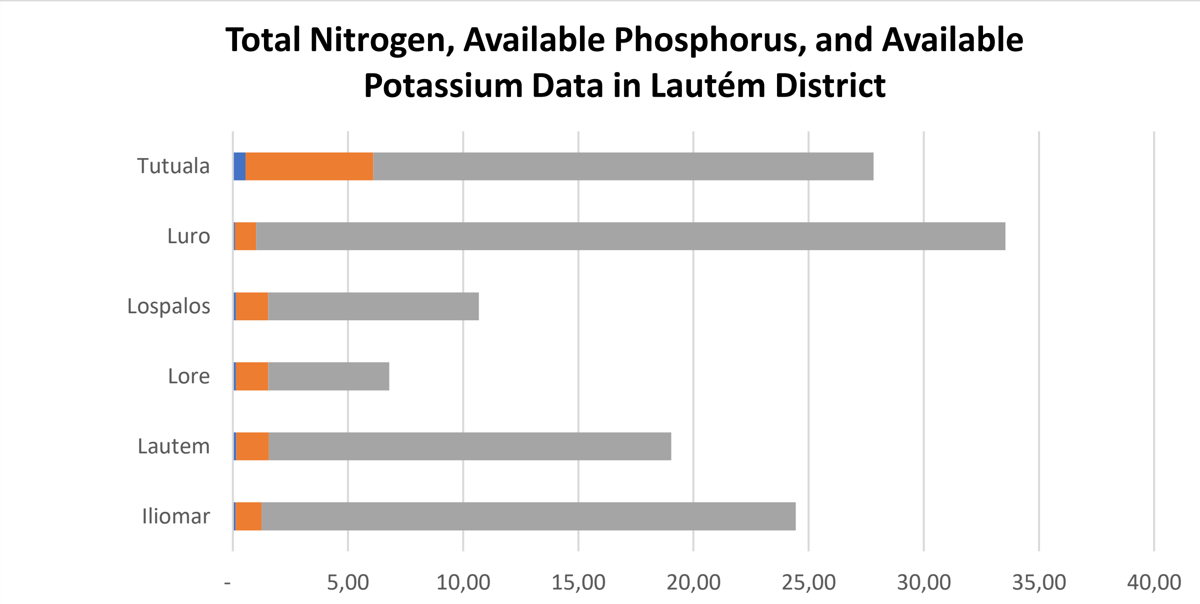
Figure 4.11 Soil Texture Data (%) in Lautém District

4.12 pH

Soil pH is one of the key indicators in determining soil fertility and land suitability. In Lautém District, Timor-Leste, soil pH generally falls within the neutral range, from 6.54 to 7.31 **(Figure 5.1 in Chapter 5)**. The soil pH characteristics in this area are heavily influenced by factors such as hilly topography, parent material, land use patterns (such as agriculture and shifting cultivation), and soil management practices, including slash-and-burn and grazing. Soil pH is crucial because it provides an indication of soil fertility. In the neutral pH range, nutrients are optimally available and easily soluble in water, making it easier for plants to absorb them (Fajeriana and Wijaya, 2020). Soil pH is closely related to base saturation (BS); the higher the pH value, the higher the BS value, and conversely, the lower the BS, the lower the soil pH.

4.13 TOTAL NITROGEN

Based on the research results, the total nitrogen (N-total) content in Lautém District ranges from very low to high **(Figure 4.12)**. Tutuala Sub-District has a high N-total content of 0.55%, while Luro Sub-District has a very low N-total content of 0.09%. The low N-total levels in some areas are caused by runoff triggered by excessive grazing, which reduces soil porosity and increases leaching during the rainy season. Continuous grazing in most of this area has led to significant land cover loss, accelerated erosion, and the loss of soil organic carbon and nitrogen (Da Costa, 2023). Furthermore, slope gradient also affects the availability of N-total in the soil, as increased runoff and erosion wash away nutrients, especially from the topsoil, which is rich in organic matter and nutrients. Nitrogen is a hygroscopic nutrient, so during the dry season, it evaporates, and during the rainy season, it is easily leached due to its slipperiness, which reduces its availability in the soil.



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
Total N	0,11	0,14	0,14	0,14	0,09	0,55
Available Phosphorus	1,14	1,42	1,40	1,40	0,92	5,54
Available Pottasium	23,19	17,47	5,24	9,14	32,53	21,73

Figure 4.12 Graph of Total Nitrogen, Available Phosphorus, and Available Potassium

4.14 AVAILABLE PHOSPHORUS

Available phosphorus is the form of phosphorus found in the soil that can be accessed and utilized by plants (Ariawan *et al.*, 2016). The availability of phosphorus in the soil is influenced by several factors, including parent material, pH level, organic matter content, and soil texture, so each soil type has different phosphorus levels. Based on the research results, the phosphorus content in Lautém District ranges from very low to low **(Figure 4.12)**. Tutuala Sub-District has a low P-available content of 5.54 ppm, while Luro Sub-District has a very low P-available content of 0.92 ppm. The low phosphorus availability in these areas is caused by the dominance of limestone rock formations, which contain high levels of calcium (Ca). The presence of Ca in the soil fixes or adsorbs phosphorus into a form that is not easily soluble, making it unavailable to plants (Asril *et al.*, 2022).

The soil organic carbon (SOC) content at the study sites also affects phosphorus availability in the soil, as organic matter is one of the sources of phosphorus that can increase its availability in the soil. When the amount of organic matter in the soil is low, phosphorus availability also becomes low. Additionally, the slope gradient at the study sites also affects phosphorus availability in the soil. At higher elevations, soil phosphorus tends to decrease due to lower temperatures and higher rainfall, which accelerates nutrient leaching. Available phosphorus in the soil plays a key role in accelerating root growth and strengthening the growth of young plants.

4.15 AVAILABLE POTASSIUM

Based on the research results, the potassium content in Lautém District ranges from very low to moderate **(Figure 4.12).** Luro Sub-District has a moderate Available Potassium content of 32.53 cmolc kg^{-1}, while Lore Sub-District has a very low Available Potassium content of 5.24 cmolc kg^{-1}. The low K-available values at the study sites are closely related to soil pH and base saturation. Potassium is easily leached when pH and base saturation are low, and tends to be bound when pH and base saturation are neutral. Due to its high mobility in the soil, K is easily leached by rainfall from the root zone, especially in soils with low cation exchange capacity (CEC) (Supartha *et al.*, 2022).

The magnitude of Available Potassium in the soil can also be influenced by soil CEC. The higher the CEC value, the greater the soil's capacity to retain potassium, and vice versa. Potassium is highly mobile and therefore prone to leaching from the root zone by rainfall, particularly in soils with low CEC. Under such conditions, K fertilization is required to overcome the low availability of K in the soil (Ramadani *et al*., 2023).

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4.16 ELECTRICAL CONDUCTIVITY (EC) / TOXICITY

The toxicity level of land is determined by soil salinity or salt content. The results of soil sample analysis in Lautém District show that salinity in this area ranges from low to moderate, between 1.34 to 2.63 dS m^{-1} (Figure 5.1 in Chapter 5). Based on the survey of land use patterns at the study sites, the area is dominated by grazing land and postharvest rice fields with fill soil and open land, which contributes to salt accumulation in the soil. In addition, salinity levels are also influenced by Na^{+} content, soil organic carbon (SOC), CEC, and soil texture. Fine textures that dominate this area, particularly clay soils, tend to slow the leaching of salts, thereby increasing salinity accumulation. This is consistent with Muliawan *et al.* (2016), who stated that increasing salt concentration raises electrical conductivity, which in turn increases soil toxicity.

Furthermore, Lautém District has rivers that discharge into the sea, and several sub-district areas are located close to the coastline, which affects salinity distribution. According to Indahwati (2012), the closer an area is to the coastline or to river flows that discharge into the sea, the higher the salinity tends to be. Conversely, Marwanto *et al.* (2009) stated that the farther an area is from the coast, the lower the soil salinity level.

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)

The CEC of soil reflects the ability of colloids to adsorb and exchange cations within the soil. The higher the clay content, the higher the CEC will be. Laboratory analysis shows that the CEC of soil in Lautém District ranges from low to very high **(Figure 5.1)**. Tutuala Sub-District has a very high CEC value of 40.39 me/100g, followed by Luro Sub-District with a high category of 35.78 me/100g, while Lore Sub-District has a low CEC value of 11.22 me/100g. The CEC value in this region is influenced by soil texture, clay mineral types, and organic matter content. Soils with finer textures tend to have higher colloidal clay and organic colloid content, thus increasing the CEC. In contrast, soils with coarse textures, such as sand or dust, have relatively fewer clay colloids and organic colloids, resulting in a lower CEC (Hakim *et al*., 1986).

Furthermore, the influence of organic matter on soil fertility is significant. Organic matter is known to have a higher cation absorption capacity than clay colloids. Therefore, the higher the organic matter content in the soil, the higher the CEC will be (Rosmarkam and Yuwono, 2002). Low CEC can be improved by adding organic materials such as compost or manure, and the addition of crushed zeolite rock can significantly increase soil CEC (Novizan, 2005).

5.2 BASE SATURATION (BS)

The analysis of base saturation in Lautém District indicates high to very high levels **(Figure 5.1).** Lautém Sub-District has an extremely high BS value of 99.94%, followed by Luro Sub-District with a value of 98.25%, while Lospalos Sub-District has a high BS value of 72%. High base saturation occurs when the amount and types of available base cations are high, and the leaching and soil acidity levels are low. In contrast, low base saturation occurs when base cations are leached due to high rainfall, acidic fertilizer use, coarse-textured soils, or soils with low clay mineral and organic matter content. Soils with high CEC, which are typically rich in clay fractions and organic matter, can retain more base cations, thus increasing base saturation. Fine-textured soils and high organic matter content also contribute to higher base saturation.

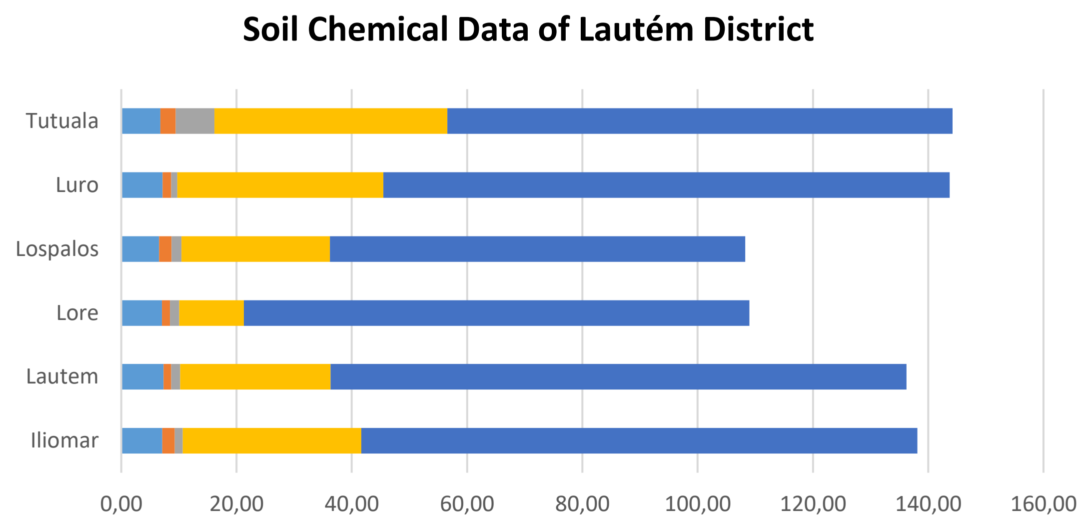
The high content of base cations (Na, Ca, Mg, and K) in the area results in higher BS values. Additionally, low BS levels can be associated with highly acidic soil pH. Acidic soils lower the BS of the soil. According to Hardjowigeno (1995), base saturation is closely related to soil pH, where soils with low pH generally have low base saturation, while soils with higher pH tend to have higher base saturation.

5.3 ORGANIC CARBON (C-ORGANIC)

The analysis of organic carbon (C-organic) content in Lautém District ranges from low to very high **(Figure 5.1).** Tutuala Sub-District has a very high C-organic value of 6.74%, while several other sub-districts in the region have low C-organic values ranging from 1.05% to 1.73%. Organic carbon values are positively correlated with organic matter content, as C-organic reflects the amount of carbon in soil organic matter. If a soil has a high organic matter content, its C-organic value will also be high.

The C-organic value is also influenced by microbial activity in the soil. C-organic, as part of organic matter, is a result of decomposition processes carried out by microorganisms. Increased microbial activity promotes the decomposition rate of organic matter and the availability of C-organic (Sipahutar, 2014).

The C-organic value of soil is influenced by the complex interaction between organic matter content, microbial activity, climate, land management practices, soil physical properties, and weathering and erosion processes. These factors together determine whether the organic carbon content of a soil will be high or low, which ultimately affects the soil's fertility and quality.



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
pH	7,14	7,31	7,05	6,54	7,15	6,79
EC	2,11	1,34	1,43	2,17	1,52	2,63
C Organic (%)	1,44	1,60	1,56	1,73	1,05	6,74
CEC	30,92	26,06	11,22	25,79	35,78	40,39
BS	96,51	99,94	87,73	72,00	98,25	87,67

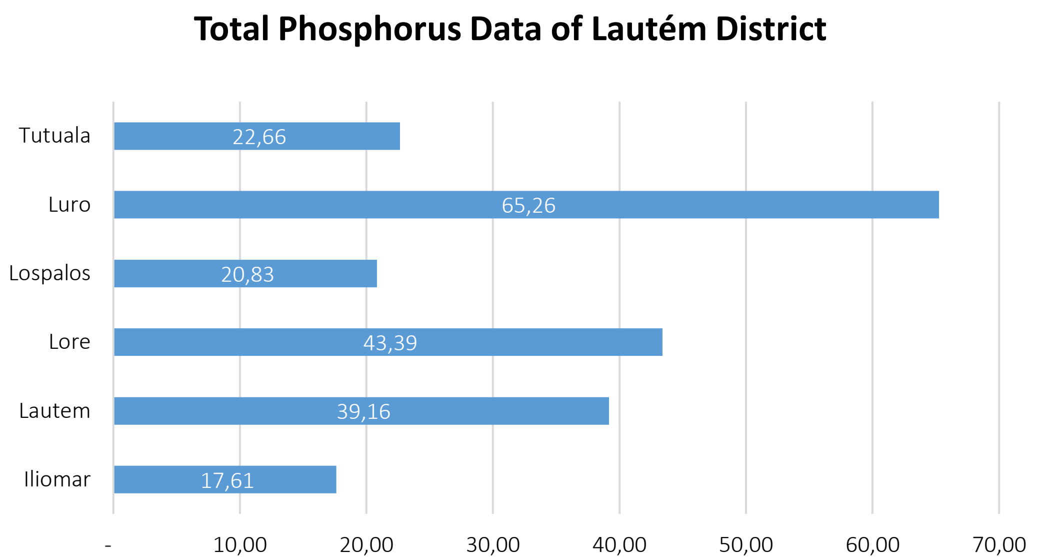
Figure 5.1 Soil Chemical Data of Lautém District

5.4 TOTAL PHOSPHORUS

Laboratory analysis results show that the total phosphorus (P-total) content in Munisípiu Lautém ranges from low to very high **(Figure 5.2).** Luro Sub-District has a very high P-total value of 65.26 mg/100g, followed by Lore Sub-District with a high category of 43.39 mg/100g, while Iliomar Sub-District has a low P-total value of 17.61 mg/100g.

The availability and retention of phosphorus in the soil are significantly influenced by soil pH. Phosphorus tends to precipitate or bind to soil minerals in soils with either very low (acidic) or very high (alkaline) pH, reducing its availability to plants. A neutral pH is generally the most favorable for maintaining phosphorus availability.

Human activities and land management practices, such as planting intensity, phosphate fertilizer use, irrigation, and other agricultural practices, play a critical role in determining the P-total content of the soil. According to Rahmah *et al*. (2014), land use activities can influence the availability of phosphorus nutrients. High phosphorus status is suspected to result from intensive planting followed by high and frequent fertilization. Although the P-total content in the soil may be high, this does not necessarily indicate that phosphorus is available in sufficient quantities for plant uptake. This difference illustrates that phosphorus availability depends greatly on how phosphorus is distributed and interacts with soil minerals, as well as the land management practices applied.



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
Total	17,61	39,16	43,39	20,83	65,26	22,66

Figure 5.2 Total Phosphorus Data of Lautém District

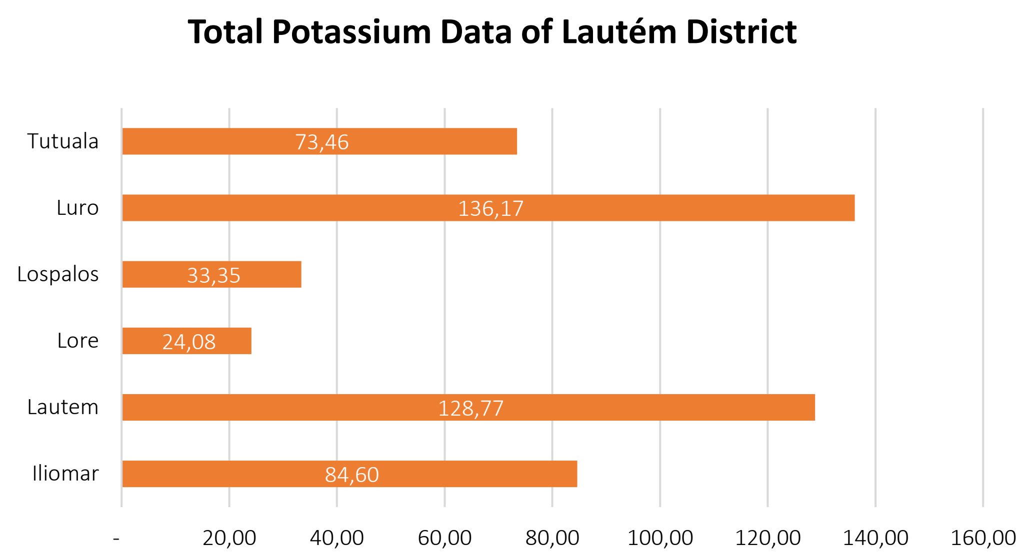
5.5 TOTAL POTASSIUM

The analysis of total potassium (K-total) content in Lautém District shows values ranging from moderate to very high **(Figure 5.3).** Luro Sub-District has a very high K-total value of 136.17 mg/100g, followed by Lautém Sub-District with a value of 128.77 mg/100g, while Lore Sub-District has a moderate K-total value of 24.08 mg/100g.

Generally, the topsoil layer (0-20 cm) has higher K-total content compared to deeper layers due to the accumulation of nutrients from organic matter and biological activity on the soil surface.

In addition, soil texture and cation exchange capacity (CEC) can affect K-total values. Soils with high CEC, typically fine-textured soils rich in clay and organic matter, can retain more potassium in exchangeable and plant-available forms. In contrast, coarse-textured soils tend to have lower K-total content.

Soil pH influences the availability and balance of potassium cations. A neutral to slightly alkaline pH helps retain potassium, preventing it from being easily leached, whereas a very low or acidic pH can accelerate potassium loss. Leaching due to high rainfall can reduce total potassium content in the soil because potassium is soluble in water and can be washed away from the root zone.



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
Total	84,60	128,77	24,08	33,35	136,17	73,46

Figure 5.3 Total Potassium Data of Lautém District

5.6 TOTAL ZINC

Laboratory analysis shows that the total zinc (Zn-total) content in Lautém District varies **(Figure 5.4).** Luro Sub-District shows the highest Zn-total value of 83.52 ppm, followed by Lospalos Sub-District with a value of 70.60 ppm, while Lautém Sub-District has the lowest Zn-total value of 53.32 ppm.

Zinc (Zn) is a micronutrient that is highly sensitive to changes in pH. The variation in Zn content in the soil is significantly influenced by soil pH. In high pH (alkaline) conditions, Zn tends to form insoluble complex compounds, making it unavailable to plants. In contrast, a decrease in soil pH to more acidic levels can increase the solubility of Zn, making it more readily absorbed by plant roots, but caution should be taken regarding potential toxicity if concentrations are too high.

Soil texture also affects Zn-total values, with sandy soils and calcareous/alkaline soils generally containing lower Zn levels. Additionally, high phosphorus (P) fertilization can lead to Zn deficiency in soils due to Zn-P binding. The availability of Zn is notably low in soils with high organic matter content, as Zn-humus complexes can form (Riwandi *et al.*, 2016).

5.7 AVAILABLE ZINC

Laboratory analysis shows that the available zinc (Zn-available) content in Lautém District varies **(Figure 5.4).** Luro Sub-District has the highest Zn-available value of 1.19 ppm, followed by Lospalos Sub-District with a value of 0.95 ppm, while Lautém Sub-District has the lowest Zn-available value of 0.51 ppm.

When soil pH is high, the availability of Zn decreases. In contrast, when soil pH is low, Zn becomes more available. Zinc deficiency generally occurs in alkaline soils and is higher in acidic soils. The increase in Zn availability is caused by high phosphorus content in the soil due to intensive phosphorus fertilization, resulting in the accumulation of Zn from the applied P fertilizers.

High Zn-available levels in the soil are also influenced by high organic carbon content. The addition of organic matter stimulates microbial activity, which increases the demand for Zn by microorganisms for their growth, thereby reducing its availability to plants. Acids from organic matter decomposition can bind Zn, making it available.

Furthermore, the antagonistic relationship between phosphorus (P) and zinc (Zn) in the soil also affects Zn availability. As the Zn content increases, the available phosphorus in the soil decreases, forming Zn-P complexes in the soil solution (Barber, 1995).

5.8 TOTAL SULFUR

Sulfur is a soil ameliorant that can enhance the availability of other nutrients through various mechanisms, such as ion interactions after being converted to sulfide, electron donation, and acting as a reductant (Sofyan, 2014). The sulfur content in the soil ranges around 1000 mg S kg^{-1} (0.1%). The availability of sulfur (S) in the soil is highly influenced by soil pH. In acidic soils, sulfur tends to bind with hydrogen ions (H^+) and aluminum ions (Al^{3+}), reducing its availability to plants. In contrast, in alkaline soils, sulfur can interact with calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, which can also hinder sulfur uptake by plant roots.

At neutral pH, microbial activity increases during organic matter decomposition. This decomposition process results in organic compounds, including organic sulfur, which then mineralizes into inorganic forms (SO_4^{2-}) that are available to plants (Widjanto *et al.*, 2013).

Laboratory analysis results indicate that total sulfur (S-total) content in Lautém District varies **(Figure 5.4).** Lores Sub-District shows the highest S-total value of 660.93 ppm, followed by Tutuala Sub-District with 567.13 ppm, while

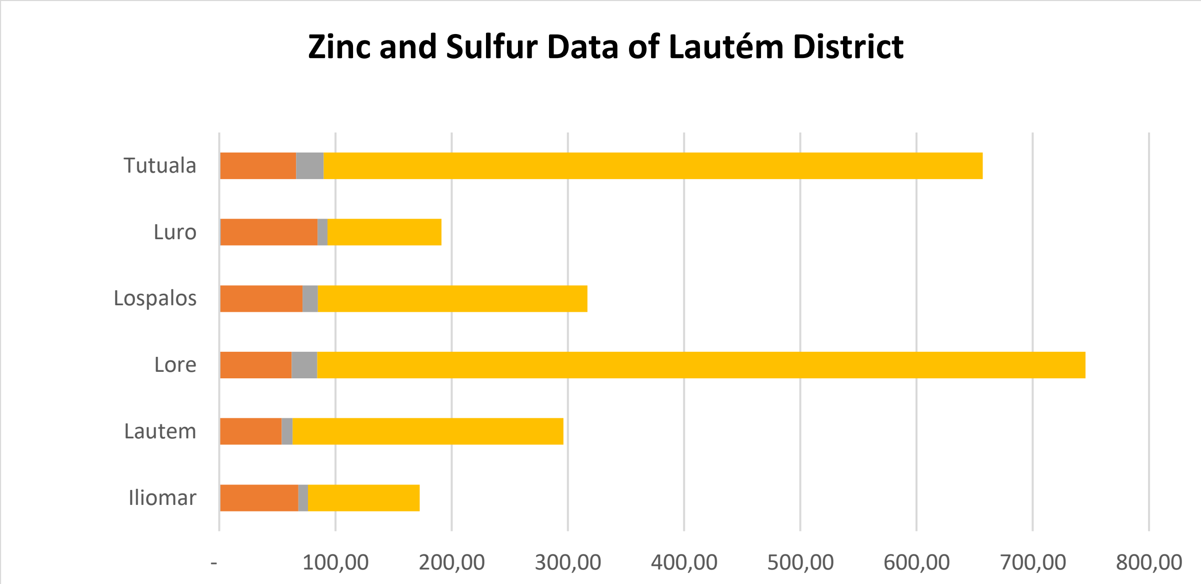
Iliomar Sub-District has the lowest S-total value of 96.16 ppm. The high S-total content can be influenced by very high organic matter content, such as plant residues and manure, which undergo decomposition and release sulfur into the soil. High sulfur content in the soil lowers pH, and the reduction of alkaline pH increases the availability of other essential nutrients. Rainfall and humidity conditions also affect sulfur mobility and leaching from the upper soil layers, with regions receiving high rainfall potentially experiencing decreased sulfur content due to leaching.

5.9 AVAILABLE SULFUR

Laboratory analysis shows that the available sulfur (S-available) content in Lautém District varies **(Figure 5.4).** Tutuala Sub-District has the highest S-available value of 23.80 ppm, followed by Lore Sub-District with 21.93 ppm, while Iliomar Sub-District has the lowest S-available value of 8.01 ppm.

Sulfur can be absorbed by plants in its inorganic form (SO_4^{2-}). High S-available levels are also influenced by high organic matter content. Organic matter undergoes decomposition, producing organic compounds such as organic sulfur, which eventually mineralizes into inorganic forms (SO_4^{2-}) available to plants (Widjanto *et al.,* 2011).

Steep slopes, especially very steep ones, increase sulfur loss. Leaching, surface runoff, and erosion are more pronounced in sloped areas compared to flatter regions. The minimal use of sulfur fertilizers and the steep terrain further contribute to the unavailability of sulfur for plants. Sulfur loss in the soil is due to erosion, volatilization, and leaching, resulting in low sulfur availability.



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
AVAILABLE ZINC	0,91	0,51	0,93	0,95	1,19	0,84
TOTAL ZINC	67,32	53,32	61,45	70,60	83,52	65,24
AVAILABLE SULFUR	8,01	9,37	21,93	13,39	8,44	23,80
TOTAL SULFUR	96,16	232,97	660,93	231,85	97,98	567,13

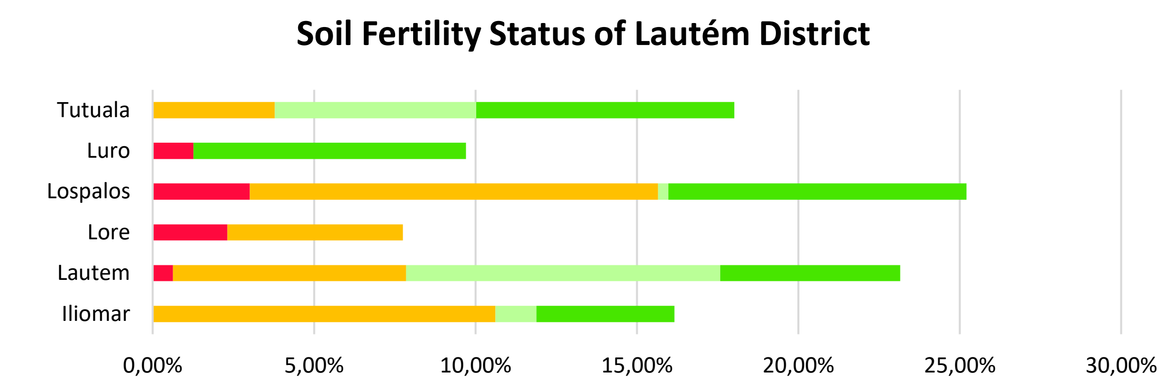
Figure 5.4 Zinc and Sulfur Data of Lautém District

5.10 SOIL FERTILITY STATUS

The analysis of soil fertility status in Lautém District indicates that the majority of the area has low fertility levels, covering an area of 719.71 km² (39.71%). The area with high fertility accounts for 643.97 km² (35.53%) of the total land, followed by moderate fertility with 318.16 km² (17.55%). The area with very low fertility is the smallest, covering only 130.71 km² (7.21%). This data suggests that more than half of the land in Lautém District is considered less fertile and requires efforts to improve soil quality to support agricultural productivity. On the other hand, high-fertility land is relatively limited, making it crucial to utilize it optimally to ensure the sustainability of agricultural production in the region.

Based on the soil fertility status data **(Figure 5.5),** Iliomar Sub-District is predominantly categorized as low fertility, covering an area of 192.38 km², followed by high fertility with 77.46 km². The moderate category covers only 23.13 km², while very low fertility was not found in this sub-district. In Lautém Sub-District, the largest area falls under the moderate fertility category, covering 176.27 km², followed by low fertility with 130.91 km² and high fertility with 101.10 km². Very low fertility has the smallest area, covering 11.41 km². In Lore Sub-District, most of the land falls into the low fertility category, covering 98.66

km², followed by very low fertility with 41.88 km². Both high and moderate fertility categories were not present. In Lospalos Sub-District, the low fertility category occupies the largest area, covering 229.25 km², followed by high fertility with 167.41 km². Very low fertility covers 54.61 km², while the moderate category is very small at 5.64 km². Luro Sub-District is dominated by high fertility, covering 153.08 km², followed by very low fertility with 22.81 km². No land was classified as low or moderate fertility. In Tutuala Sub-District, high fertility is the most widespread, covering 144.93 km², followed by moderate fertility with 113.12 km², and low fertility with 68.51 km². Very low fertility was not found in this area.



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
Very Low	0,00%	0,63%	2,31%	3,01%	1,26%	0,00%
Low	10,61%	7,22%	5,44%	12,65%	0,00%	3,78%
Moderate	1,28%	9,72%	0,00%	0,31%	0,00%	6,24%
High	4,27%	5,58%	0,00%	9,24%	8,45%	8,00%

Very Low Low Moderate High

Figure 5.5 Soil Fertility Status of Lautém District

Thus, it is evident that the low fertility category is most dominant in several sub-districts such as Iliomar, Lore, and Lospalos, while the high fertility category dominates in Luro and Tutuala. The very low fertility category generally has the smallest area or is even absent in some sub-districts, indicating that areas with very low fertility are relatively limited. Given the dominance of less fertile land, effective land management strategies are required, such as the use of organic fertilizers, the implementation of soil conservation techniques, and improved irrigation systems. Additionally, optimizing land with moderate and high fertility can help improve agricultural yields to support food security and the well-being of local communities. Collaboration between farmers, academics, and the government is crucial to designing solutions that can increase agricultural productivity in Lautém District. The Soil Fertility Status Map is presented in **Figure 5.6.**

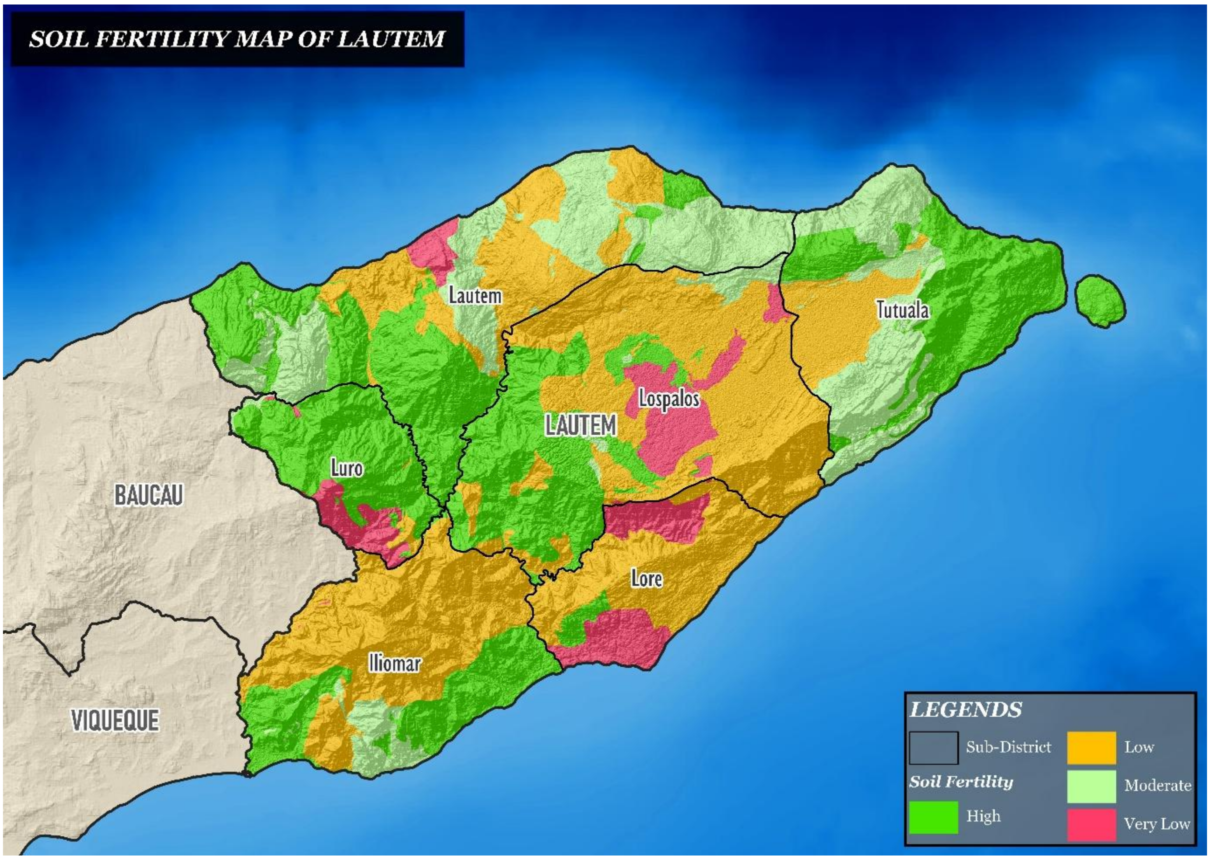


Figure 5.6 Soil Fertility Status Map of Lautém District

VI. EROSION AND CONSERVATION

6.1 SOIL EROSION

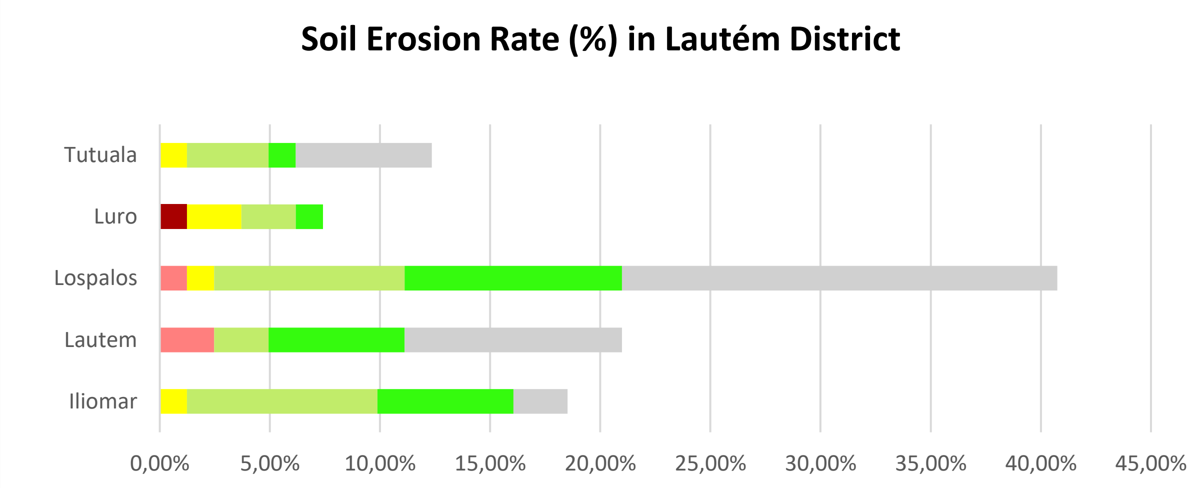
A Soil erosion analysis plays a crucial role in land suitability evaluation, particularly for the development of agricultural commodities. Soil erosion not only affects land productivity but also impacts ecosystem sustainability, environmental degradation, and the loss of soil capacity to retain nutrients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

According to the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978), soil erosion is influenced by several primary factors, namely rainfall erosivity, soil erodibility, slope length and steepness, vegetation cover, and land management practices. In Timor-Leste, most of these factors exhibit characteristics that trigger high erosion rates. Steep topography, low levels of land conservation, unstable soil structure due to geological influence, and minimal vegetation cover are the main factors accelerating erosion. As noted by Morgan (2005), uncontrolled soil erosion can lead to the loss of topsoil—the most fertile component of the soil—thereby limiting its productive capacity.

Lautém District exhibits varying levels of erosion, ranging from light to very severe. The very severe erosion category is found only in Luro Sub-District **(Figure 6.1)**, characterized by steep slopes. **As explained in Chapter 2 of this book**, steep slopes increase the potential for erosion by accelerating surface runoff (Akbar, 2024; Siswanto *et al.*, 2019; Andrian *et al.*, 2014; Martono, 2004).

In addition to topography, soil type also plays an important role in determining erosion levels. The dominant soil in this area is Inceptisols, which have blocky, massive, and granular structures. These structures are easily detached when exposed to water erosion. Soils dominated by clay texture exhibit low water infiltration. According to Munir (1996), Inceptisols are susceptible to erosion because stable soil aggregates have not yet formed. Furthermore, severe erosion is found in Lospalos and Lautém Sub-Districts. In addition to slope and soil type, drainage is another important factor influencing erosion in Lautém District. As described in **Chapter 4**, areas with somewhat poorly drained conditions, such as Lautém Sub-District, and very poorly drained conditions, such as Lospalos Sub-District, experience disrupted water infiltration, increasing the volume of surface runoff (Moeini *et al*., 2015; Kuswari *et al*., 2024). When water cannot infiltrate the soil optimally, surface runoff increases, which can erode the topsoil. This accelerates land degradation, particularly in areas with unstable soil structure and clay textures.

In contrast, sub-districts such as Iliomar exhibit very light to light erosion levels. This can be attributed to better drainage conditions, relatively gentle slopes, and soils that are more resistant to water erosion. The erosion distribution map of Lautém District is presented in **Figure 6.2.**



	Iliomar	Lautem	Lospalos	Luro	Tutuala
Very Heavy	0,00%	0,00%	0,00%	1,23%	0,00%
Heavy	0,00%	2,47%	1,23%	0,00%	0,00%
Moderate	1,23%	0,00%	1,23%	2,47%	1,23%
Light	8,64%	2,47%	8,64%	2,47%	3,70%
Very Light	6,17%	6,17%	9,88%	1,23%	1,23%
No Erosion	2,47%	9,88%	19,75%	0,00%	6,17%

Figure 6.1 Soil Erosion Rate in Lautém District

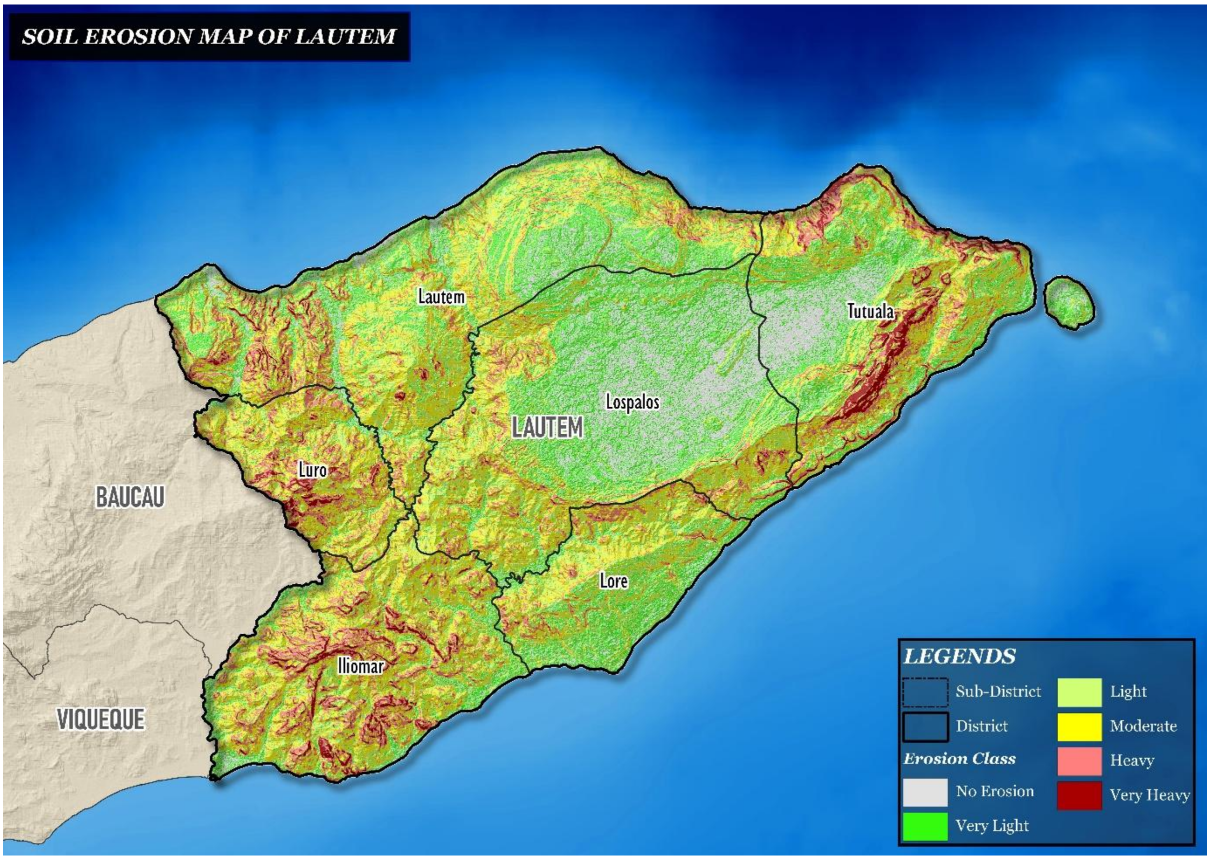


Figure 6.2 Soil Erosion Distribution Map of Lautém District

6.2 SOIL AND WATER CONSERVATION

Conservation is a long-term natural resource management effort aimed at maintaining land quality and productivity. It plays a crucial role in protecting soil from degradation, rehabilitating degraded soils, improving water infiltration, and maintaining soil fertility. Conservation practices include mechanical, vegetative, and chemical methods.

In Lautém District, soil and water conservation strategies are based on slope steepness, which ranges from flat to very steep (0 to > 45%). For areas with flat to gentle slopes (0-8%), it is recommended to cultivate food crops, secondary crops, and horticultural plants. These crops can also be cultivated on land with slopes up to 40%, provided that terraces are constructed to facilitate rainwater infiltration into the soil, thus reducing erosion and surface runoff.

For slopes greater than 45%, the land is recommended for perennial crops (e.g., tree crops such as banyan, mahogany, legung, teak, gamal, *lamtoro*, and others). The purpose is to minimize the risk of erosion and landslides, especially if terraces are built in narrow planting areas. These areas are prone to erosion and can easily experience landslides during heavy rain.

The slope data of Lautém District is presented in **Table 6.1,** and the Conservation Map based on slope steepness in Lautém District is presented in **Figure 6.3.**

Table 6.1 Conservation Data Based on Slope in Lautém District

Sub-District	lope Gradient (%)	Potential Class	Area (ha)	Area (%)
Iliomar	>45	Agroforestry	1.663	0,92
Iliomar	25-45	Agroforestry	7.146	3,94
Iliomar	15-25	Moderately Potential	10.721	5,92
Iliomar	8-15	Potential	6.567	3,62
Iliomar	0-8	Highly Potential	4.085	2,25
Lautém	>45	Agroforestry	606	0,33
Lautém	25-45	Agroforestry	5.842	3,22
Lautém	15-25	Moderately Potential	11.645	6,43
Lautém	8-15	Potential	5.842	6,36
Lautém	0-8	Sangat Potensial	15.189	8,38
Lospalos	>45	Agroforestry	304	0,17
Lospalos	25-45	Agroforestry	5.054	2,79
Lospalos	15-25	Moderately Potential	12.900	7,12
Lospalos	8-15	Potential	13.060	7,21
Lospalos	0-8	Highly Potential	31.054	17,14
Luro	>45	Agroforestry	623	0,34
Luro	25-45	Agroforestry	3.554	1,96
Luro	15-25	Moderately Potential	5.169	2,85
Luro	8-15	Potential	2.434	1,34
Luro	0-8	Highly Potential	1.033	0,57
Tutuala	>45	Agroforestry	2.142	1,18
Tutuala	25-45	Agroforestry	4.618	2,55
Tutuala	15-25	Moderately Potential	6.237	3,44
Tutuala	8-15	Potential	6.169	3,40
Tutuala	0-8	Highly Potential	11.853	6,54

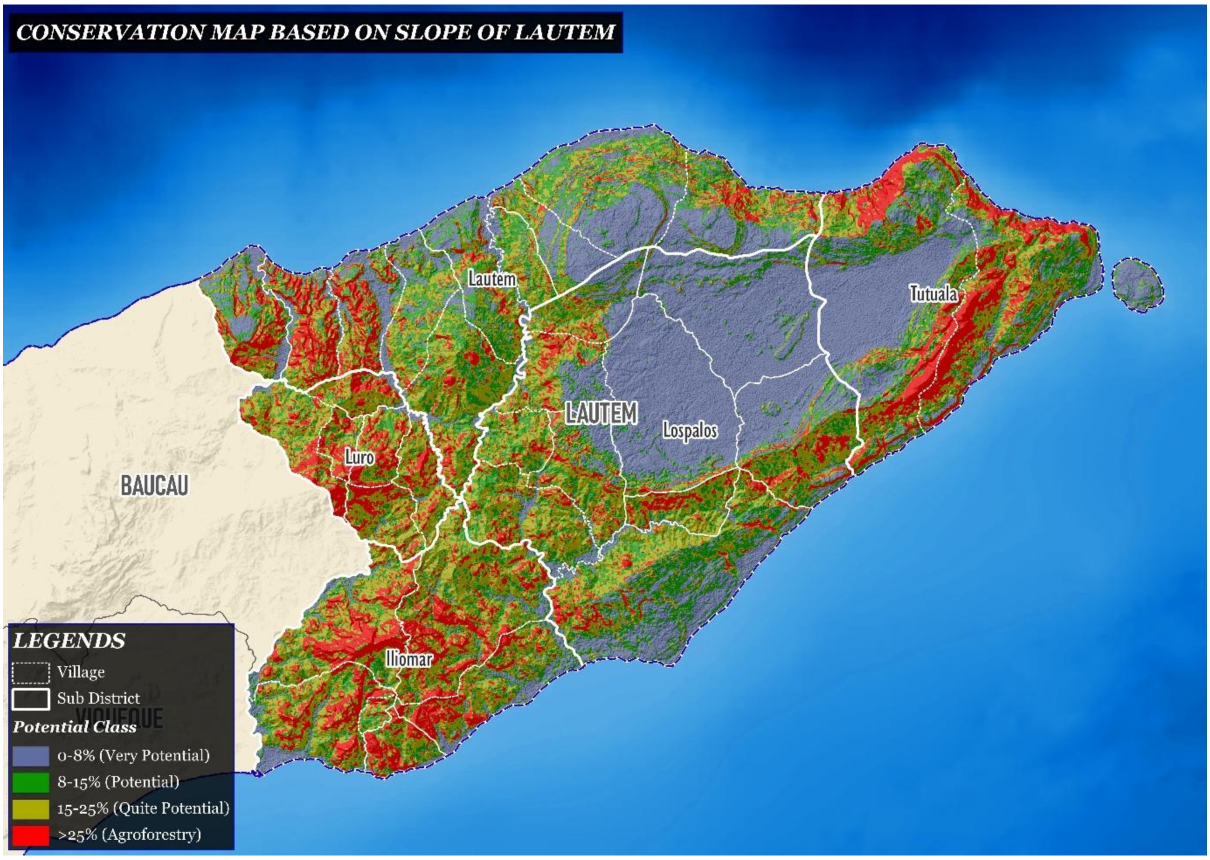


Figure 6.3 Slope-Based Conservation Map of Lautém District

Lautém District has a varied slope gradient across its sub-districts, with differing areas for each category. Land with very high potential for use, characterized by gentle slopes (0-8%), covers an area of 63,214 ha (34.88%). Land with potential for use, having slopes between 8-15%, covers 34,072 ha or 21.93%. Land with moderate potential for use, with slopes ranging from 15-25%, spans 46,672 ha or 25.76%. The area with slopes greater than 25% covers 31,099 ha or 17.4%. The sub-district with the largest area of slopes > 25% is Tutuala Sub-District, which covers 2,142 ha or 1.18%. Land with very steep slopes can only be used for perennial crops or agroforestry.

The area with the largest portion of gentle slopes (0-8%) is in Lospalos Sub-District, which covers 31,054 ha or 17.14%, indicating its potential for developing food crops, horticulture, and plantation crops.

Based on the slope-based conservation map of Lautém (**Figure 6.3**), the central and some coastal areas, with gentle slopes (0-8%) to moderate slopes (8-25%), are suitable for the cultivation of food crops, secondary crops, plantation crops, and horticulture. To improve growth, land with moderate to slightly steep slopes should be terraced to reduce erosion. In contrast, areas in red, located mainly in the eastern part of the district, are classified as very steep (>25%). In these locations, only perennial crops or tree crops can be developed and used for agroforestry.

Agroforestry is a land management system that combines trees, agricultural crops, and/or livestock on the same land to provide ecological interactions and a diverse ecosystem. The integration of agroforestry components (trees, agricultural crops, and livestock) can enhance soil fertility and improve physical, biological, and chemical soil properties, provide specific habitats, increase biodiversity, reduce runoff, hold rainfall water kinetic energy, bind soil particles, improve water retention, and control erosion.

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

1. Agrosilviculture System: Integration of trees and specific food crops on the same land.
2. Silvopastoral System: A combination of tree cultivation and livestock grazing to support livestock management.
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 Garden System: Characterized by intensive cultivation of annual and seasonal crops, generally consisting of vegetables, cereals, fruit trees, grass, and livestock maintenance.
5. Other Systems: Including the cultivation of multipurpose trees, beekeeping, fisheries, and forestry, all of which can be used for various agricultural and non-agricultural purposes.

The agroforestry conservation model is presented in **Figure 6.4**

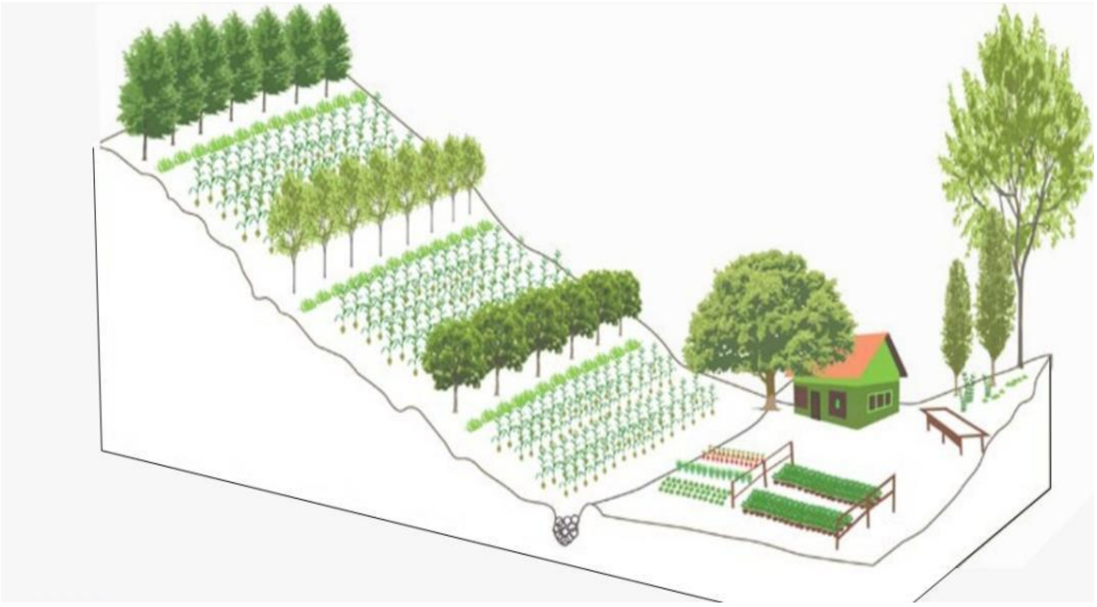


FIgure 6.4 Agroforestry Conservation Model
(Source: La *et al*., 2016)

A. Agroforestry Conservation Model

Agroforestry plays a crucial role in the production of local commodities (firewood, timber, fruits, and livestock feed) as well as global commodities (coffee, tea, cocoa, rubber, and latex). It also plays a strategic role in assisting countries in combating poverty, ensuring food security, and promoting environmental sustainability. Agroforestry enhances farmers' resilience and increases household income by providing a diverse range of products harvested at different times throughout the year. The combination of trees, crops, and livestock helps reduce environmental risks, creates permanent ground cover to combat erosion, minimizes flood damage, and improves water retention, benefiting both crops and pastures.

Agroforestry offers a range of benefits, including:

1. Improving Food Security and Nutritional Enrichment

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

2. Resilient Livelihoods
   The integration of trees, food crops, and livestock can reduce production vulnerability to climate disasters and market shocks. Additionally, agroforestry helps control pest infestations common in monoculture systems by creating a better microclimate. Agroforestry influences climate impacts that hinder agricultural systems, fostering more resilient livelihoods.
3. Climate Change Mitigation and Adaptation
   The integration of different agricultural crops helps mitigate the impact of climate change on the agricultural sector. The use of trees in agroforestry plays a role in carbon sequestration, regulating the microclimate, which helps reduce the rate of climate change and promotes plant growth.
4. Environmental Protection
   Agroforestry systems regulate climate and environmental services. Perennial plants help improve air and water quality. Tree litter can be used as organic material, reducing the need for chemical fertilizers. The deep root systems play a role in supporting the nutrient cycle. Agroforestry components also support biodiversity by creating environments suitable for flora and fauna habitats within agricultural landscapes.
5. Poverty Alleviation
   Agroforestry can enhance income diversification through the cultivation of commercial crops, timber sales, and livestock earnings. Diversification improves sustainable agricultural productivity, increases farmers' income, creates job opportunities, and contributes to poverty reduction and the well-being of communities.

B. Agroforestry and Agro-Ecology in Lautém District

The most successful agroforestry systems in Lautém District typically involve a mixed cultivation of fruit trees and timber-producing trees along with spices. The main fruit crops selected include jackfruit, banana, mango, pineapple, and orange. Timber-producing trees commonly planted alongside fruit crops include mahogany, sandalwood, moringa, and albizia. Agroforestry in the region has adopted modern approaches, focusing on techniques such as crop rotation, intercropping, and agro-silvopastoral systems.

Paudel *et al*. (2022) describe an agroforestry model commonly applied in Timor-Leste, including in Lautém District:

1. Alley Cropping in hilly areas along contour lines to reduce the risk of landslides and improve long-term water flow. The concept of the alley cropping system is presented in **Figure 6.5.**

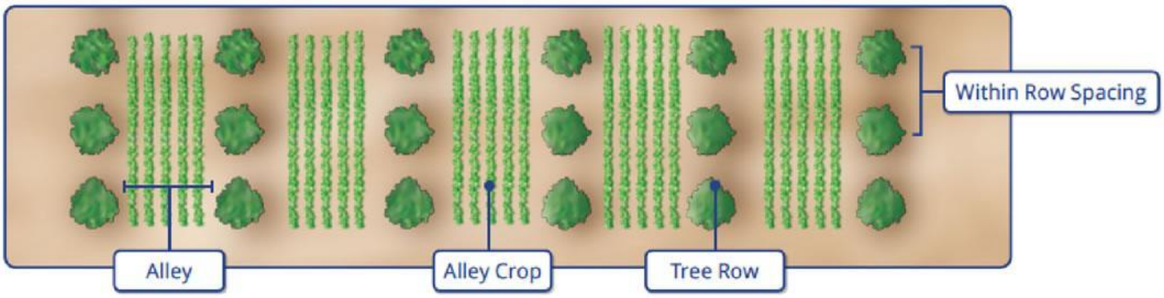


Figure 6.5 Concept of Alley Cropping System
(Source: https://www.fs.usda.gov/nac/practices/alley-cropping.php)

2. Hedge planting involves creating boundaries or fences using trees or shrubs. This practice is primarily applied in steep hilly areas to preserve soil and prevent erosion. The concept of this system is presented in **Figure 6.6.**

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

3. Random planting involves the cultivation of both woody plants and annual crops with irregular planting distances in lowland areas. The concept of random planting is presented in **Figure 6.7.**

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

4. The regular alternating row planting system involves planting crops in rows, with seasonal crops planted between the rows on flat and expansive land. An example of an agroforestry model that can be implemented in Lautém District is the cultivation of vanilla (wood + fruit + spices + staple crops), with vanilla as the main crop and supporting plants such as casuarina, albizia, forest pepper, jackfruit, cassava, mango, banana, and cocoa. This agroforestry model can be applied at elevations of 500-1500 meters, with average annual rainfall ranging from 1500–3000 mm.

According to Cogné & Lescuyer (2024), by combining agro-ecological and socio-technical data to identify types of Agroforestry Systems (AFS) in Lautém District, which consists of home gardens integrating perennial crops, spices, and small livestock; a combination of crops and fallow land for the development of food crops and trees planted at certain distances; planting perennial plants (papaya, banana, chili, etc.) combined with tree species like palms; forest gardens typically near water sources; and silvopastoral systems that integrate trees, shrubs, and grazing livestock on the same land.

Lautém District has three agro-ecological zones (AEZ/Agro-Ecological Zones) based on agro-climatic zones. These zones have bio-physical parameters such as elevation, average rainfall, and soil types, which are important in selecting suitable crops and agroforestry models to apply in Lautém District. The data on agro-ecological zones and main crop types are presented in **Table 6.2**. The agro-climatic zone map of Lautém District is presented in **Figure 6.8**.

Recommendations for the Implementation of Agroforestry Based on Agro-Ecological Zones and Agro-Climatic Zones:

1. Zone D

Appropriate conservation techniques include terraces with channels, bench terraces, rainwater reservoirs, drainage systems, grass planting, and Check Dams. Suitable tree species include mahogany and sandalwood, while suitable food crops include corn, cassava, and sweet potatoes.

2. Zone E

Applicable conservation methods include channel terraces, bench terraces, rainwater reservoirs, drainage systems, grasslands, and Check Dams.

3. Zone F

Appropriate conservation techniques include dams, Check Dams, gabions, ridge terraces, biopore holes, riverbank protection, rainwater reservoirs, and drainage systems. Suitable plants include mahogany, teak, sandalwood, corn, and cassava.

Table 6.2 Data on Agro-Ecological Zones and Main Crop Types

Zone	Elevation (m)	Rainfall (mm/year)	Main Crops
Zone D	500-1500	500-1500	Corn, cassava, rice, sweet potato, cowpea
Zone E	100-500	500-1500	Corn, cassava, rice, sweet potato, cowpea
Zone F	<100	1500-3500	Rice, corn, cassava, coconut

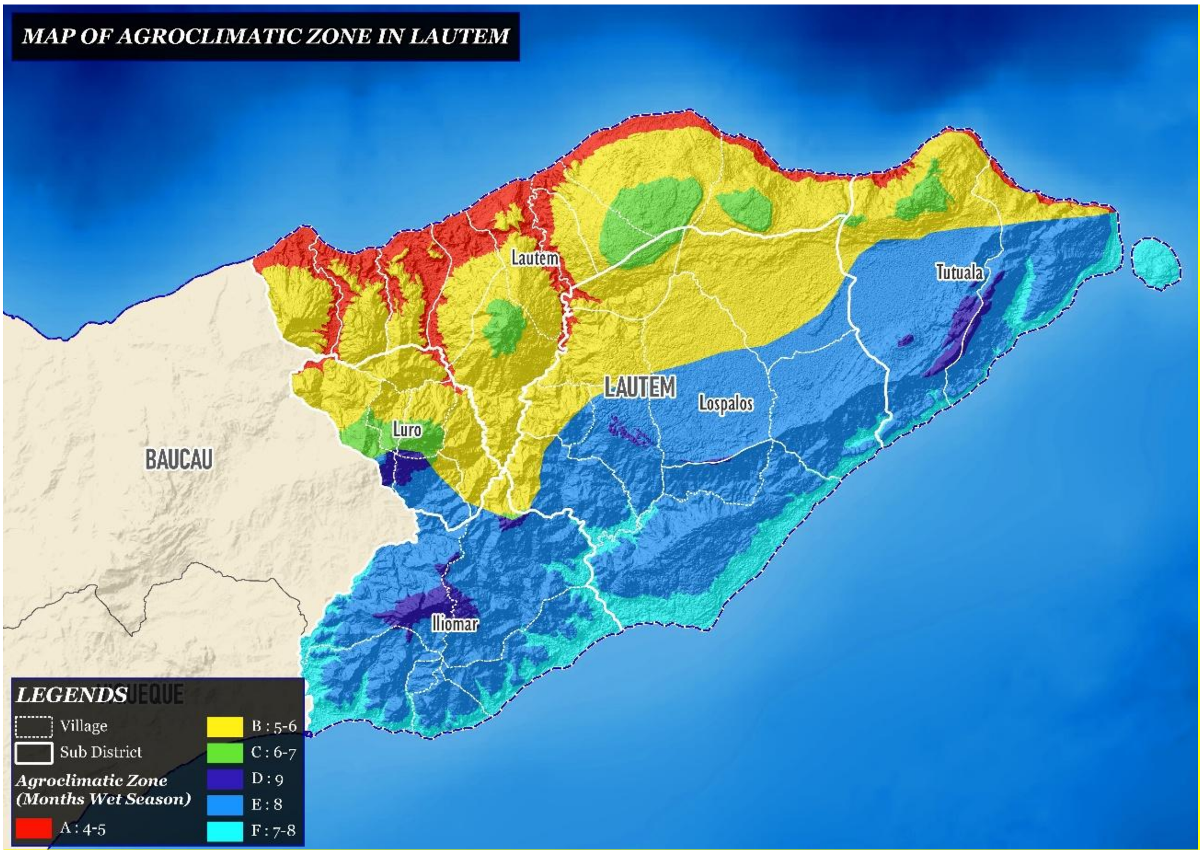


Figure 6.8 Agro-Climatic Zone Map of Lautém District

C. Soil Conservation Techniques in Lautém District

Soil conservation techniques are operational and managerial strategies aimed at maintaining and improving 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 implemented in many areas of Asia, such as converting agricultural land back to forest or grassland, terracing, mulching, and land management (Huang *et al.,* 2022).

1. Check Dam

A Check Dam is a small, low dam built in riverbeds or other water channels to reduce the speed of the river flow, minimize erosion, and encourage the sedimentation of eroded materials through the spillway. Dams are beneficial for preserving agricultural land and strengthening the retaining structures in hilly and disaster-prone areas. Some types of dams include:

a. *Brushwood,* This dam is made of wood or branches, making it suitable for small riverbeds. It generally has an effective height of around 1 meter above the ground surface, and the minimum foundation depth for the posts is 0.75–1 meter. The conservation model of brushwood is presented in **Figure 6.9**. Steps to build a brushwood dam include*:*

1) Dig a trench about 5 cm wide, then insert wooden posts (150–200 cm) with a depth of one-third to half the length of the posts, and the distance between posts should be 30–50 cm.
2) The center should be lower than the sides to form a gap for holding maximum water flow
3) Branches from trees (e.g., mahogany, rosewood, sesbania) and shrubs are woven between the wood until the desired height is reached.
4) The ends of the tied materials should enter the sides of the riverbed at least 30 cm
5) The back side of the dam should be filled with soil.
6) The sides 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) The side walls should be built to direct the water flow into the dam
8) Repair the slope of the head of the riverbed, especially in steep areas.

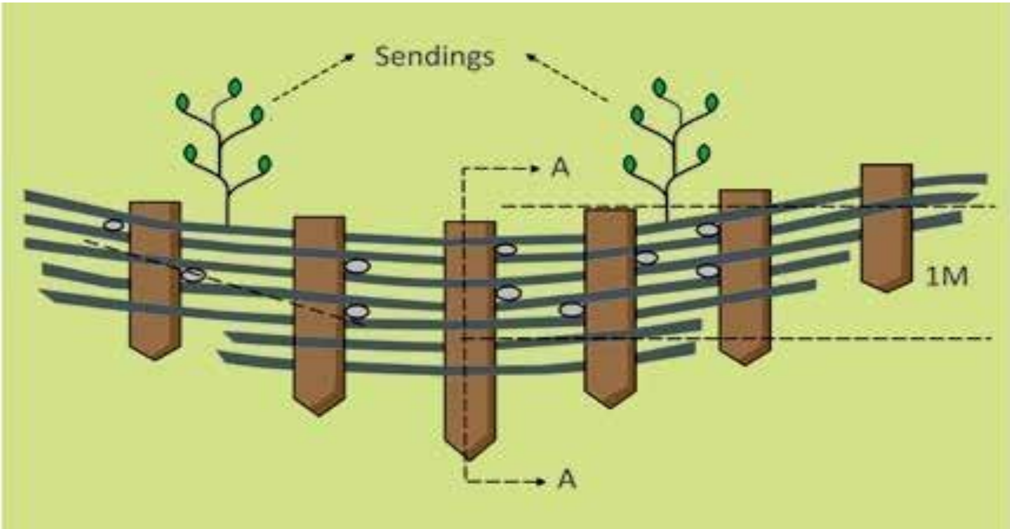


Figure 6.9 Brushwood *Check Dam*
(Source: Godinho *et al*., 2023)

b. A **Loose Stone** Check Dam is made from loose stones used to block small to medium-sized riverbeds. A Boulder Check Dam uses large stones as barriers, operating on the same principle as the loose stone dam. Typically, these dams have an effective height between 1-2 meters, with a minimum foundation depth of half the effective height, and a spillway thickness ranging from 0.5 to 1 meter. The Loose Stone model is presented in **Figure 6.10**, Steps for Building a Loose Stone or Boulder Check Dam:

1) Clear the site and mark the construction line with string.
2) Cut the riverbed sides with a 1:1 slope. The foundation of the wing walls should be greater than 0.5 meters. The height of the wing walls should match the depth of the spillway.
3) The foundation of the dam should extend beyond the spillway
4) For larger dams, construct two wing walls with appropriate foundations to guide the water into the spillway and prevent erosion of the riverbed edges.
5) Use boulders for the gap and the downstream section of the spillway. The center section should remain low to facilitate water flow through the spillway.
6) For high water flow volumes, concrete should be used at the gap and top of the dam, or cover the entire structure with wire mesh.
7) Build an apron of stones beneath the dam for added stability
8) Place large stones at the base of the dam, with stones about 50 x 30 cm in size used throughout.
9) On the upstream side, fill the dam with soil to enhance its stability

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

c. A **Gabion** Check Dam is constructed using hexagonal or square wire baskets filled with stones. The general specifications for a gabion dam are an effective height of less than 5 meters, a foundation depth that is half of the effective height, and a spillway thickness of less than 1 meter. The concept of the Gabion Conservation model is shown in **Figure 6.11**. Steps for Building a Gabion Check Dam:

1) The structure must extend at least 0.5 meters into the riverbed and should be protected from floodwater with wing walls.
2) Wing walls with appropriate foundations must be built on top to direct the flow into the spillway or gap and prevent erosion at the river's edge. The space between the dam and the wing walls should be filled with soil.
3) The foundation of the dam should extend beyond the spillway.
4) Large stones should be placed along the sides of the gabion baskets, with smaller stones used to fill the center. The size of the stones used for construction should be larger than the wire mesh (mesh sizes of 10 x 10 cm and 15 x 15 cm).
5) If there are debris materials, a concrete layer should be added at the front of the dam to protect the gabion wire from damage.
6) The dimensions of the spillway should be calculated based on the maximum flow from the river catchment area.
7) An apron should be built beneath the dam for additional stability.
8) The back section of the dam should be filled with soil to increase the dam's strength
9) The gabion boxes should be secured with 12-gauge wire.

Figure 6.11 Gabion Check Dam
(Source: *https://i.pinimg.com/originals/32/6e/5e/326e5e1d490cc5da1dd6ad.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 directly controls water flow and reduces large-scale soil loss. It alters the continuity of the topography and shortens the slope length by intercepting 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 gradually increase land cover and water infiltration, reduce nutrient loss, and improve crop productivity. Terracing is not suitable for application on 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.**

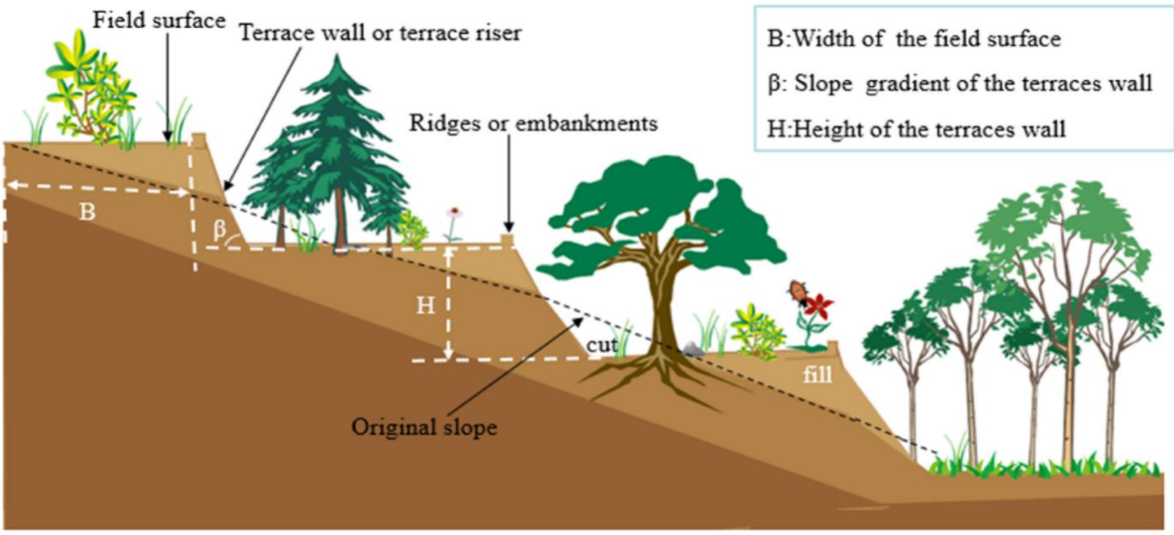
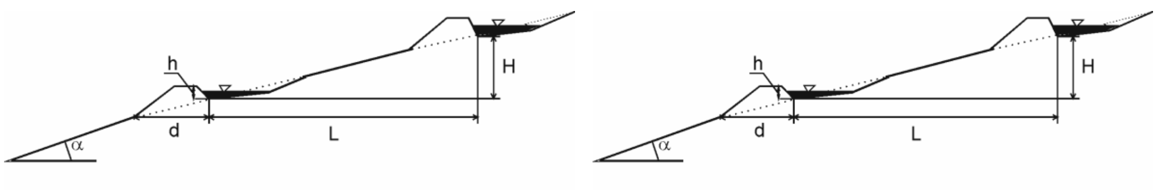


Figure 6.12 Concept of Terracing Conservation
(Source: Deng *et al*., 2021)

Several types of terraces based on their suitability for slopes include:

a. Broad Channel Terraces: These are typically built to capture and channel excess water on fields. These terraces are suitable for development in wet areas with slopes not exceeding 20%.
b. Ridge Terraces, made to capture and hold excess water by spreading it over the land area between the hilltops. This terrace is commonly applied on gentle slopes (<3%) because water spreads more widely without the need to create high hilltops. Ridge terraces have water channels at the back of the ridge (the hillcrest) to direct surface water to drainage channels and increase water absorption into the soil. The ridge terraces divide the

slope into smaller hydrographic units, thus reducing water flow paths and affecting water circulation on the slope and across the entire watershed. According to Prochal (1984) in Baryła & Pierzgalski (2008), ridge terraces are divided into two types: with and without water outflow. Ridge terraces without water outflow, have a shape parallel to the contours. Built on soil that is easily penetrable by water and with relatively low rainfall. The water flowing will be trapped on the embankments and absorbed into the soil. Ridge terraces with water outflow, Ridge terraces with water outflow, terraces with drainage on the surface or underground. In terraces with underground drainage, water will be discharged through wells or underground pumps to ditches, rivers, or reservoirs. These terraces are used in areas with high precipitation levels and soils that have low absorption capacity. The concept of dividing ridge terraces is presented 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 Ridge Terraces Concept: 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 lined with stones or vegetation for protection. Step terraces can be made flat, sloping inward/axial tilting, or sloping outward, and are typically built in ecosystems such as rainfed rice fields, dryland farming, and various agroforestry systems.
d. **Individual Terraces**, terraces made for each individual plant, especially for perennial crops. This type of terrace is usually built on plantation areas or fruit orchards.
e. **Orchard Terraces,** a type of terrace for perennial crops, especially for plantations and fruit trees. Terraces are made with varying intervals depending on planting distance.

Terraces are built manually using the cut and fill method, where soil from a higher level is cut and moved to a lower level. The terrace design specifications are as follows:

1) **Terrace length**: Typically a maximum of 100 meters in one direction of the drainage channel for humid tropical climates. The length of the terrace is limited by the size and shape of the land, degree of cutting, and soil type.
2) **Terrace width**: The optimal width ranges between 2.5-5 meters (built manually) and 3.5-8 meters (built using machines/tractors). The width of the terrace is adjusted according to soil depth, land cultivation tools, plant types, and other requirements.
3) **Terrace gradient**: The horizontal gradient of the terrace ranges between 0.5% - 1%, depending on the climate and soil type.
4) **Height and slope of sub-terraces**: Sub-terraces are made from compacted soil and protected with grass or stones. The height of the sub-terraces should not exceed 2 meters. The Vertical Interval (VI) between two consecutive terraces can be calculated using the following formula:

$$VI = (S \times Wb) / 100 - (S \times U)$$

Description:

S = Slope (%)

Wb = Width of the bench (m)

U = Slope of the sub-terraces (m)

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

3. Biopore Infiltration Hole

A biopore hole is a cylindrical hole drilled into the ground to improve water infiltration, reduce flooding, convert organic waste into compost, reduce greenhouse gas emissions (CO_2 and methane), and enhance the role of soil and plant roots. A biopore hole can increase water infiltration up to 40 times, thereby improving soil moisture and maximizing groundwater reserves. Additionally, biopores can enhance soil fertility by converting kitchen waste into compost.

The construction of biopores can be done by digging or using a drill to create holes with a depth of 30-100 cm. The distance between holes should be around 0.5-1 m. Biopore holes made around trees can be positioned in an equilateral triangle with three holes surrounding the tree. The edges of the hole need to be reinforced with cement or short pieces of PVC pipe to prevent erosion. Only organic waste (kitchen waste and/or garden waste) should be inserted into the holes. The waste should not be packed too tightly as it would interfere with the water infiltration process. The compost produced typically takes 2-8 weeks. The concept of biopore infiltration hole application is presented in **Figure 6.15.**

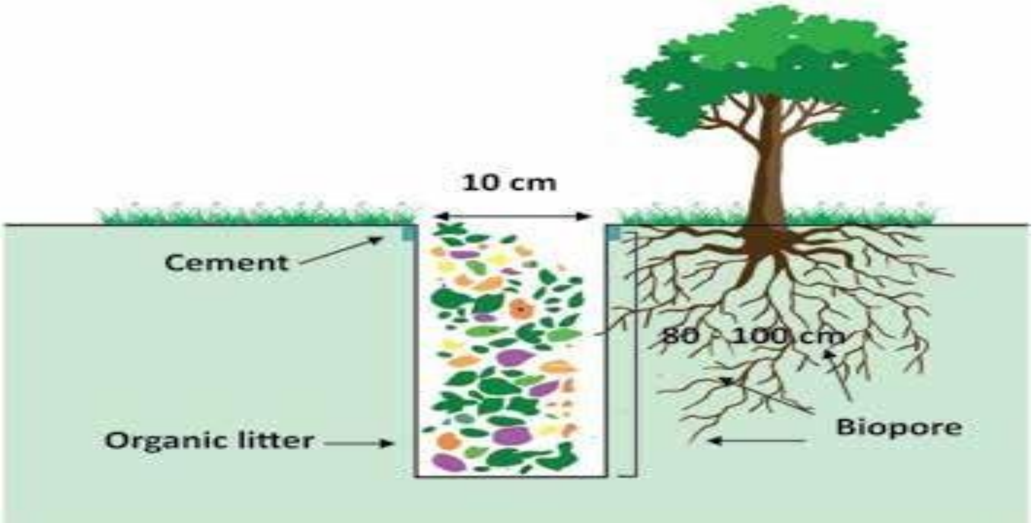


Figure 6.15 Biopore Infiltration Hole
(Source: Godinho *et al.*, 2023)

4. Riverbank Protection

Riverbank is a soil and water conservation technique applied along riverbanks to prevent landslides, reduce soil erosion, improve water quality, and mitigate sedimentation. Riverbank protection can be applied to exposed areas along riverbanks that are vulnerable to erosion and landslides, steep riverbanks, riverfronts with sparse vegetation, 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 framework. The concept of riverbank protection using vegetation is illustrated in **Figure 6.16.**

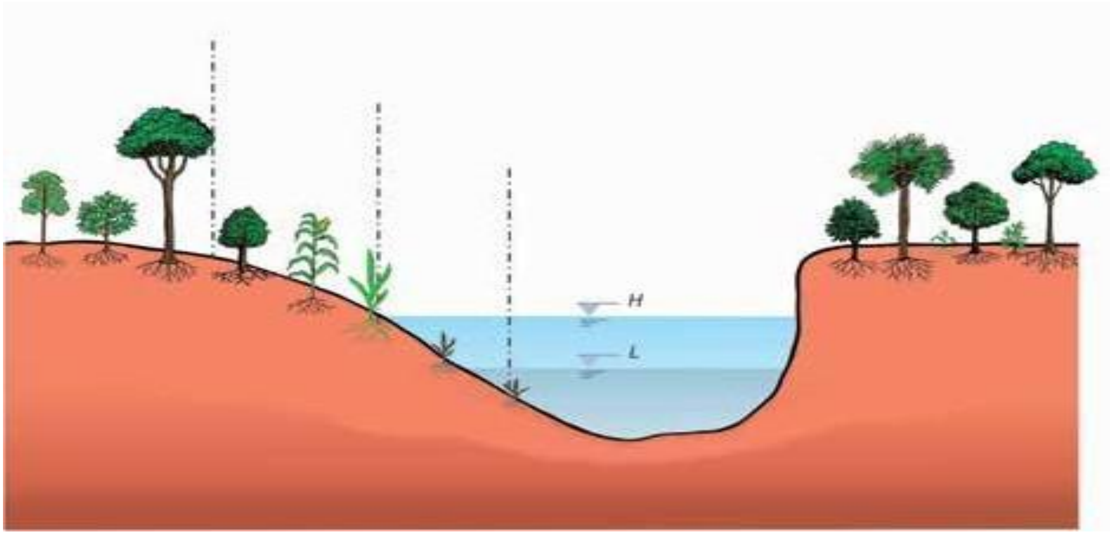


Figure 6.16 Riverbank Protection with Multiple Tree Layers,
(Source: Godinho *et al*., 2023)

5. Grass Planting

Grass planting is used to control soil erosion. The fibrous root system can form a dense mass of interconnected lateral roots, which can strengthen, hold, capture, and solidify the soil. Grasses with deep, strong, compact, and fibrous root systems are capable of penetrating and binding soil particles, thereby reducing sedimentation. Grass can also function as a component of the system and promote terrace formation, even on steep slopes (Do *et al*., 2023).

Grass planting can be carried out in three ways:

a. Horizontal/contour grass lines: This method is used on slopes less than 65 degrees and areas prone to erosion. On slopes less than 30 degrees, planting distance is 1 x 1 meter with a hole depth of 10 x 10 cm. On slopes between 30-45 degrees, planting distance is 50 x 50 cm with 10 x 10 cm hole depth, and on slopes greater than 45 degrees, a planting distance of 30 x 30 cm with 10 x 10 cm hole depth is applied. The concept of horizontal/contour grass planting is shown in **Figure 6.17.**

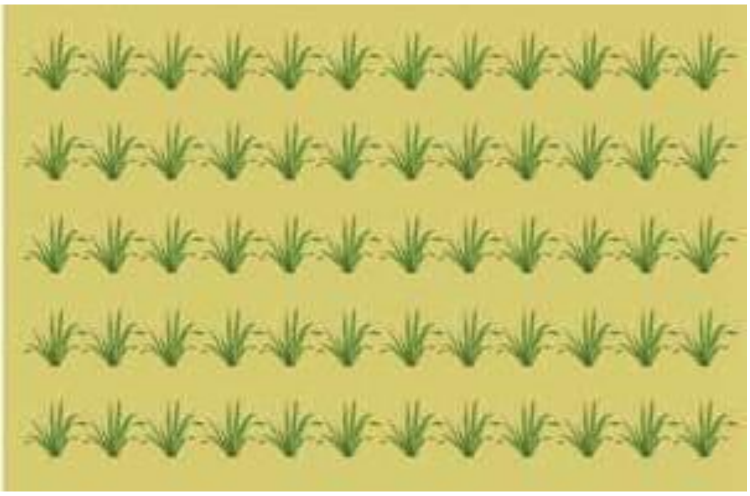


Figure 6.17 Horizontal Grass Planting
(Source: Godinho *et al*., 2023)

b. Vertical and downward grass planting can be applied on slopes less than 65 degrees in moist locations. 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**.

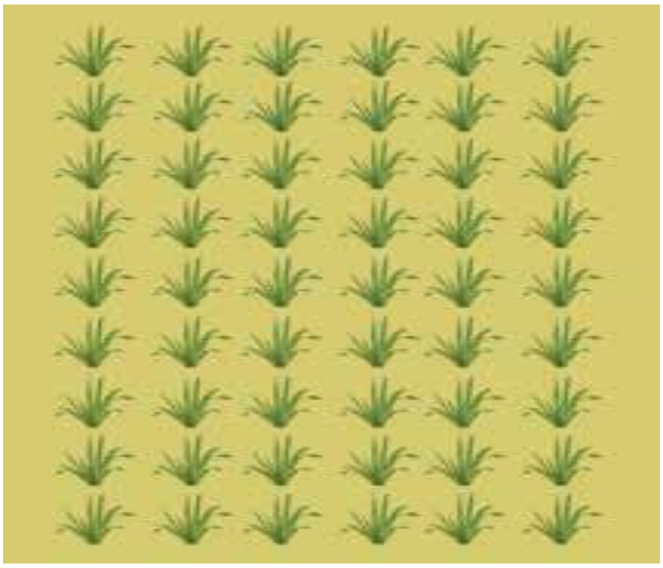


Figure 6.18 Vertical Grass Planting
(Source: Godinho *et al*., 2023)

c. Diagonal grass planting is used on slopes less than 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.**

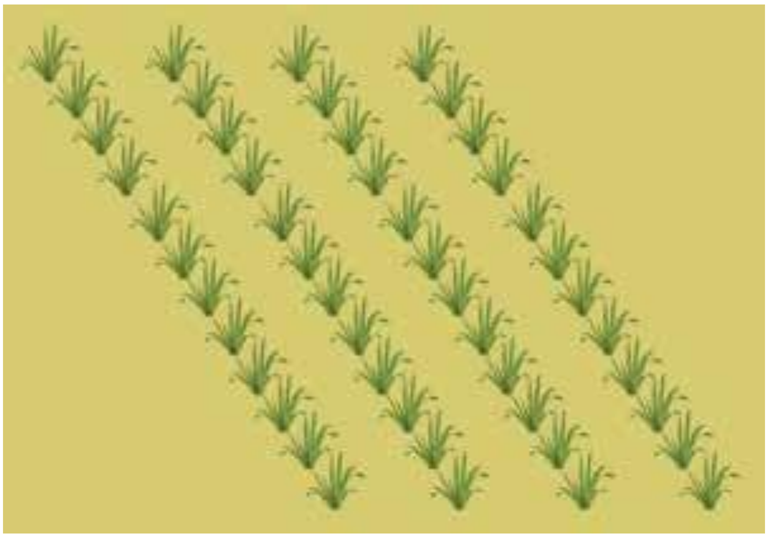


Figure 6.19 Diagonal Grass Planting
(Source: Godinho *et al*., 2023)

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, enhance water infiltration, increase soil productivity, extend the planting period, and improve farmers' income. This conservation technique can be applied in areas with high rainfall and high surface runoff conditions on slopes between 8-30%.

The construction of a rainwater reservoir involves excavating the soil, clay lining, and building runoff channels. When excavating, the embankment or edge of the reservoir should be higher than the soil surface to prevent soil from entering the reservoir. Drainage channels are made to prevent water from overflowing the reservoir. The distance between the drainage channel and the surface of the reservoir should be between 25-50 cm. Additionally, the clay lining is meant to reinforce the walls or embankments of the reservoir, typically made 25 cm thick. The walls of the reservoir should be sloped at an angle of 70-80 degrees or constructed in steps to prevent landslides. In sandy soils, the dam walls should be lined with plastic, cement, or a mixture of cement and clay (1:1 ratio) to prevent water from seeping too quickly. Finally, the runoff channel should face the area to be irrigated, with a width of 15-25 cm and a depth of 10-15 cm. Furthermore, the rainwater reservoir needs regular maintenance by cleaning the runoff channels, reservoir edges, dam walls, and removing silt deposits. The concept of rainwater reservoir construction is illustrated in **Figure 6.20.**

Figure 6.20 Construction of a Rainwater Reservoir
(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. These channels are often equipped with small waterfalls to prevent erosion and landslides by slowing down the water's flow. The construction of a drainage channel begins by excavating the soil to a minimum depth of 50 cm from the cultivation area and a base width of 50 cm. The channel floor on bench terraces is constructed with a slope of 0.1 - 0.5% outward. For every 1 meter along the drainage, grass is planted 20 cm across the channel. Next, the construction of the waterfall involves placing two or three split bamboo poles horizontally at the waterfall with a depth of 0.5 m, with the outer side of the bamboo facing outward. Maintenance efforts include cleaning the channel of sediment, trimming weeds, and repairing any damaged bamboo structures. The concept of the drainage channel is illustrated in **Figure 6.21.**

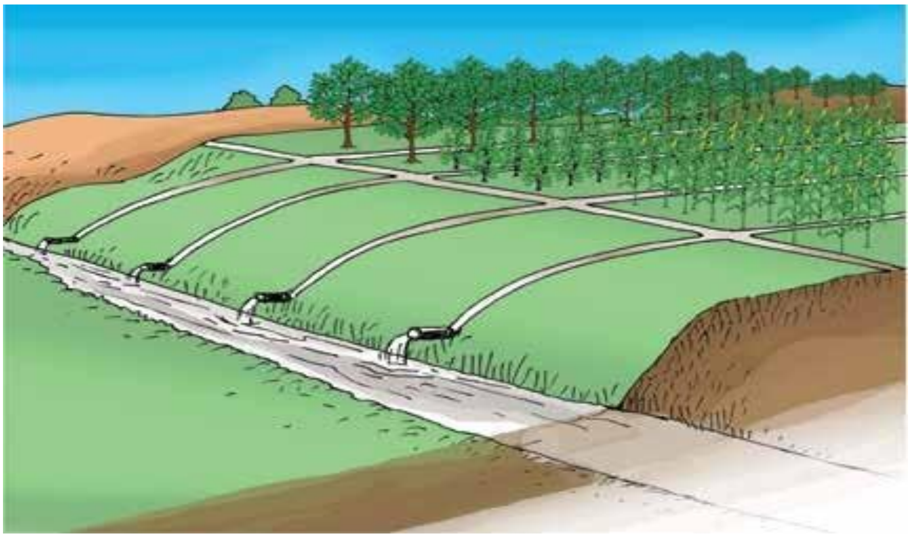


Figure 6.21 Drainage Channel
(Source: Godinho *et al.*, 2023)

8. Wattle Fence / Live Check Dam

A wattle fence is a line of short fences or walls made from vegetative materials, constructed along the contour to capture debris moving downhill on slopes, strengthen, and modify the slope. This conservation technique creates microhabitats for various plant species.

The wattle fence is constructed by clearing vegetation materials (wood or branches) to serve as posts. Next, 100 cm long posts are placed 100 cm apart along the fence line. Two additional posts, each 50 cm long, are placed between the main posts and should protrude about 20-30 cm above the ground. A trench (with a minimum depth of 15 cm) is dug along the contour between the installed posts. The lower ends of plant cuttings are placed in the trench, and the cuttings are woven between the posts, with the soil tightly packed back into the trench. The concept of wattle fence application is illustrated in **Figure 6.22**.

Figure 6.22 Wattle Fence

9. Vegetative Actions

Vegetative actions are aimed at achieving better soil and water conservation efficiency through alternating planting of fruit trees, spices, and food crops. Conservation practices must minimize soil disturbance (minimum tillage), enhance ground cover, and incorporate crop rotation to improve agricultural sustainability (Huang *et al*., 2022).

a. **Conservation Forests:** In soil and water conservation, conservation forests can reduce surface runoff erosion and maintain or restore soil fertility. Tree species and stand structure are the most important factors determining the effectiveness of conservation. Native tree species and layered vegetation structures (e.g., trees + shrubs + spices) are the priority reforestation patterns.

b. **Hedgerows:** The use of hedgerow plants is also effective in controlling slope soil erosion, trapping runoff, and improving soil fertility. Hedgerow plants that can be used include *Vetiveria zizanioides*, *Leucaena leucocephala*, Guinea grass, *Gamal* (*Gliricidia sepium*), *Calliandra calothyrsus*, elephant grass (*Pennisetum purpureum*), and others.

c. **Ground Cover:** The intensity of land cover is divided into:
   1) Full cover, primarily for areas prone to erosion, mountainous regions, near rivers, and reservoirs.
   2) Partial cover, applied only during certain seasons
   3) Rotational cover, applied in areas with light erosion divided into sub-areas for rotating cover
   4) Cover combined with planting, for areas with moderate erosion and very low vegetation cover.

Additionally, increasing vegetation cover can be achieved by using mulch, which consists of leaves, compost, and manure to cover the soil surface. The use of mulch can prevent soil moisture loss due to evaporation, prevent soil erosion, and control weeds. Materials that can be used for mulch include rice and corn straw, legume and vetiver grass residues, and plastic film (Huang *et al.,* 2022).

d. **Crop Rotation:** Crops grown in rotation yield more than those grown continuously. The yield benefit from crop rotation also depends on seasonal weather conditions and long-term practices. Long-term crop diversification can enhance agroecosystem productivity compared to monoculture systems and lead to reduced input usage. The combination of leguminous plants and brassicas tends to have a positive impact on the soil due to the combination of taproot and fibrous roots, creating a complex and diverse soil organism population (Quintarelli *et al*., 2022).

e. **Water Reservoirs:** According to Rustam (2010), an embung is an artificial structure designed to capture and store water with a small volume capacity, smaller than that of a reservoir or dam. Embung are typically built by damming small rivers or constructed away from rivers. The embung stores water during the rainy season, and the water is then used by a village only during the dry season according to the priority needs of the population, livestock, and gardens or rice fields. The amount of water needed determines the height of the embung and its storage capacity. An example of applying conservation through embung construction is shown in **Figure 6.23.**

Figure 6.23 Application of Water Reservoir

VII. LAND SUITABILITY EVALUATION FOR AGRICULTURE

Land suitability refers to the extent to which a land area is suitable for a specific use. For example, land can be classified as highly suitable for irrigated rice, moderately suitable for coffee, or marginally suitable for citrus crops. Land suitability can be evaluated 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 assessment reflects the land's capacity in its existing state, without additional interventions. Actual land suitability, or current suitability, refers to the land's condition in its natural state, without considering improvement efforts or management practices that could address existing limitations or constraints in each land unit or mapping unit. To determine the actual land suitability class, the evaluation begins by assessing the land quality based on the most limiting factor or the poorest land characteristic. The land suitability class is then determined based on the poorest/most limiting quality.
Potential land suitability refers to the suitability of land after improvements have been made. For instance, land that is currently classified as marginally suitable (S3) due to nutrient deficiencies may become moderately suitable (S2) or even highly suitable (S1) after soil amendments such as fertilization. Potential land suitability assessment is performed by implementing improvements that address the limiting factors affecting land quality, with the expectation that land suitability will improve. With the right technology, land that naturally has a low suitability class (actual suitability) can, through improvements, rise to a higher suitability class (potential suitability). However, not all land qualities or characteristics can be improved with current technologies, and some may require high levels of management to make improvements.

In land use planning, the primary focus is on potential land suitability, as this evaluation provides an overview of the land's maximum potential for various uses after improvements are made. Therefore, potential land suitability is crucial for planning the effective and sustainable use of land and determining the necessary improvement measures to achieve optimal outcomes

7.2 LAND SUITABILITY CLASSIFICATION SYSTEM

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

Table 7.1. Land Suitability Classification System (FAO, 1976)

Order	:	Indicates whether a land area is suitable or not for a specific use.
Class	:	Indicates the level of suitability of a land area.
Subclass	:	Indicates the type of limitations or the types of improvements that need to be made within each class.
Unit	:	Indicates the differences in the severity of limiting factors that affect the management of the subclass

Order and Class are typically used in land mapping at the reconnaissance level, **subclass** is used in semi-detailed land mapping, and **unit** is used for detailed land mapping. Order is also applied in land mapping at a coarse scale (exploration):

Order of Suitability

The order of suitability describes the general suitability of land, meaning whether a given land area is suitable or not for a specific land use purpose that has been considered. At this order level, land is categorized into suitable (S) and not suitable (N) land.

Suitable Order (S)

Land in this order can be used for a long time for a given purpose, and the benefits of land management will be satisfactory after accounting for the inputs provided, with little or no risk of damage to the land's resources.

Not Suitable Order (N)

Land in this order has various difficulties or constraints, either physically (such as very steep slopes, rocky areas, etc.) or economically (where the inputs provided are not balanced with the outputs produced, preventing its use for the intended purpose).

Suitability Class

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

Highly Suitable Class (S1)

Land that has no significant or noticeable limiting factors against sustainable land use, or only has minor limiting factors that do not substantially reduce land productivity.

Moderately Suitable Class (S2)

Land with moderately severe limitations that require a higher level of management to maintain. These limitations will reduce productivity or benefits and increase the required inputs.

Marginally Suitable Class (S3)

Land with severe limitations that make it difficult to maintain the required management level. These severe limitations will reduce productivity and benefits and require additional inputs to achieve the expected output.

Not Suitable Class (N1)

Land with very severe constraints that are difficult to overcome, preventing its sustainable use in the long term.

Class N2: Land with permanent limitations that prevent any possibility of sustainable land use in the long term.

7.3 LAND SUITABILITY EVALUATION RESULTS

Land suitability analysis is a fundamental step in designing sustainable land resource management strategies. 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 both the potential and limitations of the land's biophysical characteristics for the development of various agricultural, horticultural, 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 about the land's biophysical conditions, such as slope, vegetation cover, and drainage quality. Laboratory soil sample analysis complements this process by providing data on macro-nutrient content (Total Nitrogen, Available Phosphorus, Available Potassium), organic matter, cation exchange capacity (CEC), base saturation (BS), pH, and soil texture.

Subsequently, the data obtained is analyzed based on the growing requirements of each crop, both in its current condition and its potential suitability after various land improvement efforts, such as fertilization, organic matter addition, or the application of soil conservation techniques. This process generates comprehensive information for determining commodity development priorities, identifying limiting factors, and designing relevant technical solutions.

The placement of several types of crops in the same column in **Table 7.2** indicates that these crops share similar growing conditions and limiting factors. This means they require similar environmental conditions to grow optimally and face relatively the same constraints in cultivation. Conversely, crops placed in different columns have distinct growing conditions and limiting factors, requiring a tailored management approach to meet their specific needs.

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

A. Land Suitability Evaluation for Lospalos Sub-District

Lospalos Sub-District has moderate suitability for the development of various agricultural commodities, such as food crops (upland rice, cassava, corn, peanuts, and others), horticultural vegetables including shallots, green beans, chili, eggplant, and bitter melon, as well as fruit crops like banana, papaya, orange, rambutan, avocado, and mango. Additionally, flower crops such as rose, aster, and sunflower can be developed. Spices and medicinal plants like aromatic ginger and vetiver root are also suitable for development. Industrial crops, such as robusta coffee, cashew, tobacco, and sugarcane, can be cultivated. For grazing areas, leguminous plants and forage crops, such as elephantgrass and setaria, can be developed in Lospalos Sub-District with added inputs to improve soil fertility.

The main constraints in the development of agricultural crops in Lospalos Sub-District include low rainfall, the Dry Month period, drainage issues, and low levels of Total Nitrogen, Available Phosphorus, and Available Potassium as well as limited cation exchange capacity (CEC) and base saturation (BS). Additionally, physical land conditions such as shallow effective soil depth, slope, erosion hazards, surface rocks, rock outcrops, and flood risks pose challenges. However, most of these technical constraints can still be addressed through the application of appropriate technology and land management practices.

Recommended improvement measures include optimizing the irrigation system, constructing drainage channels, creating water storage ponds, applying balanced NPK fertilization, adding organic matter, creating planting holes, and implementing soil conservation techniques, such as the construction of terraces with supporting plants and ground cover. Furthermore, land management in areas with rock outcrops and surface rocks can be achieved through rock removal and the creation of planting holes in between the rocks. This strategy aims to enhance land efficiency and support agricultural productivity.

However, it is important to recognize that there are permanent constraints, such as temperature, that cannot be improved and must be considered when planning agricultural development strategies.

This area has the potential for moderate land suitability to support sustainable agriculture. However, crops such as potatoes, carrots, garlic, arabica coffee, Altingia, and pine are not recommended for cultivation in this Sub-District due to permanent temperature constraints that cannot be improved. Other crops that can be developed in Lospalos Sub-District are presented in Table 7.5.

B. Land Suitability Evaluation for Iliomar Sub-District

Iliomar Sub-District has moderate land suitability for the development of various agricultural commodities. Food crops such as irrigated rice, upland rice, corn, cassava, and sweet potato show suitable land conditions. Horticultural commodities, including vegetables (such as cucumber, eggplant, bitter melon, tomato, and long beans), fruits (orange, rambutan, avocado, durian, and mango), and flowers (rose, aster, and sunflower), also have promising development potential. Spices and medicinal plants like vanilla and pepper, as well as industrial crops such as robusta coffee, sugarcane, and coconut, are also viable for cultivation. Additionally, forage crops such as elephantgrass and setaria are moderately suitable. However, the cultivation of commodities like potatoes, carrots, garlic, arabica coffee, Altingia, and pine is not recommended due to permanent temperature constraints that cannot be technically improved.

The development of agricultural crops in Iliomar Sub-District faces several main constraints, both climatic and related to the physical and chemical properties of the soil. These limiting factors include low rainfall, a long Dry Month, poor drainage systems, and low nutrient content in the soil, such as Total Nitrogen, Available Phosphorus, Available Potassium, cation exchange capacity (CEC), and base saturation (BS). From a physical perspective, limitations include shallow effective soil depth, steep slopes, potential erosion hazards, surface rocks, rock outcrops, and seasonal flooding risks. However, most of these constraints are technical and can be addressed through the application of appropriate technology and land management practices.

Improvement measures that can be implemented include optimizing the irrigation system, constructing drainage channels and water storage ponds (*embung*), applying balanced NPK fertilization, adding organic matter, creating planting holes, and using soil conservation techniques such as terracing combined with support plants and ground cover.

In areas with surface rocks and rock outcrops, land management can be carried out by removing rocks and creating planting holes between the rocks. This approach aims to improve land use efficiency and support sustainable agricultural productivity. However, it is important to note that there are permanent limiting factors, such as temperature, that cannot be technically improved. Therefore, adaptation strategies must be carefully formulated in the agricultural development planning for this area.

Overall, Iliomar Sub-District has a relatively good land suitability level for supporting sustainable agriculture. In addition to the commodities mentioned above, Table 7.5 presents a list of other crops with potential for development in this area

C. Land Suitability Evaluation for Lautém Sub-District

Lautém Sub-District has potential for the development of food crops such as irrigated rice, upland rice, corn, and soybean. Horticultural crops, including vegetables (such as shallots, chili, bitter melon, long beans), fruits (banana, avocado, rambutan, and snakefruit), and flowers (rose, aster, sunflower), are also suitable for cultivation. Additionally, spices and medicinal plants like ginger, cinnamon, and galangal, as well as industrial crops such as tobacco and robusta coffee, can be developed. For grazing and forage crops, elephant grass and legumes show moderate land suitability. Other crops that can be developed in Lautém Sub-District are listed in Table 7.5.

Land suitability is influenced by several limiting factors, including slope, rainfall intensity, drainage, soil depth, Dry Month duration, coarse materials, flood potential, and erosion risk. These factors can technically be addressed through measures such as optimizing the irrigation system, creating drainage channels, and applying soil conservation techniques, such as terracing combined with support plants and ground cover. However, there are also permanent limiting factors, such as temperature, surface rocks, and rock outcrops, that cannot be improved. Despite these limitations, land management is still possible through surface rock removal and the creation of planting holes between the rock outcrops, which can help improve land use efficiency and support crop productivity.

This area holds potential for sustainable agriculture. However, crops such as potatoes, carrots, garlic, arabica coffee, Altingia, and pine cannot be developed in this region due to permanent temperature constraints that cannot be mitigated.

D. Land Suitability Evaluation for Luro Sub-District

Luro Sub-District has potential for the development of food crops such as cassava, sweet potato, and corn. Horticultural crops, including vegetables (such as chili, bell pepper, cucumber), fruits (orange, jackfruit, soursop, and pineapple), and flowers (rose, aster, sunflower), are also suitable for cultivation. Additionally, spices and medicinal plants such as candlenut, pepper, and cardamom, as well as industrial crops like tobacco and cashew, are viable for development. For grazing and forage crops, elephant grass and legumes can be cultivated. While the land in this area is generally suitable for sustainable agriculture, the cultivation of crops such as potatoes, carrots, garlic, arabica coffee, Altingia, and pine is not recommended due to permanent temperature constraints that cannot be technically improved. Other crops that can be developed in Luro Sub-District are presented in **Table 7.5**.

The main constraints in the development of agricultural crops in Luro Sub-District include low rainfall, a long Dry Month, drainage issues, and low levels of Total Nitrogen (*N-Total*), Available Phosphorus (*P-Tersedia*), Available Potassium (*K-Tersedia*), as well as limited cation exchange capacity (CEC) and base saturation (BS). Furthermore, physical land conditions such as shallow effective soil depth, steep slopes, erosion risks, surface rocks, rock outcrops, and flood hazards are also limiting factors. However, most of these technical constraints can still be addressed through the application of appropriate technology and land management practices.

Improvement measures include optimizing the irrigation system, constructing drainage channels, creating water storage ponds (*embung*), applying balanced NPK fertilization, adding organic matter, creating planting holes, and implementing soil conservation techniques, such as constructing terraces with supporting plants and ground cover.

In areas with surface rocks and rock outcrops, land management can be carried out by removing rocks and creating planting holes between the rocks. This strategy aims to improve land use efficiency and support agricultural productivity. However, it must be acknowledged that permanent limiting factors, such as temperature, cannot be improved and must be considered in the agricultural development planning process. Therefore, adaptation strategies should be carefully incorporated into the development planning for this area.

E. Land Suitability Evaluation for Lore Sub-District

Lore Sub-District has moderate suitability for the development of various agricultural commodities, including food crops such as upland rice, cassava, corn, peanuts, and others. Horticultural crops such as vegetables (green beans, chili, eggplant, and bitter melon), fruits (banana, papaya, orange, rambutan, avocado, and mango), and flowers (rose, aster, and sunflower) have promising development potential. Spices and medicinal plants such as aromatic ginger and vetiver root, as well as industrial crops like robusta coffee, cashew, and tobacco, are also suitable for cultivation. For grazing areas, leguminous plants and forage crops like elephant grass and Setaria can be developed with added inputs to improve soil fertility.

The main constraints in the development of agricultural crops in Lore Sub-District include low rainfall, long dry seasons, drainage issues, low levels of Total Nitrogen (*N-Total*), Available Phosphorus (*P-Tersedia*), Available Potassium (*K-Tersedia*), and limited cation exchange capacity (CEC) and base saturation (BS). Additionally, physical land conditions such as shallow effective soil depth, steep slopes, erosion hazards, surface rocks, rock outcrops, and flood risks pose significant challenges. However, most of these technical constraints can still be addressed through proper land management practices.

Improvement measures that can be implemented include optimizing the irrigation system, constructing drainage channels, creating water storage ponds (*embung*), applying balanced NPK fertilization, adding organic matter, creating planting holes, and implementing soil conservation techniques, such as constructing terraces with supporting plants and ground cover. Additionally, land management in areas with surface rocks and rock outcrops can be achieved by removing rocks and creating planting holes between the rocks.

This area holds potential for sustainable agriculture. However, crops such as potatoes, carrots, garlic, arabica coffee, Altingia, and pine cannot be developed in this region due to permanent temperature constraints that cannot be improved. Other crops that can be developed in Lore Sub-District are presented in Table 7.5.

F. Land Suitability Evaluation for Tutuala Sub-District

Tutuala Sub-District has potential for the development of food crops such as cassava, soybean, and corn. Horticultural crops, including vegetables (mustard greens, eggplant, bitter melon), fruits (guava, durian, and pineapple), and flowers (rose, aster, and sunflower), are also suitable for cultivation. Additionally, spices and medicinal plants like lemongrass, pepper, and aromatic ginger, as well as industrial crops such as coconut, cocoa, and cloves, can be developed. For grazing and forage crops, elephantgrass and legumes are viable. Although the land in this region is generally suitable for sustainable agriculture, the cultivation of crops such as potatoes, carrots, garlic, arabica coffee, Altingia, and pine is not recommended due to permanent temperature constraints that cannot be improved. Other crops that can be developed in Tutuala Sub-District are presented in Table 7.5.

Land suitability in this area is influenced by several limiting factors, including slope, rainfall intensity, drainage, soil depth, Dry Month duration, coarse materials, flood potential, and erosion risk. These factors can technically be addressed through optimizing the irrigation system, constructing drainage channels, and applying soil conservation techniques, such as constructing terraces with supporting plants and ground cover. However, permanent limiting factors such as temperature, surface rocks, and rock outcrops cannot be improved. Nevertheless, land management is still possible through the removal of surface rocks and the creation of planting holes between the rock outcrops, which will help improve land use efficiency and support crop productivity.

Table 7.2 Land Suitability Evaluation Matrix for Lautém Distric

Commodities	Sub-District	Limiting Factors	Potential Land Suitability
Food Commodities			
Irrigated Rice	• Iliomar • Lautém	**S3:** Flooding	**S1 :** Flooding
Rainfed Rice	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S2:** Slope, Surface Rocks, Rock Outcrops	**S2:** Surface Rocks, Rock Outcrops, Flooding
Dryland Food Commodities			
Upland Rice	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**S3:** Drainage **S2:** Slope, Surface Rocks, Rock Outcrops	**S2:** Surface Rocks, Rock Outcrops
Sweet Potato Cassava	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Drainage, Rock Outcrops **S2:** Effective Depth, Erosion, Slope, Surface Rocks	**S2:** Effective Depth, Surface Rocks, Rock Outcrops, Flooding
Corn	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Drainage **S2:** Rainfall, Slope, Surface Rocks, Rock Outcrops	**S2:** Surface Rocks, Rock Outcrops, Flooding
Cowpea	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rainfall, Rock Outcrops **S2:** Erosion, Slope, Surface Rocks	**S3:** Rock Outcrops **S2:** Surface Rocks, Flooding
Wheat	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Drainage **S2:** Temperature, Rainfall, Slope, Erosion, Surface Rocks, Rock Outcrops	**S2:** Temperature, Surface Rocks, Rock Outcrops, Flooding

Peanut **Mung Bean**	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rainfall, Drainage, Slope, Rock Outcrops **S2:** Temperature, Surface Rocks	**S3:** Rock Outcrops **S2:** Temperature, Surface Rocks, Flooding
Taro	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Temperature, Rainfall, Drainage, Rock Outcrops **S2:** Erosion, Slope, Surface Rocks	**S3:** Temperature, Rock Outcrops **S2:** Surface Rocks, Flooding
Sorgum	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Rainfall, Flooding **S3:** Temperature **S2:** Erosion, Slope, Surface Rocks, Rock Outcrops	**S3:** Temperature **S2:** Rainfall, Surface Rocks, Rock Outcrops, Flooding
HORTICULTURAL VEGETABLE COMMODITIES			
Potatoes	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Temperature, Flooding **S3:** Rainfall, Drainage, Slope, Rock Outcrops, Erosion **S2:** Surface Rocks, Texture, N-Total, Available Phosphorus, Available Potassium, CEC, Base Saturation	**N:** Temperature **S2:** Slope, Rock Outcrops, Surface Rocks, Texture
Carrots **Garlic**	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Temperature, Flooding **S3:** Drainage, Slope, Rock Outcrops, Erosion **S2:** Rainfall, Surface Rocks, Texture, pH, N-Total, Available Phosphorus, Available Potassium, CEC, Base Saturation	**N:** Temperature **S2:** Slope, Rock Outcrops, Surface Rocks, Texture
Chili	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Rainfall, Flooding **S3:** Drainage, Slope, Rock Outcrops, Erosion **S2:** Surface Rocks, pH, N-Total, Available Phosphorus, Available Potassium, CEC, Base Saturation	**S2:** Slope, Rock Outcrops, Surface Rocks

Shallot	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Drainage, Slope, Rock Outcrops, Erosion **S2:** Temperature, rainfall, surface rock, texture, soil pH, Total Nitrogen, Available Phosphorus, Available Potassium, cation exchange capacity (CEC), base saturation (BS)	**S2:** Slope, Rock Outcrops, Temperature, Surface Rocks, Texture
Bell Pepper **Green Beans** **Cabbage**	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rainfall, Drainage, Slope, Erosion **S2:** Temperature, Surface Rocks, Rock Outcrops, Texture, pH, N-Total, Available Phosphorus, Available Potassium, CEC, Base Saturation	**S2:** Temperature, Surface Rocks, Rock Outcrops, Texture
Caisim	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** rainage, Slope, Rock Outcrops, Erosion **S2:** Temperature, Rainfall, Dry Month, Surface Rocks, Texture, pH, N-Total, Available Phosphorus, Available Potassium, CEC, Base Saturation	**S2:** Slope, Rock Outcrops, Temperature, Dry Month, Surface Rocks, Texture
Snow Pea	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Temperature, Drainage, Slope, Rock Outcrops, Erosion **S2:** Rainfall, Surface Rocks, pH, N-Total, Available Phosphorus, Available Potassium, CEC, Base Saturation	**S2:** Temperature, Slope, Rock Outcrops, Surface Rocks
Cucumber	• Iliomar • Lautém • Lospalos • Luro • Lore	**S3:** Rainfall, Drainage, Slope, Rock Outcrops, Flooding, Erosion **S2:** Surface Rocks, N-Total, Available Phosphorus,	**S2:** Slope, Rock Outcrops, Surface Rocks

	• Tutuala	Available Potassium, CEC, Base Saturation	
Eggplant **Tomato** **Vegetable**	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rainfall, Drainage, Slope, Erosion **S2:** Temperature, Surface Rocks, Rock Outcrops, pH, N-Total, Available Phosphorus, Available Potassium, CEC, Base Saturation	**S2:** Slope, Temperature, Surface Rocks, Rock Outcrops
Cabbage	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rainfall, Drainage, Slope, Erosion **S2:** Temperature, Surface Rocks, Rock Outcrops, Texture, pH, N-Total, Available Phosphorus, Available Potassium, CEC, Base Saturation	**S2:** Slope, Temperature, Surface Rocks, Rock Outcrops, Texture
Bitter Melon **Long Beans**	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rainfall, Drainage, Slope, Erosion **S2:** Temperature, Surface Rocks, Available Phosphorus, N-Total, Available Potassium, CEC, Base Saturation	**S2:** Slope, Temperature, Surface Rocks, Rock Outcrops
HORTICULTURAL FRUIT COMMODITIES			
Avocado **Mango** **Guava Jackfruit** **Soursop** **Breadfruit** **Longan** **Custard Apple** **Grapes**	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rainfall, N-Total, Available Phosphorus **S2:** Drainage, Erosion, Slope, Rock Outcrops, Surface Rocks, Texture, Available Potassium	**S2:** Flooding, Rock Outcrops, Surface Rocks
Watermelon **Melon**	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rainfall, N-Total, Available Phosphorus **S2:** Drainage, Erosion, Slope, Rock Outcrops, Surface Rocks, Texture, Available Potassium	**S2:** Flooding, Rock Outcrops, Surface Rocks

Banana	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Dry Month, Surface Rocks, N-Total, Available Phosphorus **S2:** Drainage, Slope, Surface Rocks, Available Potassium, Texture	**S2:** Flooding, Dry Month, Surface Rocks, Surface Rocks, Texture
Papaya	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rock Outcrops, N-Total, Available Phosphorus **S2:** Temperature, Rainfall, Slope, Surface Rocks, pH, Available Potassium	**S2:** Flooding, Temperature, Rock Outcrops, Surface Rocks
Orange	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rock Outcrops, N-Total, Available Phosphorus **S2:** Effective Depth, Slope, Surface Rocks, Texture, Available Potassium	**S2:** Flooding, Rock Outcrops, Surface Rocks, Effective Depth, Texture
Rambutan	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rainfall, Rock Outcrops, N-Total, Available Phosphorus **S2:** Effective Depth, Slope, Surface Rocks, Available Potassium	**S2:** Flooding, Rock Outcrops, Surface Rocks, Effective Depth
Snakefruit	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rock Outcrops, N-Total, Available Phosphorus **S2:** Slope, Surface Rocks, pH, Available Potassium	**S2:** Flooding, Rock Outcrops, Surface Rocks
Durian	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rainfall, Rock Outcrops, N-Total, Available Phosphorus **S2:** Temperature, Effective Depth, Slope, Surface Rocks, Available Potassium	**S2:** Flooding, Temperature, Rock Outcrops, Surface Rocks, Effective Depth
Pineapple	• Iliomar • Lautém • Lospalos	**N:** Flooding	**S2:** Flooding, Rock Outcrops, Surface Rocks

	• Luro • Lore • Tutuala	**S3:** Rock Outcrops, N-Total, Available Phosphorus **S2:** Rainfall, Slope, Surface Rocks, Available Potassium	
Stroberi	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Slope, Rock Outcrops, N-Total, Available Phosphorus **S2:** Temperature, Erosion, Surface Rocks, Available Potassium	**S2:** Flooding, Rock Outcrops, Surface Rocks, Temperature
Passion Fruit	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Temperature, Rainfall, Rock Outcrops, N-Total, Available Phosphorus **S2:** Effective Depth, Slope, Surface Rocks, Available Potassium	**S3:** Temperature **S2:** Flooding, Rock Outcrops, Surface Rocks, Effective Depth
HORTICULTURAL FLOWER COMMODITIES			
Aster **Rose**	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Slope, Flooding **S3:** Drainage, Rainfall, Rock Outcrops **S2:** Temperature, Erosion Risk, Surface Rocks, N-Total	**S2:** Temperature, Slope, Rock Outcrops, Surface Rocks
Sun Flower	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Slope, Flooding **S3:** Drainage, Rainfall, Rock Outcrops **S2:** Erosion Risk, Surface Rocks, N-Total, Available Potassium	**S2:** Slope, Surface Rock
SPICE AND MEDICINAL PLANT COMMODITIES			
Ginger	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Rainfall, Dry Month, Flooding **S3:** Temperature, Slope **S2:** Drainage, Effective Depth, Surface Rocks, Rock Outcrops	**S3:** Temperature, Dry Month **S2:** Rainfall, Effective Depth, Surface Rocks, Rock Outcrops
Vetiver Root	• Iliomar • Lautém	**N:** Slope **S3:** Drainage, Rainfall	**S2:** Temperature, Slope, Surface Rocks, Rock Outcrops

	• Lospalos • Luro • Lore • Tutuala	**S2:** Temperature, Surface Rocks, Rock Outcrops	
Lemongrass	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Drainage, Rainfall **S2:** Temperature, Surface Rocks, Rock Outcrops, N-Total, Available Phosphorus, Available Potassium	**S2:** Temperature, Surface Rocks, Rock Outcrops
Vanilla	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Drainage, Dry Month, Rock Outcrops **S2:** Temperature, Effective Depth, Slope, Surface Rocks, N-Total, Available Phosphorus, Available Potassium	**S2:** Temperature, Dry Month, Effective Depth, Surface Rocks, Rock Outcrops
Candlenut	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**S3:** Drainage, Rock Outcrops **S2:** Dry Month, Effective Depth, Slope, Surface Rocks	**S2:** Effective Depth, Surface Rocks, Rock Outcrops
Cinnamon	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Dry Month **S3:** Drainage **S2:** Temperature, Rainfall, Effective Depth, Slope, Surface Rock	**S3:** Dry Month **S2:** Temperature, Effective Depth, Surface Rock
Nutmeg	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Rainfall, Dry Month **S3:** Drainage, Rock Outcrops **S2:** Temperature, Erosion, Effective Depth, Slope, Surface Roc	**S3:** Dry Month **S2:** Temperature, Effective Depth, Surface Rocks, Rock Outcrops
Pepper	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**S3:** Drainage, Dry Month, Rock Outcrops **S2:** Rainfall, Slope, Surface Rock	**S2:** Dry Month, Surface Rocks, Rock Outcrop

Jatropha	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**S3:** Drainage, Rock Outcrop **S2:** Rainfall, Erosion, Slope, Surface Rock	**S2:** Rock Outcrops, Surface Rock
Aromatic Ginger	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S2:** Temperature, Drainage, Rainfall, Effective Depth, Slope, Surface Rocks, Rock Outcrop	**S2:** Temperature, Effective Depth, Surface Rocks, Rock Outcrop
Turmeric	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S2:** Temperature, Rainfall, Erosion, Effective Depth, Slope, Surface Rocks, Rock Outcrops, N-Total, Available Phosphorus, Available Potassium	**S2:** Temperature, Effective Depth, Surface Rocks, Rock Outcrops
Galangal Sesame	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Rainfall, Flooding **S3:** Effective Depth **S2:** Drainage, Erosion, Slope, Surface Rocks, Rock Outcrops	**S3:** Flooding **S2:** Rainfall, Effective Depth, Surface Rocks, Rock Outcrop
Cardamom	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Rainfall, Flooding **S3:** Effective Depth, Slope **S2:** Drainage, Erosion, Surface Rocks, Rock Outcrop	**S2:** Rainfall, Effective Depth, Effective Depth, Flooding
INDUSTRIAL COMMODITIES			
Rubber	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Dry Month **S3:** Rainfall, Rock Outcrops, N-Total, Available Phosphorus, Available Potassium **S2:** Temperature, Drainage, Effective Depth, Surface Rocks	**S3:** Dry Month **S2:** Temperature, Rock Outcrops, Surface Rocks, Effective Depth
Coconut	• Iliomar • Lautém • Lospalos • Luro	**N:** Flooding **S3:** Dry Month, Rock Outcrops, N-Total, Available	**S3:** Dry Month, Rock Outcrops, Surface Rocks, Effective Depth

	• Lore • Tutuala	Phosphorus, Available Potassium **S2:** Rainfall, Effective Depth, Surface Rocks	
Oil Palm	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Dry Month **S3:** Rock Outcrops, N-Total, Available Phosphorus, Available Potassium **S2:** Rainfall, Effective Depth, Surface Rocks	**S3:** Dry Month **S2:** Rock Outcrops, Surface Rocks, Effective Depth
Arabika Coffee	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Temperature, Dry Month, Flooding **S3:** Rock Outcrops **S2:** Effective Depth, Surface Rocks	**N:** Temperature **S3:** Dry Month **S2:** Rock Outcrops, Effective Depth, Surface Rocks
Robusta Coffee	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rainfall, Rock Outcrops, N-Total, Available Phosphorus, Available Potassium **S2:** Temperature, Drainage, Dry Month, Effective Depth, Surface Rocks	**S2:** Rock Outcrops, Temperature, Effective Depth, Surface Rocks
Cacao, Clove	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Dry Month, Flooding **S3:** Rock Outcrops, N-Total, Available Phosphorus, Available Potassium **S2:** Effective Depth, Surface Rocks	**S3:** Dry Month **S2:** Rock Outcrops, Effective Depth, Surface Rocks
Tea	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Dry Month, Flooding **S3:** Temperature, Rainfall, Rock Outcrops, N-Total, Available Phosphorus, Available Potassium **S2:** Effective Depth, Surface Rocks	**S3:** Dry Month, Temperature **S2:** Rock Outcrops, Effective Depth, Surface Rocks
Tobacco	• Iliomar • Lautém • Lospalos • Luro	**N:** Rainfall, Flooding	**S2:** Rock Outcrops, Surface Rock

	• Lore • Tutuala	**S3:** Rock Outcrops, N-Total, Available Phosphorus, Available Potassium **S2:** Erosion, Surface Rocks	
Sugarcane	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Slope, Rock Outcrops, N-Total, Available Phosphorus, Available Potassium **S2:** Erosion, Surface Rocks	**S2:** Rock Outcrops, Surface Rocks
Cashew	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Flooding **S3:** Rock Outcrops, N-Total, Available Phosphorus, Available Potassium **S2:** Drainage, Rainfall, Dry Month, Slope, Surface Rocks	**S2:** Rock Outcrops, Dry Month, Surface Rocks
Melinjo	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**N:** Dry Month, Flooding **S3:** Rock Outcrops, N-Total, Available Phosphorus, Available Potassium **S2:** Effective Depth, Surface Rocks	**S3:** Dry Month **S2:** Rock Outcrops, Effective Depth, Surface Rocks
Cotton	• Iliomar • Lautém • Lospalos • Luro • Lore • Tutuala	**S3:** Rock Outcrops, N-Total, Available Phosphorus, Available Potassium **S2:** Temperature, Rainfall, Slope, Surface Rock	**S2:** Temperature, Rock Outcrops, Surface Rock
GRAZING AREA AND LIVESTOCK FEED			
Elephantgrass	• Lautém • Lospalos • Luro • Lore • Tutuala • Iliomar	**N:** Flooding **S3:** Rock Outcrops **S2:** Surface Rocks, Drainage, Rainfall, N-Total, Available Phosphorus, Available Potassium	**S3:** Rock Outcrop **S2:** Flooding, Surface Rock
Setaria	• Lautém • Lospalos • Luro • Lore • Tutuala • Iliomar	**N:** Flooding **S3:** Rock Outcrops **S2:** Surface Rocks, Drainage, N-Total, Available Phosphorus, Available Potassium	**S3:** Rock Outcrops **S2:** Flooding, Surface Rocks

Legumes	• Lautém • Lospalos • Luro • Lore • Tutuala • Iliomar	**N:** Flooding **S3:** Rock Outcrops **S2:** Surface Rocks, Drainage, Erosion, Slope, N-Total, Available Phosphorus, Available Potassium	**S3:** Rock Outcrops **S2:** Flooding, Surface Rock

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

7.4 LAND IMPROVEMENT EFFORTS

Efforts to improve each limiting factor are crucial for enhancing productivity and the sustainability of the agricultural sector. Various challenges, such as shallow effective soil depth, poor drainage, erosion hazards, and surface rocks, require appropriate solutions to maximize land potential. On the other hand, certain soil chemical parameters, such as Organic Carbon *(C-Organik*) and nutrients (Total Nitrogen [*N-Total*], Available Phosphorus [*P-Tersedia*], Available Potassium [*K-Tersedia*]), which are relatively low in their current state, require land improvement efforts to transform them into potential land for agricultural commodity development.

Recommendations for land improvement efforts for each limiting factor, as the basis for implementing the enhancement of land suitability potential for agricultural commodity development, are presented in **Table 7.3**. The level of improvement required to transform current land quality into potential land quality, according to management practices, is presented in **Table 7.4**. This information is then used by the researchers as a guideline for transforming actual land suitability into potential suitability.

Table 7.3 Recommendations for Improvement Efforts for Each Limiting Factor

No	Land Quality/Characteristics	Improvement Measures	Management Level
1.	**Temperature (tc)** Average annual temperatur	No improvement possible Replacement with suitable commodities/varieties	Cannot be improved
2.	**Water Availability (wa)** - Annual rainfall - Rainfall during growth period	Irrigation / creating ponds / drip irrigation p pattern adjustment / planting calendar	Moderate, High
3.	**Root Media (rc)** - Drainage - Texture	Drainage system improvements, such as creating drainage channels, ridges / beds	Moderate, High High

	- Effective Depth - Coarse Fragment	Cannot be improved, can be mitigated by adding organic matter nerally cannot be improved, except in soft and thin hardpan layers which can be broken during land preparation Depending on their amount and distribution in the profile (if the amount is <35%, it is called Obstructing Layer, which can be mitigated by adding organic matter and minimum soil management; if >90%, it is called Restricting Layer, which is hard to improve).	Moderate, High High
4.	Nutrient Retention (nr) - Cation Exchange Capacity (CEC) - Base Saturation (KB) - pH - Organic Carbon (C-organic)	Addition of organic matter Liming, addition of organic matter Liming if soil pH is low, while if pH is high, sulfur or ZA fertilizer can be added Addition of organic matter/organic fertilizers, and returning litter to the soil	Moderate, High Moderate, High Moderate, High Moderate, High
5.	Nutrient Availability (na) - Total Nitrogen - Available Phosphorus - Available Potassium	Nitrogen Fertilization (Urea and ZA) Phosphorus Fertilization (SP36 and TSP) Potassium Fertilization (KCl) Compound Fertilizers (NPK)	Low, Moderate, High Low, Moderate, High Low, Moderate, High
6.	Erosion Hazard (eh) - Slope (%) - Erosion Hazard	Erosion control, terracing, contour planting, cover crops, mulching, and agroforestry practices	Moderate, High
7.	Flood Hazard (fh) - Height - Duration	Construction of flood barriers, drainage systems to speed up water drainage, and recharge wells	High
8.	- Land Preparation (lp)		

	- Surface Rock (%) - Rock Outcrop (%)	If few (remove rocks), if many/very many, apply TOT (no-till), create planting holes, add organic matter	Moderate, High
9.	Technical Cultivation Improvement	Field Establishment, Pruning, Maintenance/ Care	Moderate, High

Explanation:

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

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

No	Land Quality and Characteristics	Management Level Medium	 High	Improvement Type
1	**Radiation Regime**	-	-	-
2	**Temperature Regime**	-	-	-
3	**Air Humidity Regime**	-	-	-
4	**Water Availability** - Dry Month - Rainfall	 + +	 ++ ++	 Plant Combinations Irrigation
5	**Root Media** - Drainage - Soil Texture - Effective Depth - Peat, Maturity - Peat Thickness	 + - - - -	 ++ + + - -	 Drainage Channels *) Addition of Organic Matter Planting Holes and Organic Matter Addition - -
6	**Nutrient Retention** - Cation Exchange Capacity (CEC) - Base Saturation (KB) - pH - Organic Carbon	 - - + +	 + + + ++	 Organic Matter Addition
7	**Nutrient Availability** - Total Nitrogen - Available Phosphorus - Available Potassium	 + + +	 ++ ++ ++	 Urea Fertilizer SP36 and TSP Fertilizers KCL Fertilizer
8	- **Flood Hazard** - Period - Frequency	 + +	 ++ ++	 - -
9	- **Salinity** Salinity	 +	 ++	Irrigation and Addition of Organic Matter
10	**Toxicity** - Aluminum Saturatio - Depth of Pyrite	 + -	 ++ +	Lime Groundwater Level Management
11	**Ease of Cultivation**	-	+	Mechanization
12	**Terrain Mechanization Potential**	-	+	Terracing
13	**Erosion Hazard**	+	++	Soil Conservation Measures

Explanation:

- **-** No improvements can be made to the current condition
- \+ The condition can be improved and results in an increase of one suitability class higher (e.g., S3 to S2).
- ++ The condition can be improved and results in an increase of two suitability classes higher (e.g., S3 to S1)

***)** Poor drainage can be improved to a better level by creating drainage channels, but very fast or excessively fast drainage is difficult to change into moderate or good drainage.

7.5 LAND USE RECOMMENDATIONS

The land use recommendations in this study are based on the results of the land suitability evaluation, considering various improvement interventions that can be implemented. This analysis follows a matching approach between the current land characteristics and the crop requirements, as outlined in Table 7.3 and **7.4.** The process produces land use recommendations that not only reflect the existing biophysical conditions but also take into account the potential for enhancing suitability through management actions and land improvements. Land use recommendations for various agricultural commodities, forestry, and grazing/feed crops are presented in Table 7.5.

The selection of recommended crop commodities is done carefully, based on the 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, erosion and flood risks, and ease of land cultivation. Each of these factors is analyzed from the perspective of its potential for improvement, whether through mechanical, chemical, or biological approaches.

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

Therefore, 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 recommendations requires synergy between farmers, agricultural extension officers, and institutional support from the government in the form of policies, technical assistance, and access to production resources.

These recommendations are expected to serve as a strategic reference in planning the sustainable use of land resources, while maintaining productivity, efficiency, and environmental sustainability. Furthermore, this document is intended to support decision-making in the zoning of priority commodity development, both at the site level and in regional planning scales.

Table 7.5 Land Use Recommendations (Guidelines) for the Development of Agricultural Commodities, Industry, Horticulture, Spices and Medicinal Plants, and Forestry in Lautém District

NO	DISTRICT	SUB-DISTRICT	CROP COMMODITIES	DRYLAND AGRICULTURE (PLANTATIONS & HORTICULTURE)	FORESTRY	FORAGE & PASTURELAND
1	Lautém	Lospalos	**DRYLAND FOOD CROPS** **S2:** Irrigated rice (rainfed), upland rice, cassava, sweet potato, corn, wheat, soybean **S3:** Cowpea, peanuts, mung beans, taro, sorghum,	**INDUSTRIAL** **S3:** Rubber, coconut, oil palm, cacao, clove, tea, melinjo, quinine **S2:** Robusta coffee, tobacco, sugarcane, cashew, cotton, kapok **FRUITS** **S3:** Passion fruit **S2:** Banana, papaya, orange, rambutan, avocado, mango, guava, durian, watermelon, melon, jackfruit, soursop, custard apple, breadfruit, snake fruit, pineapple, longan, strawberry, grape **VEGETABLES** **S2:** Shallots, green beans, broccoli, chili, bell pepper, caisim, snow pea, cucumber, eggplant, bitter melon, vegetable tomato, cabbage, long beans **FLOWERS** **S2**: Rose, sunflower, aster **SPICES & MEDICINAL PLANTS** **S3**: Ginger, cinnamon, nutmeg, galangal	**S3:** Teak, mahogany, albizia, eucalyptus **S2:** Agathis, leucaena, acacia, melaleuca, sandalwood	**S3:** Elephant grass, Setaria, legumes, grazing

				S2: Vetiver root, lemongrass, vanilla, candlenut, pepper, jatropha, aromatic ginger, turmeric, cardamom		
2	Lautém	Iliomar	WETLAND FOOD CROPS **S1:** Irrigated rice DRYLAND FOOD CROPS **S2:** Rainfed rice, upland rice, cassava, sweet potato, corn, wheat, soybean **S3:** Cowpea, peanuts, mung beans, taro, sorghum	INDUSTRIAL **S3:** Rubber, coconut, oil palm, cacao, clove, tea, melinjo, quinine **S2:** Robusta coffee, tobacco, sugarcane, cashew, cotton, kapok FRUITS **S3:** Passion fruit **S2:** Banana, papaya, orange, rambutan, avocado, mango, guava, durian, watermelon, melon, jackfruit, soursop, custard apple, breadfruit, snake fruit, pineapple, longan, strawberry, grape VEGETABLES **S2:** Shallots, green beans, broccoli, chili, bell pepper, caisim, snow pea, cucumber, eggplant, bitter melon, vegetable tomato, cabbage, long beans FLOWERS **S2:** Rose, aster, sunflower SPICES & MEDICINAL PLANTS **S3:** Ginger, cinnamon, nutmeg, galangal **S2:** Vetiver root, lemongrass, vanilla, candlenut, pepper, jatropha, aromatic ginger, turmeric, cardamom	**S3:** Teak, mahogany, albizia, eucalyptus **S2:** Agathis, leucaena, acacia, melaleuca, sandalwood	**S3:** Elephant grass, Setaria, Legumes, Grazing

3	Lautém	Lautém	WETLAND CROPS **S1:** Irrigated rice DRYLAND CROPS **S2:** Rainfed rice, upland rice, cassava, sweet potato, corn, wheat, soybean, **S3:** Cowpea, peanuts, mung beans, taro, sorghum,	INDUSTRIAL **S3:** Rubber, coconut, oil palm, cacao, clove, tea, melinjo, cinchona **S2:** Robusta coffee, tobacco, sugarcane, cashew, cotton, kapok FRUITS **S3:** Passion fruit **S2:** Banana, papaya, orange, rambutan, avocado, mango, guava, durian, watermelon, melon, jackfruit, soursop, custard apple, breadfruit, snake fruit, pineapple, longan, strawberry, grapes VEGETABLES **S2:** Shallots, green beans, broccoli, chili, bell pepper, caisim, snow pea, cucumber, eggplant, bitter melon, tomato, cabbage, long beans FLOWERS **S2:** Rose, aster, sunflower SPICES & MEDICINAL PLANTS **S3:** Ginger, cinnamon, nutmeg, galangal **S2:** etiver, lemongrass, vanilla, candlenut, pepper, jatropha, aromatic ginger, turmeric, cardamom	**S3:** Teak, mahogany, albizia, eucalyptus **S2:** Agathis, leucaena, acacia, melaleuca, sandalwood	**S3:** Elephantgrass, Setaria, Legumes, Grazing
4	Lautém	Luro	DRYLAND CROPS **S2:** Irrigated rice, upland rice, cassava,	INDUSTRIAL	**S3:** Teak, mahogany, albizia, eucalyptus	**S3:** Elephantgrass, Setaria,

			sweet potato, corn, wheat, soybean, **S3:** Cowpea, peanut, mung beans, taro, sorghum	**S3:** Rubber, coconut, oil palm, cacao, clove, tea, melinjo, quinine **S2:** Robusta coffee, tobacco, sugarcane, cashew, cotton, kapok FRUITS **S3**: Passion fruit **S2:** Banana, papaya, orange, rambutan, avocado, mango, guava, durian, watermelon, melon, jackfruit, soursop, custard apple, breadfruit, salak, pineapple, longan, strawberry, grapes VEGETABLES **S2:** Shallot, green beans, broccoli, chili, bell pepper, caisim, snow pea, cucumber, eggplant, bitter melon, vegetable tomato, cabbage, long beans FLOWERS **S2**: Rose, aster, sunflower SPICES & MEDICINAL PLANTS **S3:** Ginger, cinnamon, nutmeg, galangal **S2:** Vetiver, lemongrass, vanilla, candlenut, pepper, jatropha, aromatic ginger, turmeric, cardamom	**S2:** Agathis, leucaena, acacia, melaleuca, sandalwood	Legumes, Grazing
5	Lautém	Lore	DRYLAND CROPS	INDUSTRIAL	**S3:** Teak, mahogany, albizia, eucalyptus	**S3:** Elephantgrass,

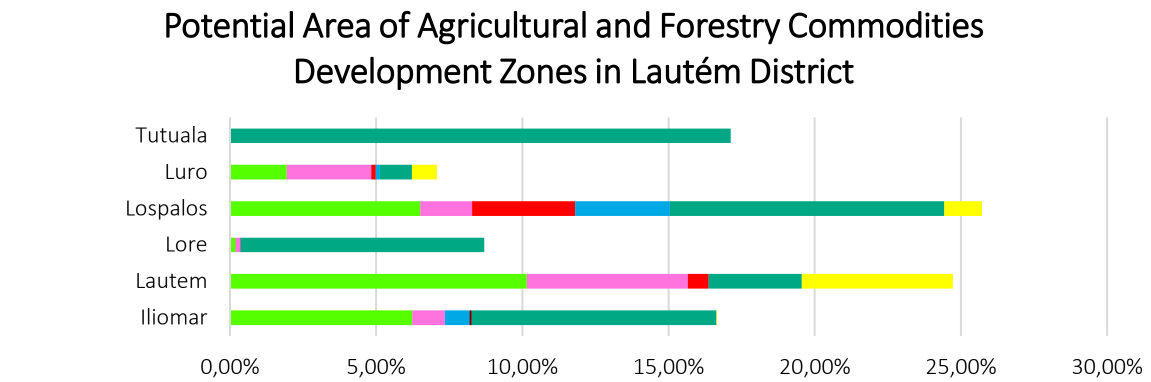
			S2: Rainfed rice, upland rice, cassava, sweet potato, corn, wheat, soybean, **S3:** Cowpea, peanut, mung beans, taro, sorghum,	**S3:** Rubber, coconut, oil palm, cacao, clove, tea, melinjo, quinine **S2:** Robusta coffee, tobacco, sugarcane, cashew, cotton, kapok **FRUITS** **S3**: Passion fruit **S2:** Banana, papaya, orange, rambutan, avocado, mango, guava, durian, watermelon, melon, jackfruit, soursop, custard apple, breadfruit, salak, pineapple, longan, strawberry, grapes **VEGETABLES** **S2:** Shallot, green beans, broccoli, chili, bell pepper, caisim, snow pea, cucumber, eggplant, bitter melon, vegetable tomato, cabbage, long beans **FLOWERS** **S2**: Rose, sunflower, aster **SPICES & MEDICINAL PLANTS** **S3:** Ginger, cinnamon, nutmeg, galangal **S2:** Vetiver, lemongrass, vanilla, candlenut, pepper, jatropha, aromatic ginger, turmeric, cardamom	**S2:** Agathis, leucaena, acacia, melaleuca, sandalwood	Setaria, legumes, grazing

6	**Lautém**	**Tutuala**	**DRYLAND CROPS** **S2:** Rainfed rice, upland rice, cassava, sweet potato, corn, wheat, soybean, **S3:** Cowpea, peanut, mung beans, taro, sorghum,	**INDUSTRIAL** **S3:** Rubber, coconut, oil palm, cacao, clove, tea, melinjo, quinine **S2:** Robusta coffee, tobacco, sugarcane, cashew, cotton, kapok **FRUITS** **S3**: Passion fruit **S2:** Banana, papaya, orange, rambutan, avocado, mango, guava, durian, watermelon, melon, jackfruit, soursop, custard apple, breadfruit, salak, pineapple, longan, strawberry, grapes **VEGETABLES** **S2:** Shallot, green beans, broccoli, chili, bell pepper, caisim, snow pea, cucumber, eggplant, bitter melon, vegetable tomato, cabbage, long beans **FLOWERS** **S2:** Rose, sunflower, aster **SPICES & MEDICINAL PLANTS** **S3:** Ginger, cinnamon, nutmeg, galangal **S2:** Vetiver, lemongrass, vanilla, candlenut, pepper, jatropha, aromatic ginger, turmeric, cardamom	**S3:** Teak, mahogany, albizia, eucalyptus **S2**: Agathis, leucaena, acacia, melaleuca, sandalwood	**S3:** Elephantgrass, Setaria, legumes, grazing

7.6 ZONING FOR AGRICULTURAL POTENTIAL DEVELOPMENT

The research results indicate that Lautém District has vast land resource potential to support the development of agriculture, forestry, and livestock sectors. To optimize this potential, a comprehensive scientific land suitability evaluation was conducted, which included agroclimatic patterns, soil types, geological conditions, slope, elevation, field observations, and laboratory soil tests. The evaluation results produced a systematic, science-based land use zoning, which serves to identify opportunities for developing various strategic commodities. This zoning reflects the diversity of land use potential that can support agriculture, forestry, and livestock in a sustainable manner. Additionally, it contributes to food security, environmental protection, and community welfare. With planned and continuous management, the land potential in this area can be maximized through synergy between the government, policymakers, and local communities, ensuring that the benefits are shared equitably.

Based on this analysis, Lautém District has land development potential categorized into several main types: irrigated rice fields covering 76.48 km² (4.22%), rainfed rice fields covering 132.94 km² (7.33%), grazing areas covering 79.30 km² (4.38%), dryland agriculture or mixed gardens covering 207.96 km² (11.47%), agroforestry covering 453.58 km² (25.02%), mangrove forests covering 1.45 km² (0.08%), and protected and conservation forests covering 860.81 km² (47.49%), as shown in **Figure 7.1**. The spatial distribution of these zones is presented in **Figure 7.2**. This zoning reflects the diversity of land use potential to support agriculture and forestry sustainably, contributing to food security, environmental protection, and the enhancement of community welfare.



	Iliomar	Lautem	Lore	Lospalos	Luro	Tutuala
Agroforestry	6,23%	10,15%	0,19%	6,51%	1,94%	0,00%
Dryland Farming	1,12%	5,51%	0,18%	1,77%	2,89%	0,00%
Grazing Area	0,00%	0,70%	0,00%	3,53%	0,14%	0,00%
Irrigated Rice Fields	0,84%	0,00%	0,00%	3,24%	0,13%	0,00%
Mangrove Forest	0,07%	0,01%	0,00%	0,00%	0,00%	0,00%
Protected Forest	8,36%	3,18%	8,33%	9,38%	1,11%	17,13%
Rainfed Rice Fields	0,02%	5,17%	0,00%	1,29%	0,85%	0,00%

Figure 7.1 Potential Area for Agricultural and Forestry Commodities Development in Lautém District

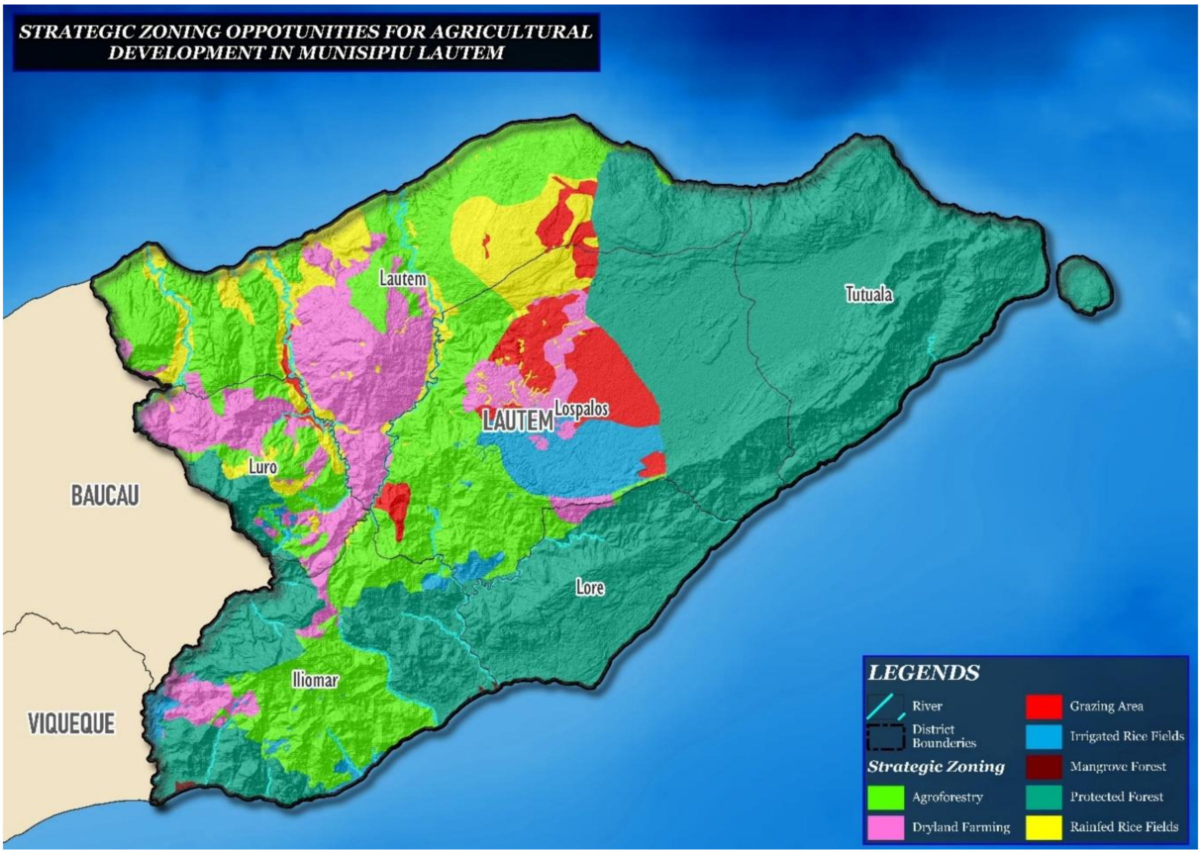


Figure 7.2 Spatial Distribution of Agricultural and Forestry Commodities Development in Lautém District

A. Irrigated Rice Fields

The irrigated rice field zone in Lautém District covers 76.48 km² or approximately 4.22% of the total area. This area is generally located in lowland and alluvial valley regions with a slope of 0–8% and an elevation of less than 100 meters above sea level (masl). Geologically, this zone is dominated by loose sediments, ranging from clay to gravel, with Entisols and Inceptisols, which respond well to water management. Agroclimatically, the irrigated rice fields fall within a bimodal rainfall regime, allowing for two growing seasons per year.

Postu Lospalos is the most promising area for the development of irrigated rice fields due to its vast lowland areas and water supply from the Mehara River. The presence of river networks is a key factor supporting the irrigation system, thereby improving water utilization efficiency and optimizing rice productivity. To further optimize the development of irrigated rice fields, strategic actions such as modernizing tertiary water management, applying alternate wetting and drying techniques for water efficiency, and strengthening post-harvest systems are necessary. These efforts are expected to increase agricultural productivity while enhancing local food security.

B. Rainfed Rice Fields

The rainfed rice field zone in Lautém District spans 132.94 km², or approximately 7.33% of the total area. This zone is located at an elevation of 50–100 masl with a slope of 0–8%. Geologically, this region is dominated by loose sediments such as clay and boulders, with Entisols and a monomodal agroclimate that limits the productivity of rainfed rice fields, as they are heavily reliant on rainfall. However, the region still holds development potential if supported by water conservation technology and proper land management.

Main commodities that can be developed in this area include upland rice, corn, wheat, peanuts, and mung beans. These crops not only diversify local food sources but also provide plant-based protein. With proper management strategies such as balanced fertilization, the use of adaptive varieties, and crop rotation, the rainfed rice field zone can strengthen food security and reduce dependence on rice as the primary staple food.

C. Dryland Agriculture (Mixed Gardens and Fields)

The dryland agriculture zone in Lautém District plays a strategic role, covering 207.96 km² or approximately 11.47% of the total area. This zone is located at an elevation of 0–1,000 masl, with slopes varying from 0–40%, reflecting a diverse biophysical condition. Geologically, the area is dominated by Phyllite, Schist, Amphibolite, Slate, and some volcanic rocks, with Inceptisols as the main soil type. Agroclimatically, this area falls within a monomodal regime, necessitating a planting pattern that aligns with seasonal water availability.

The zone supports a variety of crops, including food crops (cassava, sweet potato, corn, soybean), horticultural vegetables and fruits, spices, medicinal plants, and industrial crops such as coconut, cocoa, and cashew. However, the dryland agriculture zone faces significant challenges that affect productivity. Certain food crops like cassava, maize, and peanuts often produce suboptimal yields, and horticultural fruit crops, such as oranges and rambutan, may grow but rarely bear fruit optimally. This indicates land suitability limitations and environmental factors affecting successful cultivation. As a result, agricultural development in Lautém District should focus more on horticulture and crops that are more resilient to the dryland conditions of the region.

D. Grazing Area

The grazing zone in Lautém District covers an area of 79.30 km², or approximately 4.38% of the total area. This area is located at an elevation of 500–1,000 meters above sea level (masl) with slopes ranging from 8–20%, making it more suitable for grazing activities than for intensive farming. Geologically, the region is dominated by Phyllite, Schist, Amphibolite, Slate, and some volcanic rocks, with Inceptisols as the primary soil type, which has moderate fertility. Agroclimatically, this area falls within a monomodal regime, meaning that the availability of livestock forage is highly influenced by the seasonal differences between the wet and dry seasons.

The main commodities developed in this grazing zone include elephant grass, king grass, and legumes such as gamal and lamtoro. Elephant grass and king grass are highly adaptable to the area's dry conditions and help maintain soil stability by preventing erosion. Meanwhile, gamal and lamtoro not only serve as high-quality forage with good protein content but also contribute to improving soil fertility through nitrogen fixation.

Lautém District is highly suitable as a grazing area. By implementing management strategies based on rotational grazing, planting forage during the wet season, and integrating farming-livestock systems, this area has significant potential to increase livestock productivity. In addition to providing animal protein to support food security, the grazing zone also generates organic fertilizers that benefit the surrounding agricultural land. Therefore, continuous evaluation is necessary to ensure that the use of this area remains productive and sustainable.

VIII. FORESTRY POTENTIAL

8.1 LAND SUITABILITY EVALUATION RESULTS

Land Suitability Evaluation is a fundamental step in designing sustainable land resource management strategies. This evaluation process is based on an integrated approach that includes the dutilization of geospatial data, field observations, and physical and chemical soil analyses in the laboratory. This approach enables the identification of both the potential and limitations of the land's biophysical characteristics for the development of various 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 on the biophysical conditions of the land, such as slope gradient, vegetation cover, and drainage quality. Laboratory soil sample analyses complement this process by providing data on macro-nutrient content (Total Nitrogen, Available Phosphorus, Available Potassium), organic matter, Cation Exchange Capacity (CEC), Base Saturation (BS), pH, and soil texture.

Subsequently, the obtained data is analyzed based on the actual growth requirements of each crop species, as well as the potential suitability after implementing various land improvement measures, such as fertilization, organic matter addition, or soil conservation techniques. This process results in comprehensive information for determining commodity development priorities, identifying limiting factors, and designing relevant technical solutions.

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

A. Land Suitability Evaluation of Lospalos Sub-District

Lospalos Sub-District has a land potential that is fairly suitable for the development of various forestry commodities. Based on the land suitability evaluation results, most of these commodities fall into the S2 (moderately suitable) and S3 (marginally suitable) classes with several limiting factors. Acacia and Melaleuca are among the commodities that are moderately suitable for development, while teak, mahogany, and sandalwood fall under the marginally suitable category. The dominant limiting factors in this area include the dry period, poor drainage, low nutrient content (Total Nitrogen, Available Phosphorus, and Available Potassium), as well as physical land conditions such as shallow soil depth, slope gradient, surface rocks, and rock outcrops. Nevertheless, through the implementation of sustainable land management practices, the potential for developing forestry commodities in this area can still be optimized to support the productive and sustainable management of land resources.

Commodities such as *Altingia* and pine are generally not recommended for development in this area due to permanent temperature-related limiting factors that cannot be improved. In addition to the commodities mentioned, **Table 8.1** presents alternative plant species considered suitable for forestry development in Lospalos Sub-District, while **Table 7.5** provides recommendations for forestry development in Lospalos as part of a land use diversification and optimization strategy for sustainable land utilization.

B. Land Suitability Evaluation of Iliomar Sub-District

Iliomar Sub-District has land potential that is fairly suitable (S2) to marginally suitable (S3) for the development of various forestry commodities, such as sandalwood, albizia, and eucalyptus. However, its development faces several key constraints, both from climatic aspects and the physical and chemical properties of the soil. The limiting factors that affect land suitability include a long dry period, rock outcrops, low organic carbon content, Total Nitrogen, Available Phosphorus, and Available Potassium, as well as land morphology conditions such as erosion, shallow soil depth, slope gradient, and surface rocks. These constraints are generally technical in nature and can still be addressed through the implementation of appropriate cultivation technology and land management practices, including soil conservation efforts and soil fertility improvement.

Commodities such as *Altingia* and pine are generally not recommended for development in this area due to permanent temperature-related limiting factors that cannot be improved. In addition to the mentioned commodities, **Table 8.1** presents alternative plant species deemed suitable for forestry development in Iliomar Sub-District, while **Table 7.5** provides recommendations for forestry development in Iliomar as part of a land use diversification and optimization strategy for sustainable land utilization.

C. Land Suitability Evaluation of Lautém Sub-District

Lautém Sub-District has land potential that is fairly suitable for the development of various forestry commodities. Based on the land suitability evaluation results, most of these commodities fall into the S2 (moderately suitable) and S3 (marginally suitable) classes with several limiting factors. *Melaleuca* is considered moderately suitable for development, while teak, mahogany, and sandalwood are categorized as marginally suitable. This land suitability is influenced by several limiting factors or constraints, including the dry period, low content of Total Nitrogen, Available Phosphorus, and Available Potassium, as well as physical land conditions such as shallow soil depth, slope gradient, erosion hazards, surface rocks, and rock outcrops.

Commodities such as *Altingia* and pine are generally not recommended for development in this area due to permanent temperature-related limiting factors that cannot be improved. In addition to the commodities mentioned, **Table 8.1** presents alternative plant species deemed suitable for forestry development in Lautém Sub-District, while **Table 7.5** provides recommendations for forestry development in Lautém as part of a land use diversification and optimization strategy for sustainable land utilization.

D. Land Suitability Evaluation of Luro Sub-District

Luro Sub-District has land potential that is moderately suitable (S2) for the development of several forestry species, such as Leucaena, Agathis, and albizia. However, its development still faces several key limiting factors, including a long dry period and low soil nutrient content such as Total Nitrogen, Available Phosphorus, and Available Potassium. Additionally, physical land conditions such as shallow soil depth, slope gradient, surface rocks, and rock outcrops also pose challenges to land management. Nevertheless, most of these limitations are technical in nature and can be addressed through the application of cultivation technology and adaptive land management strategies.

Commodities such as Altingia and pine are generally not recommended for development in this area due to permanent temperature-related limiting factors that cannot be improved. In addition to the aforementioned commodities, **Table 8.1** presents alternative plant species deemed suitable for forestry development in Luro Sub-District, while **Table 7.5** provides recommendations for forestry development in Luro as part of a land use diversification and optimization strategy for sustainable land utilization.

E. Land Suitability Evaluation of Lore Sub-District

Lore Sub-District has land potential that is fairly suitable for the development of various forestry commodities. Based on the land suitability evaluation results, most of these commodities fall into the S2 (moderately suitable) and S3 (marginally suitable) classes with several limiting factors. Acacia and *Melaleuca* are considered moderately suitable for development, while teak, mahogany, and sandalwood fall under the marginally suitable category. The dominant limiting factors in this area include the dry period, poor drainage, low nutrient content (Total Nitrogen, Available Phosphorus, and Available Potassium), as well as physical land conditions such as shallow soil depth, slope gradient, surface rocks, and rock outcrops. Nevertheless, through the implementation of sustainable land management practices, the potential for developing forestry commodities in this area can still be optimized to support the productive and sustainable management of land resources.

Commodities such as *Altingia* and pine are generally not recommended for development in this area due to permanent temperature-related limiting factors that cannot be improved. In addition to the commodities mentioned, **Table 8.1** presents alternative plant species deemed suitable for forestry development in Lore Sub-District, while **Table 7.5** provides recommendations for forestry development in Lore as part of a land use diversification and optimization strategy for sustainable land utilization.

F. Land Suitability Evaluation of Tutuala Sub-District

Tutuala Sub-District has land potential that is quite suitable for the development of various forestry species such as teak, mahogany, *Agathis*, and albizia. The land suitability in this area is influenced by several limiting factors, including a long dry period, rock outcrops, and low organic matter content and soil nutrients such as organic carbon, Total Nitrogen, Available Phosphorus, and Available Potassium. Additionally, land morphology conditions such as shallow soil depth, slope gradient, and surface rocks also pose challenges in forestry development.

Commodities such as *Altingia* and pine are generally not recommended for development in this area due to permanent temperature-related limiting factors that cannot be improved. In addition to the mentioned commodities, **Table 8.1** presents alternative plant species deemed suitable for forestry development in Tutuala Sub-District, while **Table 7.5** provides recommendations for forestry development in Tutuala as part of a land use diversification and optimization strategy for sustainable land utilization.

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Table 8. 1 Matrix of Land Suitability Evaluation for Forestry Plant Species in Lautém District

Commodity	Sub-District	Limiting Factors	Potential Land Suitability
Teak	• Lospalos • Ilomar • Lautém • Luro • Tutuala • Lore	**N:** Dry month **S3:** Rock outcrops, Total Nitrogen, Available Phosphorus, Available Potassium **S2**: Drainage, erosion, effective depth, slope, surface rocks	**S3:** Dry month **S2:** Rock outcrops, effective depth, surface rocks
Mahogany	• Lospalos • Ilomar • Lautém • Luro • Tutuala • Lore	**N:** Dry month **S3:** Rainfall, Rock outcrops, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Drainage, erosion, effective depth, slope, surface rocks, texture	**S3:** Dry month **S2:** Rock outcrops, effective depth, surface rocks, texture
Agathis	• Lospalos • Ilomar • Lautém • Luro • Tutuala	**N:** Dry month **S3:** Rainfall, Rock outcrops, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, erosion, effective depth, slope, surface rocks, texture	**S3:** Dry month **S2:** Temperature, Rock outcrops, effective depth, surface rocks, texture
Altingia	• Lospalos • Ilomar • Lautém • Luro • Tutuala • Lore	**N:** N: Temperature, Dry month **S3:** Rock outcrops, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Rainfall, erosion, effective depth, slope, surface rocks, texture	**N:** Temperature **S3:** Dry month **S2:** Rock outcrops, effective depth, surface rocks, texture
Albizia	• Lospalos • Ilomar • Lautém	**N:** ainfall, Dry month **S3**: Rock outcrops, Total Nitrogen, Available	**S3:** Dry month

	• Luro • Tutuala • Lore	Phosphorus, Available Potassium **S2:** Erosion, effective depth, slope, surface rocks	**S2:** Rock outcrops, effective depth, surface rocks, Rainfall
Leucaena	• Lospalos • Ilomar • Lautém • Luro • Tutuala • Lore	**S3:** Rock outcrops, pH, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Rainfall, Dry month, erosion, slope, surface rocks	**S2:** Rock outcrops, Dry month, surface rocks
Acacia	• Lospalos • Ilomar • Lautém • Luro • Tutuala • Lore	**S3:** Rock outcrops, pH, Total Nitrogen, Available Phosphorus, Available Potassium **S2**: Dry month, erosion, slope, surface rocks, texture	**S2:** Rock outcrops, Dry month, surface rocks, texture
Eucalyptus	• Lospalos • Ilomar • Lautém • Luro • Tutuala • Lore	**N:** Dry month **S3**: Rock outcrops, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Erosion, slope, surface rocks, texture	**S3:** Dry month **S2**: Rock outcrops, surface rocks, texture
Melaleuca	• Lospalos • Ilomar • Lautém • Luro • Tutuala • Lore	**S3:** Drainage, Rock outcrops, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Surface rocks, pH	**S2:** Rock outcrops, surface rocks
Pine	• Lospalos • Ilomar • Lautém • Luro • Tutuala • Lore	**N:** Temperature, Rainfall, Dry month **S3:** Rock outcrops, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Drainage, erosion, slope, surface rocks, texture	**N:** Temperature **S3:** Dry month **S2:** Rock outcrops, surface rocks, texture, Rainfall
Sandalwood	• Lospalos • Ilomar	**N:** Rock outcrops	**S3:** Rock outcrops

	• Lautém • Luro • Tutuala • Lore	**S3:** Surface rocks, pH, Organic Carbon, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Rainfall, coarse materials, erosion	**S2:** Temperature, surface rocks, coarse materials

8.2 LAND IMPROVEMENT MEASURES

Efforts to improve various land limiting factors are strategic steps to enhance productivity and sustainability in the agricultural sector. Biophysical constraints such as shallow effective soil depth and the presence of surface rocks require appropriate technical handling to optimize land potential. In addition, several chemical soil parameters, such as organic carbon content and macro-nutrient levels (Total Nitrogen, Available Phosphorus, and Available Potassium), which are relatively low, need to be increased through soil fertility improvement programs to make the land more productive.

Based on the evaluations conducted in each Sub-District of Lautém District, several improvement measures can be recommended. To address the relatively long dry period, which is linked to rainfall and drainage, planting schedules can be adjusted to coincide with the wet season to support optimal crop growth. The deficiency of macro-nutrients in the area is also insufficient to support plant vegetative growth. Therefore, balanced fertilization and organic matter addition are necessary to improve soil structure and fertility. The issue of shallow soil depth can be addressed by creating properly adjusted planting holes. In areas with rock outcrops and surface rocks, management can be carried out through selective land clearing and creating planting holes in between the rocks to maximize plant root space. This approach aims to improve land use efficiency while supporting sustainable agricultural productivity. However, it is important to note that some limiting factors are permanent, such as temperature, and therefore require adaptation strategies and agricultural development planning that are suited to the ecological conditions of the area.

8.3 FORESTRY PLANT DEVELOPMENT ZONING

The zoning of forestry plant development in Lautém District reflects a systematic effort to manage forest resources sustainably. Lautém District has biophysical characteristics that support the development of agroforestry and protected forest zoning, with both zones covering 75.68% of the total area. This area is located on slopes with gradients ranging from 5% to 45% and elevations between 800 and 1500 meters above sea level (masl), and is dominated by Inceptisols, which have moderate fertility levels and are suitable for conservative agricultural systems. According to agro-climatic classification, Lautém falls into zones A, B, C, D, and F, with a dry period lasting five to six months, thus requiring adaptive water management strategies and crop selection. The forest zones in Lautém District are divided into three main categories: agroforestry, protected and conservation forests, and mangrove forests, each serving both ecological and economic functions.

A. Agroforestry

The agroforestry zone in Lautém District covers an area of approximately 453.58 km², or about 25.02% of the total area. The highest distribution is found in Lautém Sub-District (10.15%), followed by Lospalos (6.52%), Iliomar (6.23%), Luro (1.94%), and Lore (0.19%) (**Figure 7.1 in Chapter VII**). This area is situated at an elevation of 500–1,000 meters above sea level (masl) with slope gradients of 15–40%. The agroforestry system implemented in this area is an integrated land management approach that combines agricultural crops such as coconut, cassava, and peanuts, with forestry plants that have both conservation and high economic value, such as mahogany, teak, and various local tree species. This pattern is designed to maximize land use, maintain ecosystem balance, and increase agricultural productivity without harming the environment.

The application of the agroforestry system in Lautém District provides various benefits for the community and the environment. From a socio-economic perspective, this system supports food security and increases farmer income through agricultural diversification. Ecologically, agroforestry plays a crucial role in carbon sequestration, protecting the soil from erosion, controlling floods and landslides, and rehabilitating degraded land quality. With the region's favorable characteristics and abundant natural resources, the development of agroforestry in Lautém District holds excellent prospects as a model for sustainable land management that balances economic, social, and environmental aspects.

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Figure 8.1 Agroforestry Systems Found in Lautém District
(Source: Research Documentation, 2025)

Lautém District has considerable potential for coffee cultivation, especially for Robusta coffee. This coffee variety is deemed suitable for cultivation in Lautém due to environmental conditions such as elevation, air temperature, and soil characteristics, all of which support the growth and development of Robusta plants. This suitability is evident from the individual micro-farming-based coffee cultivation in Titilasi, Fuiloro Village, which shows that coffee has become part of the local agricultural system.

Based on field observations, the productivity of Robusta coffee in this area is still relatively low and has not reached optimal yields. This condition is caused by the absence of an integrated and sustainable management system, including aspects such as the selection of superior varieties, the application of cultivation techniques suitable for local agro-ecological conditions, and post-harvest processing that meets quality standards.

Meanwhile, Arabica coffee is not recommended for development in this area due to temperature and elevation factors in Lautém that are not suitable, which could affect the growth of this variety.

Figure 8. 2 Development of Robusta Coffee in the Titilari Area, Fuiloro Village
(Source: Research Documentation, 2025)

From the perspective of sustainable agricultural development, coffee plants have strategic potential to be established as a key commodity in the agroforestry system of Lautém District. Ecologically, a coffee-based agroforestry system can increase land vegetation cover, improve soil structure and fertility, reduce erosion rates, and contribute to carbon sequestration, which is vital for climate change mitigation. Economically, this system can expand farmers' income sources through agricultural diversification and strengthen the value chain of local coffee products. Moreover, coffee has high market value both domestically and internationally, especially when cultivated sustainably.

Thus, the development of Robusta coffee agroforestry in Lautém District is a strategic alternative to improve farmers' welfare while strengthening environmental resilience and the sustainability of the agricultural system in the area.

B. Protected and Conservation Forests

Protected and conservation forests cover a substantial area of 860.81 km^2, or about 47.49% of the total area of Lautém District. The highest distribution is found in Tutuala Sub-District (17.13%), followed by Lospalos (9.38%), Iliomar (8.36%), Lore (8.33%), Lautém (3.18%), while Luro only covers 1.11% (**Figure 7.1 in Chapter VII**). This area plays a crucial role in maintaining hydrological balance, regulating watershed management, and minimizing land degradation risks due to erosion and deforestation. Furthermore, protected forests also function as natural habitats for various species of local flora and fauna, including several endemic species that have high ecological value. The presence of protected forests in this area also acts as an ecological buffer, supporting the sustainability of agricultural systems and the socio-economic life of the surrounding communities.

However, based on information obtained from the President of the Lautém Municipal Authority (PAM), the management of forest areas in Lautém District still faces various challenges and ecological pressures, particularly in the form of illegal logging and wildlife poaching by some members of the community. These activities potentially threaten biodiversity and reduce the ecological functions of the forests. To address these issues, the local government, along with relevant agencies, has implemented more stringent forest management policies, including the establishment of clear boundaries for protected forest areas, increased monitoring activities, and the enforcement of forestry law violations. In addition to monitoring efforts, the government also encourages the implementation of reforestation and ecosystem restoration programs as priority measures to rehabilitate critical lands, restore natural vegetation cover, and maintain the sustainability of forest ecosystems as providers of environmental services and water resources. This program is expected to strengthen environmental support capacity while raising community awareness of the importance of natural resource conservation.

Administratively, the protected forest areas in Lautém District consist of several Protected Areas (AP) that have been designated as conservation areas, including AP Lagoa Maurei, AP Monte Legumau, AP Be Matan Irabere, and Nino Konis Santana National Park. Each area has different biophysical characteristics and ecosystems, but overall they complement each other by maintaining water management, reducing erosion and landslide risks, and conserving biodiversity.

From an academic perspective, the presence of conservation areas in Lautém District reflects the implementation of sustainable forest management practices that balance ecological, social, and economic functions. This approach is crucial to ensure that the use of forest resources not only provides short-term benefits for the community but also guarantees the preservation of ecosystems and environmental resilience for future generations.

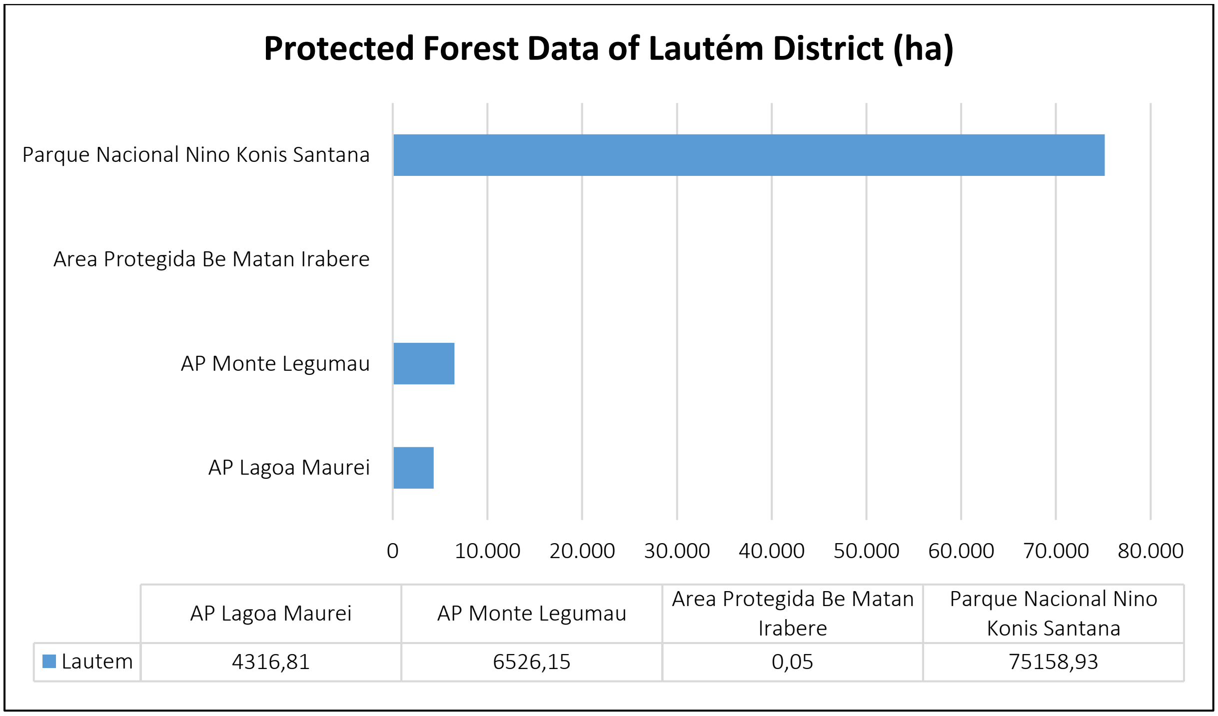

Figure 8.3 Protected Forest (ha) in Lautém District

C. Mangrove Forests

The mangrove forest zone in Lautém District covers an area of approximately 1.45 km², or 0.08% of the total area. The highest distribution is found in Iliomar (0.07%), followed by Lautém (0.01%), while other sub-districts do not have mangrove forest areas (**Figure 7.1 in Chapter VII**). Although the area is relatively small, the mangrove ecosystem plays a crucial ecological role in maintaining coastal environmental balance. Mangrove forests act as natural protectors of coastlines against abrasion and seawater intrusion, as well as energy absorbers for waves, which can reduce the impact of coastal disasters such as tidal flooding and tsunamis. In addition to their physical function, the mangrove ecosystem also holds high ecological and economic value. Mangroves serve as an important habitat for various coastal species.

Figure 8.4 Mangroves in Lautém District
(Source: Research Documentation, 2025)

Mangroves also play a significant role in mitigating global climate change. Mangrove plants have a high capacity for absorbing and storing carbon (carbon sequestration) through biomass and sediments, making them one of the most efficient ecosystems in absorbing carbon emissions in coastal areas. Overall, mangrove forests, along with protected forests and other conservation areas, form the three main categories of forest ecosystems in Lautém District. These three categories are crucial ecological assets that support environmental sustainability, ensure the availability of natural resources, and strengthen the economic resilience of communities dependent on coastal and forestry resources.

8.4 POTENTIAL FOR SANDALWOOD DEVELOPMENT

Sandalwood (*Santalum album* L.) is a high-value plant with ecological, economic, and cultural benefits. Sandalwood is well-known as a source of high-quality essential oil, which is widely used in various industries such as perfumes, cosmetics, and pharmaceuticals. In addition to its economic value, sandalwood also holds strong symbolic and spiritual significance in the traditions and cultures of communities in the Asia-Pacific region, including Timor-Leste. Besides the use of its wood and oil, sandalwood is also utilized for handicrafts, carvings, and other high-art products, making it a leading commodity with sustainable market appeal.

In Lautém District, sandalwood has long grown naturally and has become an important part of the local vegetation composition. Sandalwood distribution is predominantly found in Iliomar and Luro Sub-Districts, which have semi-arid agro-climatic conditions and varied topography. Specifically, in Iliomar, the local Forestry Department has been carrying out sandalwood planting activities in the Tirilolo area since 2011, with around ±100 seedlings. The presence of sandalwood in this area demonstrates its good adaptability to marginal lands, including rocky soils with limited rainfall.

However, the management and utilization of sandalwood in Lautém has not been fully optimized. The economic potential it holds has not been fully realized by the community due to limitations in cultivation planning, technical support, and supervision of non-timber forest resource utilization. This highlights the need for a more directed, participatory, and sustainable management approach.

Figure 8.5 Sandalwood Plants in the Tirilolo Area, Iliomar
(Source: Research Documentation, 2025)

Based on the land suitability evaluation results, the potential for sandalwood development in Lautém District is classified as S3 (Marginally Suitable). This classification indicates that the land is still viable for sandalwood development; however, there are several limiting factors, such as soil conditions, drainage, and water availability, that need to be addressed through technical interventions. Measures that can be taken include selecting appropriate planting locations, using adaptive superior seedlings, and applying soil and water conservation techniques.

With proper management, these limitations do not pose a barrier to making sandalwood a leading forestry commodity in the region.

As part of the national strategy, the Government of Timor-Leste has implemented a sandalwood tree inventory program to strengthen sustainable resource management and ensure investment certainty. This program aims to document the number, distribution, and condition of sandalwood trees in various regions, including Lautém, as a foundation for data-driven development planning. With government policy support, high economic value, and a wide market potential, the development of sandalwood in Lautém has significant prospects. If managed sustainably, sandalwood will not only become a source of income for the community but also a symbol of cultural identity and the success of local natural resource conservation.

IX. LIVESTOCK POTENTIAL

9.1 INTRODUCTION

Timor-Leste is a country whose territory is largely composed of mountains and highlands. Administratively, Timor-Leste is divided into 14 Districts: Ainaro, Aileu, Autoridade Administrativa Atauro, Bobonaro, Baucau, Covalima, Dili, Ermera, Lautém, Liquiçá, Manufahi, Manatuto, Região Administrativa Especial Oe-Cusse Ambeno (RAEOA), and Viqueque. The country has two seasons: the dry season from June to November, and the rainy season from December to May. The topography, which is dominated by hills, combined with its proximity to the Australian continent, causes Timor-Leste to be affected by the dry east monsoon winds. As a result, some areas tend to experience drought. Additionally, low rainfall impacts the growth of vegetation in various regions of the country.

The hilly topography and low rainfall not only affect vegetation growth and agricultural life but also limit the availability of forage for the livestock sector. The development of the livestock sector is heavily reliant on the potential of land resources, the appropriateness of land use, and management methods. These factors are crucial in providing animal feed, which generally consists of grasses and legumes.

Animal feed can come from natural sources or cultivation, including from grazing fields (Priyanto, 2016). Optimal land use in livestock farming is highly influenced by anthropogenic factors and the biophysical conditions of the land. Therefore, the application of various technological innovations and institutional efforts is necessary to ensure that land resources can be used effectively and optimally (Suryana and Rahman, 2006).

Generally, the livestock sector in Timor-Leste faces various obstacles. One of the main causes is the traditional and extensive livestock management system, which results in suboptimal production. The low level of awareness, knowledge, and technological mastery among farmers also hinders progress, especially in terms of meeting the nutritional requirements of livestock feed, both in terms of species and quality. Livestock are generally kept as household savings, which can be sold when needed for emergencies. Additionally, some communities still use livestock as labor in land cultivation, maintaining traditional management systems.

The success of livestock enterprises depends on three main factors: breeding, feed, and management (Aman *et al*., 2019). These three factors are interrelated components: if one is neglected or given insufficient attention, even excellent handling of the other factors will not yield optimal results. Livestock productivity, particularly in ruminants, greatly depends on effective feed management, including the quantity, quality, and continuous availability of feed (Rokhayati and Evadewi, 2023). According to Winarni and Sukaesih (2015), feed plays a vital role in supporting livestock development as it directly affects production, productivity, and animal health. The quality of livestock feed is influenced by factors such as forage variety, genotype, maturity stage at harvest, season, and applied management (Adesogan *et al*., 2015).

One of the initial steps that can be pursued in developing the livestock sector in Timor-Leste is the optimal use of land for the sustainable provision of animal feed. To utilize this land effectively, it is necessary to align land characteristics with the types of animal feed to be cultivated. Therefore, land suitability evaluation becomes an essential approach to assess the potential and carrying capacity of land resources (Harahap *et al*., 2019). This evaluation not only assesses land 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 from a given area. This assessment is conducted by identifying various land characteristics such as topography, climate, soil conditions and quality, as well as other physical environmental factors (Iswan *et al*., 2019). Through this evaluation process, information regarding the biophysical resources of the land, including climate and soil, is obtained, allowing for the determination of land suitability classes and the identification of limiting factors that need to be addressed (Jawang *et al*., 2018).

9.2 RESEARCH METHODS

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

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, involving various methods depending on the data format 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 using interview techniques with parameters such as: livestock species, livestock population, land area, livestock management/shelter systems, feed and nutrition management systems, water sources, breeding systems, animal health management systems, livestock products, marketing, infrastructure, characteristics of farmers, and customs/traditions.

2. Forage Land Suitability

The research procedure for forage land suitability is outlined in **CHAPTER III (Research Methods).**

9.3 GENERAL OVERVIEW

A. Global Existing Conditions

The livestock sector plays an important role in supporting household economies in Lautém District. The number of households engaged in livestock farming shows significant differences across each Sub-District. Households in Lautém District are predominantly involved in livestock farming, with a total of 257 households (47.42%), while the lowest number is found in Tutuala Sub-District, with only 26 households (4.80%).

Nevertheless, their contribution remains significant in meeting local needs and preserving livestock traditions, which have become an integral part of the local community's way of life. With these differences, each Sub-District contributes to the sustainability of the livestock sector in Lautém District. The number of agricultural households involved in livestock farming is presented in **Figure 9.1**.

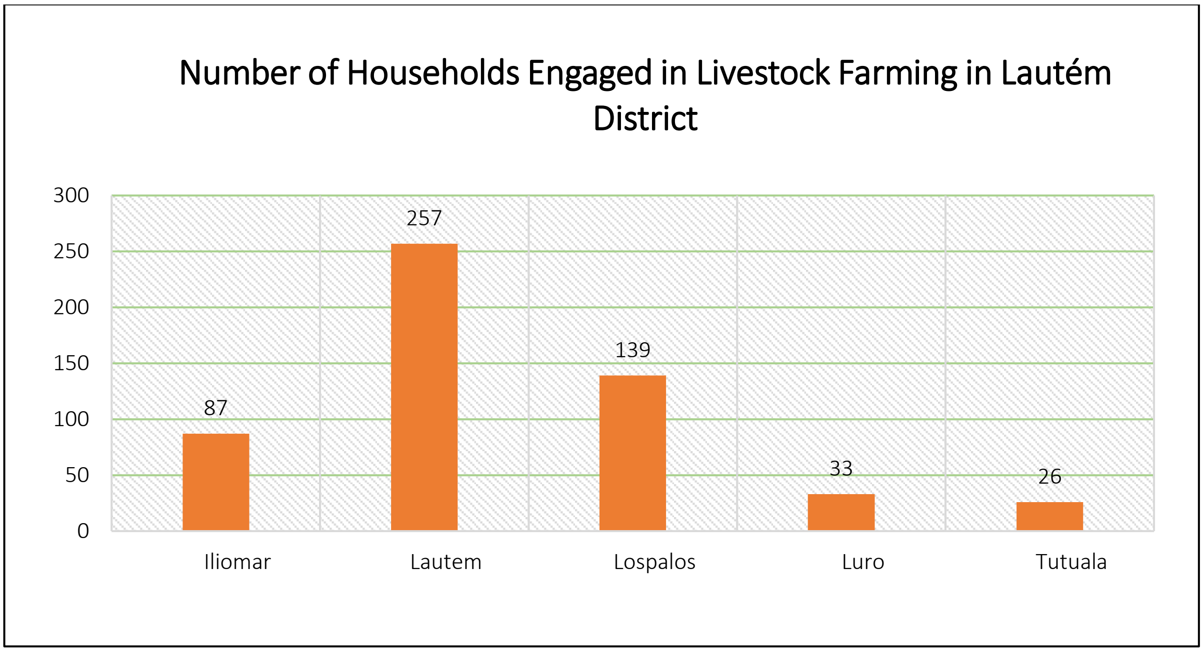

Figure 9.1 Number of Households Engaged in Livestock Farming
(Source: Timor-Leste Agriculture Census, 2019)

Cattle are the dominant type of livestock in Lautém District. The highest number of cattle-keeping households is found in Lospalos Sub-District, with 1,956 households (44.23%) and a total cattle population of 15,181. This is followed by Lautém Sub-District, with 860 households (19.45%) and a cattle population of 6,968; Iliomar Sub-District, with 740 households (16.73%) and a cattle population of 6,209; Luro Sub-District, with 584 households (13.21%) and a cattle population of 3,743; and finally, Tutuala Sub-District, with 282 households (6.38%) and a cattle population of 2,420 (**Figures 9.2 and 9.3**).

Buffalo are most commonly kept in Lospalos Sub-District, with 806 households (40.91%) and a population of 9,401. In contrast, the lowest number of buffalo-keeping households is found in Tutuala Sub-District, with only 83 households (4.57%) and a population of 158 (**Figures 9.2 and 9.3**).

For horses, Lospalos Sub-District shows the highest number of households, with 619 households (10.57%) and a population of 3,395. Conversely, the lowest number of horse-keeping households is found in Tutuala Sub-District, with 21 households (1.85%) and a population of 158 (**Figures 9.2 and 9.3**).

Dairy cattle are only kept in three Sub-Districts: Lautém, Lospalos, and Luro. In Lautém Sub-District, there are 14 dairy farming households with a total of 133 cows, while in Lospalos and Luro, only 2 and 3 households keep dairy cattle, with 6 and 8 cows, respectively (**Figures 9.2 and 9.3**)

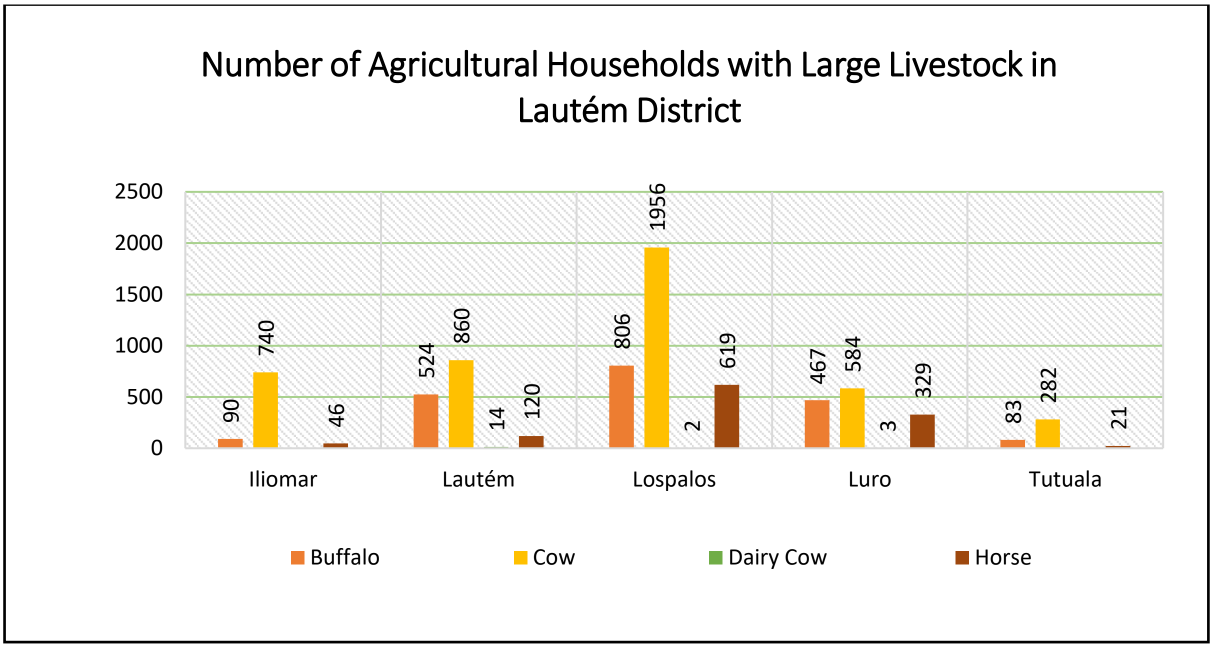

Figure 9.2 Number of Households with Large Livestock
(Source: Timor-Leste Agriculture Census, 2019)

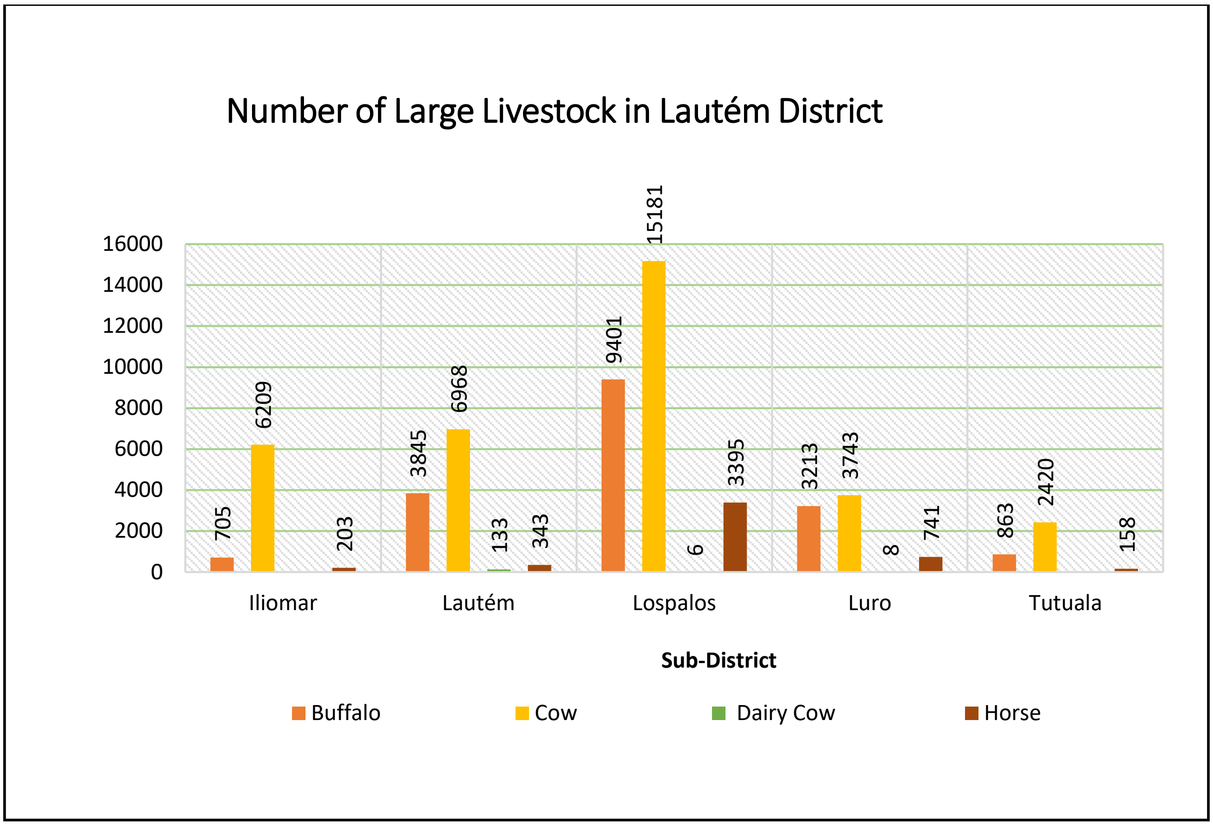

Figure 9.3 Number of Large Livestock
(Source: Timor-Leste Agriculture Census, 2019)

In Lautém District, small livestock, particularly pigs, are the most commonly kept. Lospalos Sub-District has the highest number of pig-keeping households, with 3,482 households (43.36%) and a total of 3,428 pigs. In contrast, the lowest number is found in Tutuala Sub-District, with 412 households (5.13%) and a total of 2,713 pigs (Figures 9.4 and 9.5).

The number of households keeping goats shows significant variation. Lautém Sub-District has the highest number of goat-keeping households, reaching 370 households (34%) and a total of 6,131 goats, while Tutuala Sub-District has the fewest goat-keeping households, with 34 households (2.44%) and 161 goats (Figures 9.4 and 9.5).

In addition to goats, sheep are also kept, but in relatively small numbers. Lautém Sub-District has 159 households (81.12%) keeping sheep, while the smallest number is found in Tutuala Sub-District, with only 1 household (0.51%).

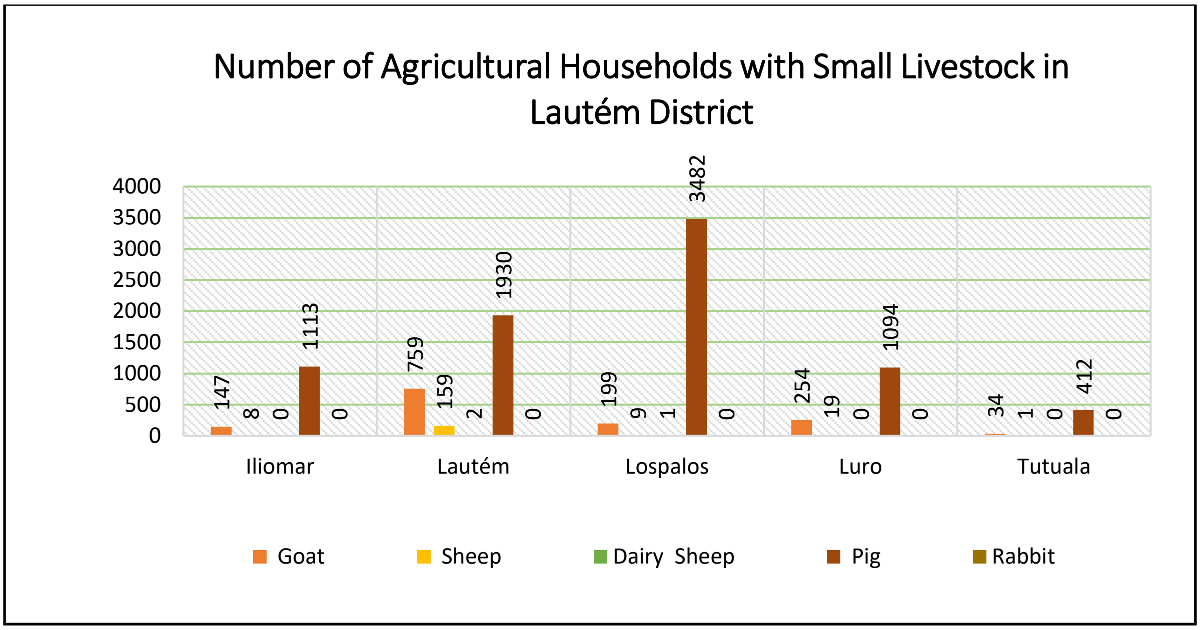

Figure 9.4 Number of Households with Small Livestock
(Source: Timor-Leste Agriculture Census, 2019)

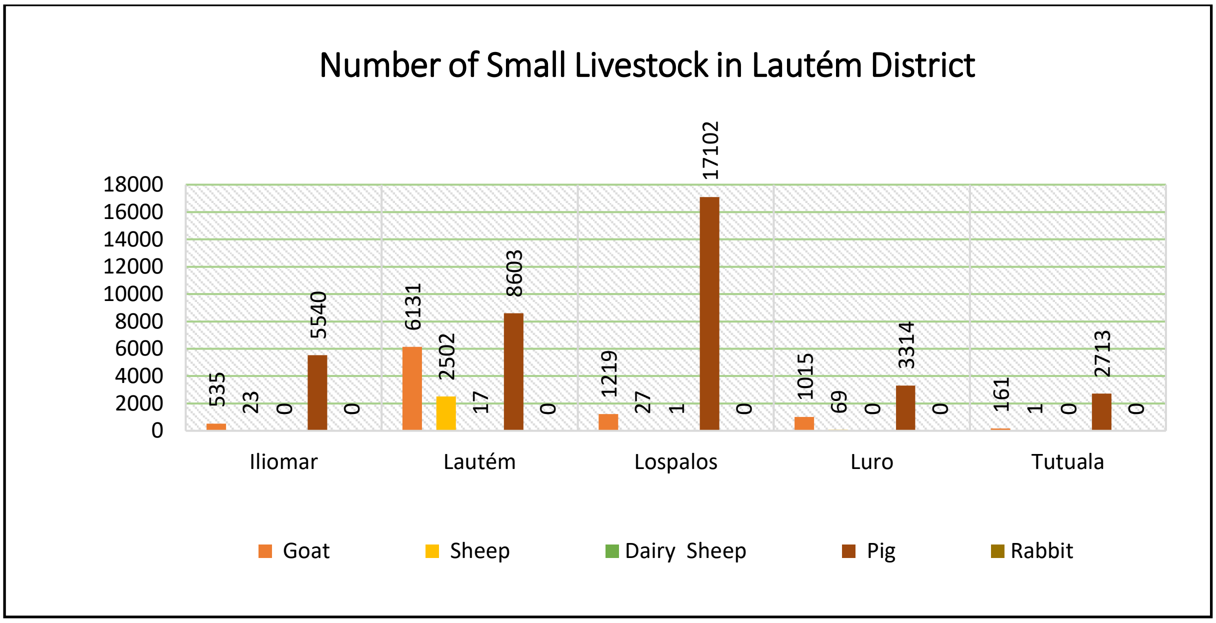

Figure 9.5 Number of Small Livestock
(Source: Timor-Leste Agriculture Census, 2019)

The number of households keeping poultry in Lautém District shows significant variation between Sub-Districts, with chickens being the most commonly raised poultry species (**Figure 9.6**). Lospalos Sub-District has the highest number of chicken-keeping households, with 3,100 households, or about 42.90%, and a total of 37,683 chickens. In contrast, Tutuala Sub-District has the smallest number of chicken-keeping households, with 295 households, or 4.08%, and a total of 3,341 chickens (**Figures 9.6 and 9.7**).

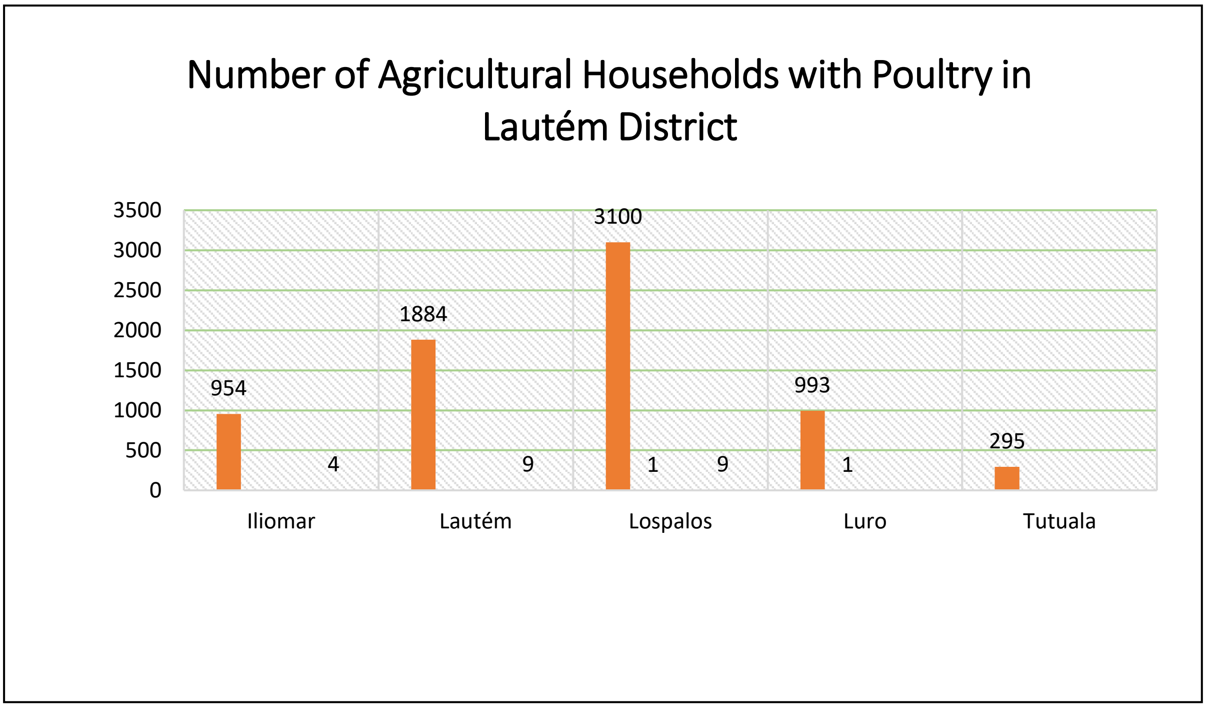

Figure 9.6 Number of Households with Poultry
(Source: Timor-Leste Agriculture Census, 2019)

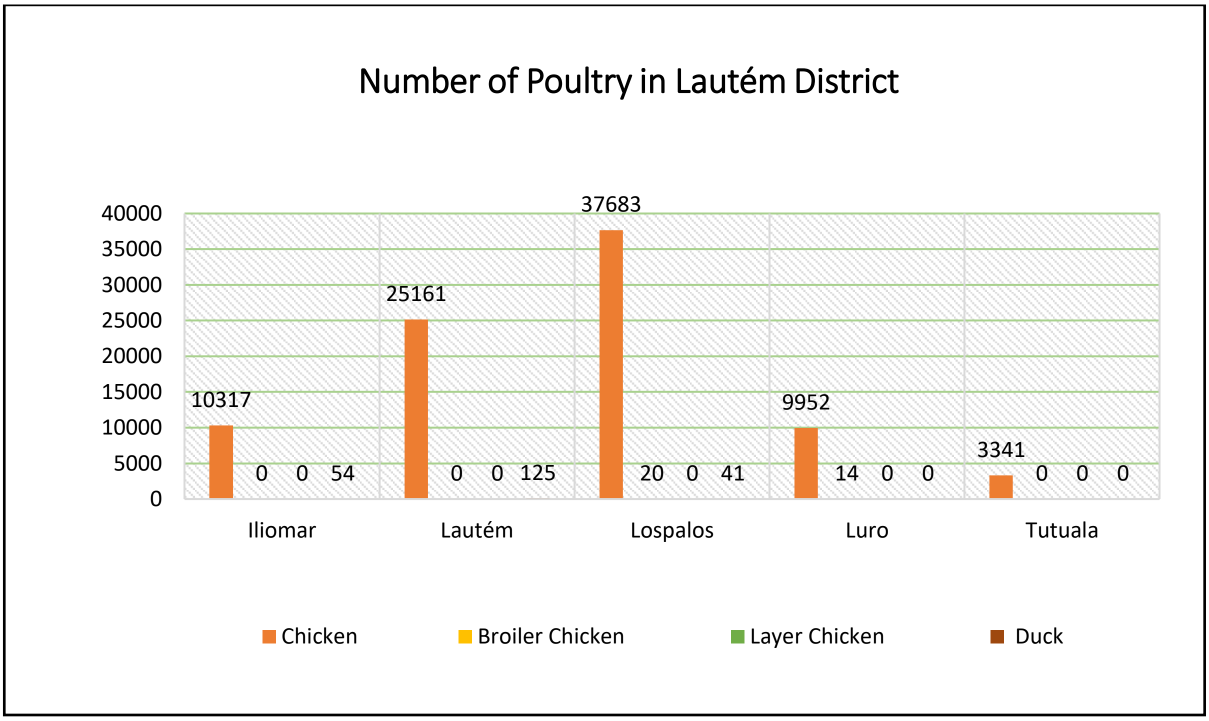

Figure 9.7 Number of Poultry
(Source: Timor-Leste Agriculture Census, 2019)

The potential of grazing lands is an important asset that can serve as a primary source of livestock feed, especially for animals such as cattle, goats, and sheep, which require high-quality grass to support growth and production in sustainable livestock farming. Lautém District has two types of grazing lands: temporary and permanent.

The area of grazing lands in Lautém District varies across Sub-Districts. Lautém Sub-District has the largest area of permanent grazing land, covering 51.80 ha (65.85%), followed by Lospalos Sub-District with 17.95 ha (22.81%). Other Sub-Districts such as Iliomar and Luro have smaller areas of permanent grazing land, at 6.62 ha (8.82%) and 2.30 ha (2.93%), respectively, while Tutuala Sub-District has no permanent grazing land. For temporary land, Lospalos shows the highest area with 69.49 ha (51.21%), followed by Lautém with 55.79 ha (41.11%). Iliomar and Luro have 4.80 ha (3.54%) and 5.62 ha (4.14%), respectively. This shows that the use of grazing land in Lautém District is highly concentrated in a few Sub-Districts, such as Lospalos and Lautém, while other Sub-Districts contribute smaller areas or have none at all. The area of grazing land is presented in **Figure 9.8**.

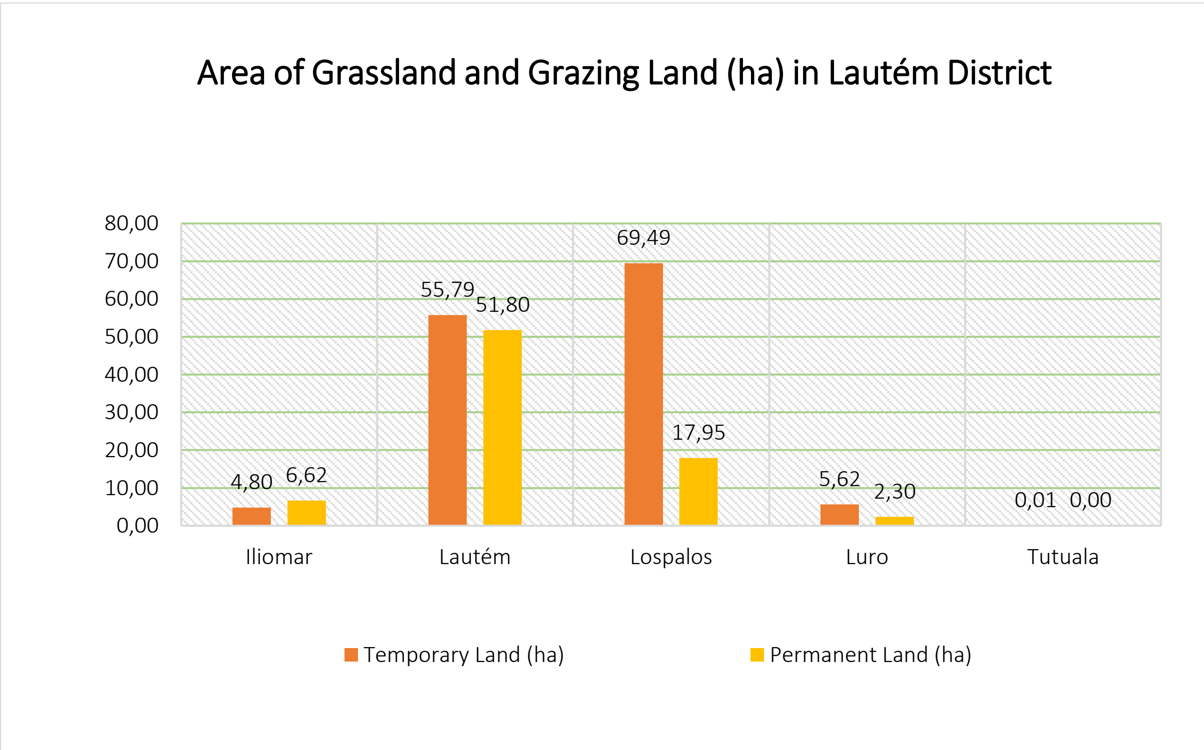

Figure 9.8 Grazing Land Area
(Source: Timor-Leste Agriculture Census, 2019)

B. Existing Conditions of Survey Locations

The observation activities were carried out at two different locations: in Mehara Sub-District and the Karau Timor Susubeen (KTS) Pato Center. The Mehara Sub-District area, located in Tutuala, has a potential land area of approximately 10 ha, which is currently managed by a farmer group. At the time of the observation, part of the land had already been planted with tuber crops by the local community. The observation results showed that, in terms of soil physical characteristics, this area has high potential to be developed into an integrated farming area. This concept includes the integration of livestock farming (such as buffalo and bali cattle), the cultivation of forage crops such as *Gliricidia sepium* (gamal) and other local feed types, as well as horticultural activities. Part of the land is also used as grazing land by the surrounding community. These findings align with the farmer group's plans to develop a farming system that not only increases livestock productivity but also strengthens food security and enhances the sustainable use of land.

Figure 9.9 Existing Conditions of the Lautém Survey Location
(Source: Research Documentation, 2025)

Based on further observations in the Pato area, a livestock center was found with a total land area of approximately 150 ha. Of this total area, only 20 ha have been utilized as forage crop (HPT) land and as a maintenance area for 11 Eastern Buffalo (Karau Timor). The buffalo population consists of 10 females and 1 male, which are the main supporting factor for the Karau Timor Susubeen (KTS) program. This program is being promoted by the ministry to provide Eastern buffalo milk for school-aged children. To support this program, the land in Pato has been planted with various types of HPT, including *Lamtoro taramba*, elephant grass, *Gamal* (*Gliricidia sepium*), and sorghum. This area is planned to become the largest Karau Timor Susubeen (KTS) center and the primary provider of milk protein for the school lunch program.

Further observations show that the productivity of the available livestock forage (HPT) is still relatively low. This condition indicates the need for intervention through soil suitability research, optimization of cultivation techniques, and the selection of forage varieties that are more adaptive to local conditions. The main challenge faced is the low productivity of HPT, most likely caused by the mismatch between the forage types and the physical and chemical characteristics of the local soil. Therefore, a comprehensive soil composition evaluation and the selection of adaptive HPT varieties are crucial steps in efforts to sustainably increase productivity.

9.4 DISCUSSION

A. Livestock Forage Land Suitability Evaluation

Land suitability analysis for livestock forage in Lautém District is a method used to evaluate the compatibility of various types of forage and grass growth in grazing lands within a specific area. 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 compatibility of a piece of land for a specific use. Land suitability can be assessed based on current conditions (actual land suitability) or after improvements have been made (potential land suitability).

The land suitability evaluation in Timor-Leste was carried out using a matching method, aligning land characteristics and quality data with suitability criteria based on the growth requirements of the evaluated plants. Several types of livestock forage commodities mapped according to the land resource potential include elephant grass (*Pennisetum purpureum*), leguminous plants, and field grasses.

The results of the land suitability evaluation in Lautém District, including the Sub-Districts of Iliomar, Lautém, Lospalos, Luro, and Tutuala, indicate potential for livestock forage development, including elephant grass, setaria, leguminous plants, and grazing lands, as presented in **Table 7.3** in this book. The table shows that, in actuality, land for livestock forage and grazing areas varies from S2 (moderately suitable) to N (not suitable), with limiting factors such as Total Nitrogen (N-total), Available Phosphorus (P), Available Potassium (K), slope, erosion, flooding, rainfall, dry period, and surface rocks. Additionally, the dry period is also a limiting factor in grazing areas. However, these challenges can still be addressed through technical interventions, such as adding NPK fertilizers, increasing organic matter, planting terrace-strengthening plants, creating terraces, building irrigation systems such as sprinklers, creating water infiltration areas like biopores, and land clearing. Moreover, surface rock outcrops are permanent limiting factors that cannot be mitigated.

The KTS Pato Center, as a survey and observation area, has potential land for livestock forage, including elephant grass, setaria, and grazing areas, with suitability criteria of S3-S2 and limiting factors such as Organic Carbon (C-organic), Available Phosphorus (P), and Cation Exchange Capacity (CEC). Technical improvement efforts can include the addition of organic materials such as compost, manure, and chemical fertilizers like SP36-TSP, which could improve the land suitability class to S1 (highly suitable). Observations show that the KTS Pato Center has been planted with forage crops, including *Lamtoro*, elephant grass, and *Gamal* as feed for Timor buffalo. Pato has the largest land area, which holds great potential for livestock forage production as well as other food commodities. Diversifying between livestock forage and food crops provides additional benefits in environmental, social, and sustainable economic aspects. It is hoped that land productivity will increase as diversification improves, which will have a positive impact on the sustainable availability of food and forage.

In the Seira, Mehara, and Tutuala regions, as survey areas, the potential land for elephant grass has a land suitability classification of S3 (marginal), with rainfall as a limiting factor. Technical improvements such as creating irrigation systems for livestock forage land could raise the suitability classification to S1 (highly suitable). Setaria grass has high land suitability with a classification of S1 (highly suitable), indicating that the land is well-suited for planting setaria grass without requiring improvements. For leguminous plants and grazing areas, the land suitability classification is S2 (moderately suitable) with rainfall as a limiting factor, and improvements such as creating irrigation could raise the land suitability classification to S1 (highly suitable). This land also holds potential for the diversification of agricultural, livestock, and aquaculture sectors.

To enhance livestock development locations, particularly livestock forage in Lautém District, several important steps need to be taken to improve both the quantity and quality of forage, including:

1. **Planting Leguminous Forage**

Planting leguminous forage is a priority, as legumes generally have higher nutritional content compared to grasses. However, due to the limitations of legumes in their use, it is important to pay attention to their proportion in the composition with grasses. As a reference, Susetyo (1980) recommends that the ideal composition for grazing lands consists of 60% grasses and 40% legumes. Furthermore, according to Skerman (1977), legumes also play a role in controlling erosion, even more effectively than forests, due to their strong and deep root systems.

2. **Increasing Forage Species Diversity, Both Legumes and Grasses**

Increasing the diversity of forage species, including both legumes and grasses, is an important aspect of livestock feed development. The greater the diversity of forage species consumed by livestock, especially ruminants, the greater the likelihood of meeting their complete nutritional needs. Several high-nutrient legume species with potential for development include *Indigofera*, *Kaliandra*, *Turi*, and *Stylo*. A commonly found local legume species is *Lamtoro taramba*. It is important to note that care should be taken when feeding *Lamtoro* to pregnant livestock. Although it has high nutritional content, *Lamtoro* leaves contain anti-nutritional substances such as mimosine and cyanide acid, which can be toxic if consumed in excess. This can be managed by providing *Lamtoro* in moderate amounts, mixed with other feeds, and ensuring that it is given in a wilted (air-dried) form, reducing the levels of anti-nutritional substances.

B. Potential and Ecological Suitability of Livestock

Lautém District has a total area of 180,553.89 ha, with 70,087.25 ha allocated for livestock sector development. This potential needs to be optimally utilized through human resource empowerment and the effective use of available land. One important factor in determining the potential of an area for livestock development is the ecological suitability or environmental conditions of the area. Areas that do not meet the ecological suitability indicators are categorized as less suitable for livestock development. Therefore, livestock development in Lautém District must consider ecological suitability aspects.

After obtaining measurements for each parameter in the field, including geophysical parameters such as rainfall and temperature, and soil chemical parameters such as Organic Carbon (C-organic), Total Potassium (K-Total), Available Potassium (K-Available), Cation Exchange Capacity (CEC), Base

Saturation (BS), etc., the data is analyzed using Geographic Information System (GIS) applications to determine the ecological suitability level for five types of livestock, including sheep, beef cattle, dairy cattle, pigs, and buffalo. The ecological suitability map for livestock is presented in **Figure 9.10**

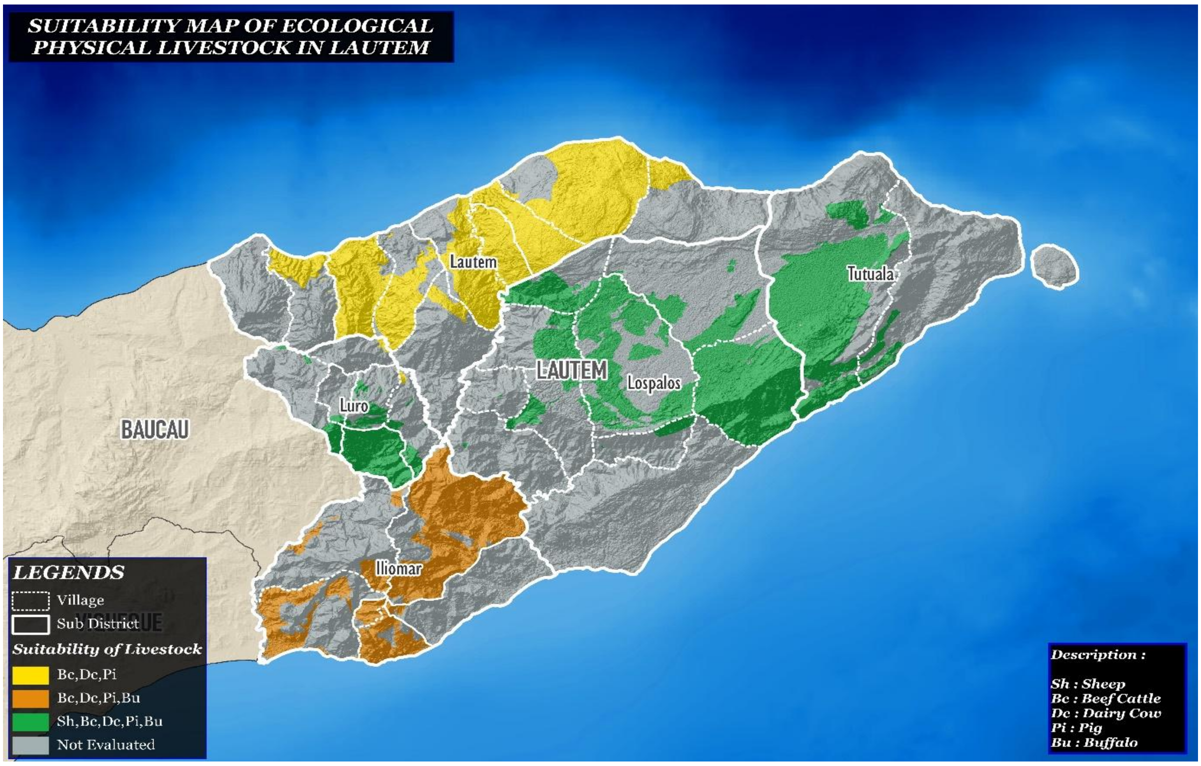

Figure 9.10 Ecological Physical Suitability Map for Livestock in Lautém District

The land available for livestock development in Lautém District consists of land designated for mixed gardens and grazing areas. These lands are categorized as available because they are assumed to be capable of producing livestock forage in the form of grasses, legumes, or agricultural by-products. Land that is categorized as unavailable for livestock development includes areas designated for forests and rice fields. From a technical perspective, this factor can be addressed with livestock housing that has proper air circulation and ventilation systems. However, for dairy cattle, temperature is a critical factor that must be met for their cultivation.

Table 9.1 Area of Livestock Develompment in Lautém District

Sub-District	Livestock Suitability for Development					Area (ha)
	Sheep	Beef Cattle	Dairy Cattle	Pigs	Buffalo	
Iliomar	N	S	S	S	S	13.551,08
Lautém	N	S	S	S	N	22.529,51
Lospalos	S	S	S	S	S	19.072,46
Luro	S	S	S	S	S	4.002,79
Tutuala	S	S	S	S	S	10.931,41

Based on the data analysis results presented in **Table 9.1**, it is known that the ecological suitability of land for large livestock development, including sheep, beef cattle, dairy cattle, pigs, and buffalo, shows a varied spatial distribution across the study area. Lautém Sub-District is the most dominant area for large livestock development in Lautém District, followed by Lospalos, Iliomar, and Tutuala Sub-Districts. Meanwhile, Luro Sub-District occupies the smallest area for livestock development. Lospalos, Luro, and Tutuala Sub-Districts are suitable for the development of sheep, beef cattle, dairy cattle, pigs, and buffalo. Livestock development in Iliomar Sub-District is suitable for beef cattle, dairy cattle, pigs, and buffalo, but not for sheep due to the limiting factor of temperature. Livestock development in Lautém Sub-District is suitable for beef cattle, dairy cattle, and pigs, but not for sheep and buffalo due to limiting factors of temperature and rainfall.

The ecological suitability of land for poultry livestock in the study area shows a very high and uniform level of suitability, with a coverage of 100%. This reflects the biological characteristics of poultry, which have a broad ability to adapt to various environmental conditions, allowing poultry to be raised on nearly all types of available land.

To support the development program of the livestock sector, it is necessary to identify and map areas that serve primarily as livestock farming locations and for the cultivation of livestock forage. Lautém District is known to have an average environmental temperature of approximately 25.26°C and annual rainfall of 1,482.43 mm, making it ecologically suitable to optimally support the sustainability of livestock farming. This condition also supports the availability of sustainable livestock forage 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, which triggers increased body heat production and basal metabolic rate. If this condition persists without adequate feed support, the livestock's metabolic energy will decrease, reducing their ability to withstand extreme temperatures. This condition impacts livestock growth, reduces productivity, and significantly increases the risk of disease outbreaks.

Conversely, excessively high environmental temperatures lead to reduced feed intake by livestock, which may prioritize increased water consumption. This reduction in nutrient intake directly impacts livestock performance and production. Therefore, optimal environmental management, particularly regulating temperature and humidity, is an essential prerequisite for a sustainable livestock farming system. This effort aims to create conditions that support the physiological balance of livestock, thereby maximizing productivity.

C. Socio-Economic Aspects of Livestock Farming

In the livestock sub-sector, the most prominent livestock farming activities in Lautém District are cattle (large livestock), pigs (small livestock), and poultry (local chickens). The most dominant livestock farming is poultry, with a population of 86,454 chickens, followed by pigs with a population of 37,272, and beef cattle with a population of 34,521 (Timor-Leste Agriculture Census, 2019). For the people of Lautém District, livestock plays a very important and multifaceted role, far beyond just being a source of food. Livestock has become an integral part of the subsistence farming system and the developing civilization. It is still common to find people using livestock, such as cattle, buffalo, and horses, as draft animals for plowing fields and farms. The use of draft animals allows farmers to work larger areas and significantly increase agricultural productivity. Additionally, in some cultures, livestock holds social, economic, or ritual significance. For example, in some traditions, livestock is used as dowry or offerings in ceremonies. Furthermore, the number of livestock owned by an individual is often seen as a measure of wealth and social status within the community.

One endemic livestock species in Timor-Leste is the Timor buffalo (*Karau Timor*). Timor buffalo plays a significant role in the social life of Timor-Leste, particularly in death, birth, and wedding ceremonies. Timor buffalo are also used in traditional transactions such as land sales, and their manure is used as fertilizer for crops. Historically, the local community has consumed Timor buffalo milk to meet their animal protein needs, making it no surprise that Timor buffalo are highly valued.

Timor buffalo milk has been consumed by the community for generations and is one of the most favored types of milk, alongside cow and goat milk. Timor buffalo milk is thicker and has a distinct smell compared to cow's milk. In the past, the community was accustomed to consuming Timor buffalo milk directly without further processing. Therefore, Timor buffalo milk has become a symbol of cultural identity.

Livestock farming is generally still carried out using the traditional system of free-range grazing, known as the extensive system. According to Williamson and Payne (1993), in the extensive system, livestock are kept freely and graze on available forage in the wild. In this system, livestock are released with a mix of males and several females in one population. The main characteristic of extensive farming is the absence of livestock housing and the lack of supplementary feed (Jamili, M. A. 2022). The advantages of the extensive system include low labor requirements, short working hours, and livestock being able to forage in grazing fields and former agricultural lands. However, the challenges faced by livestock include difficulty in controlling nutritional intake and the susceptibility to disease and death. Livestock that roam freely and are poorly supervised also create social issues, such as livestock theft and damage to farmers' crops.

Livestock farming practices still rely heavily on local knowledge passed down through generations. The absence of large-scale livestock industries means that livestock production has not yet reached optimal levels, and many aspects need improvement. Livestock distribution within the community is relatively low due to limited capital and the low practice of breeding. This is because increasing livestock numbers requires significant costs and time. As a result, livestock are not used as the primary source of income, which limits livestock production in the area (Serey *et al*., 2014).

According to interviews, the community received cattle and buffalo assistance in 2014 from MAPPF. However, over time, due to low supervision and lack of community education, the assistance has not developed as intended. The community used the assistance to meet household needs or as dowry (belis). As a result, attention to the sustainability of livestock breeding has been neglected, which may hinder sustainable development.

Other challenges faced in livestock farming are complex, spanning from the upstream to downstream processes, as well as the lack of infrastructure and facilities that also need development. In terms of breeding, the community still applies a natural breeding system without recognizing Artificial Insemination (AI) technology, making livestock breeding for sustainability difficult. The community still has limited knowledge of good livestock management practices. They are not educated on appropriate feed for livestock productivity. Additionally, in terms of marketing, farmers can only sell live animals, which makes it difficult to increase the selling price of livestock products. Although access has opened up from Dili, the capital, to other districts, there are still many roads with inadequate infrastructure. This becomes a barrier for the community in marketing their livestock products to broader markets.

Given the numerous challenges faced from pre-production to post-production stages, these issues require attention so that they can be addressed as a basis for designing a master plan for livestock development. Recommended improvements can start with educating the community on breeding and introducing Artificial Insemination (AI) technology. Additionally, education on the importance of good livestock management practices is necessary. This aims to motivate the community to be more economically oriented in livestock farming, rather than just using it as a family savings source. The government should not only provide education but also offer financial support in the form of credit loans to help streamline livestock businesses. Improving product sales can be achieved by educating and opening marketing channels for livestock that go beyond the sale of live animals

X. FRESHWATER FISHERIES POTENTIAL

10.1 INTRODUCTION

Timor-Leste, as an archipelagic country located in the tropics, possesses abundant fishery resources from the capture sector. One strategic approach to increasing national fish production is through the development of land-based aquaculture that utilizes local resources. Pond-based aquaculture is one of the most widely adopted systems because it can be adapted to the community's geographical and socio-economic conditions. One area with strong prospects in this sector is Lautém District, located at the eastern tip of Timor Island and known for its diverse aquatic ecosystems and underutilized land resources.

Lautém District has distinctive geographical characteristics, with a long coastline, extensive coastal areas, hilly terrain, and several rivers and springs originating from the mountains. Its strategic location and relatively pristine natural conditions provide high potential for the development of pond-based aquaculture, both in lowland areas and in the hills where water sources are accessible. However, prior to development, a land suitability evaluation is required to ensure that selected sites support the optimal growth and survival of cultured organisms.

In the context of regional development, aquaculture development in Lautém functions not only as a source of food and income but also as a key driver toward achieving the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 8 (Decent Work and Economic Growth), and SDG 14 (Life Below Water). Although specific production data for Lautém are not yet widely available to the public, various national programs supported by the government and development partners such as WorldFish have begun to target the eastern region, including Lautém, to increase fish production capacity through simple technologies and seed distribution.

Despite initiatives to strengthen capacity through seed distribution and the application of simple technologies, aquaculture development in Lautém still faces several challenges, including technological limitations, limited access to technical training, and pond systems that remain largely traditional. Suboptimal production is also closely related to land use that is not yet suitable and water quality management that has not been maximized. Therefore, a land suitability evaluation is an important step to support the success of aquaculture enterprises in the area. The evaluation considers key criteria such as topography, soil quality, water quality, and local climatic conditions.

Topographic aspects, such as slope gradient, influence the ease of pond construction and erosion risk. Soil conditions are also crucial, including organic matter content as an indicator of fertility, soil pH as a determinant of acid-base balance, and clay percentage, which affects the soil's water-holding capacity. Water quality is another key parameter in determining culture feasibility. Temperature, salinity, total dissolved solids (TDS), pH, dissolved oxygen (DO), and ammonia are factors that strongly affect the health and growth of cultured organisms. In addition, climatic factors such as annual rainfall patterns and dry season duration determine water availability, flood risk, and drought potential, all of which affect pond management.

Using these parameters, land suitability can be evaluated through an assessment matrix that applies a multidisciplinary approach integrating laboratory soil tests, field-based water quality measurements, and local climate analysis. The parameters to be identified are assigned specific weights that reflect their importance in determining land suitability for aquaculture. The assessment matrix provides the scientific basis for developing pond-based aquaculture in Lautém District. The results are expected to serve as a planning reference for pond development that is adapted to local conditions, environmentally sound, and sustainable over the long term.

By integrating ecological and technical scopes, this study responds to the practical needs of aquaculture practitioners in Lautém District while contributing significantly to the achievement of the SDGs, particularly in strengthening food security (SDG 2), promoting decent work and responsible economic growth (SDG 8), and conserving terrestrial ecosystems (SDG 15). Through this approach, the aquaculture potential of Lautém's coastal and inland areas can be optimized in an inclusive and sustainable manner.

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**.

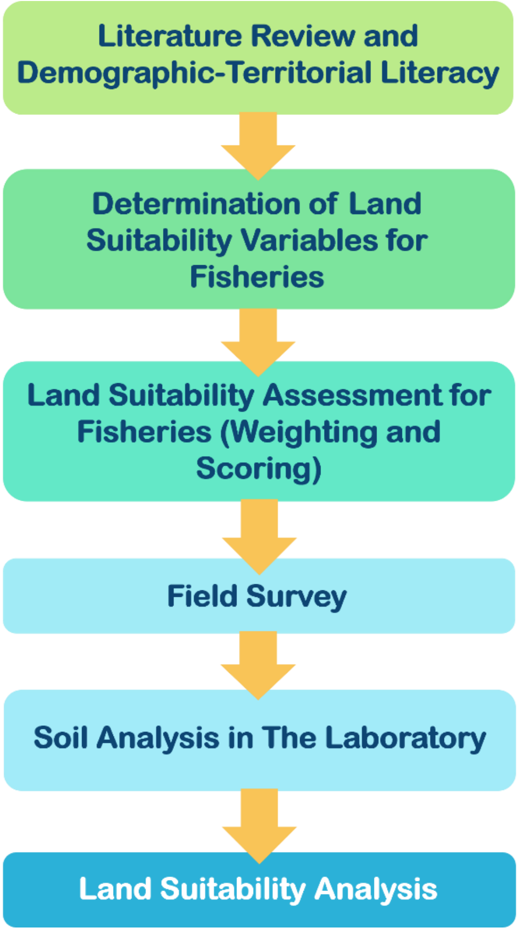

Figure 10. 1 Flowchart of the Research Process for Land Suitability in the Aquaculture Sector

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

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.
Climate	Water availability derives not only from springs but also from the hydrological cycle, which depends on the rainy season.

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	Remote Sensing/ Climatology	Ex Situ / Digital
	- Dry months			

		-	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 matter.

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 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:

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 Lautém District

No.	Schedule	Sub-District	Village	Purpose (Ownership)
1	7 May 2025	Lospalos	Souro	Business (Individual)
2	7 May 2025	Lospalos	Fuiloro	Business (Group)
3	7 May 2025	Lospalos	Muapitine	Non- Business (Government)
4	7 May 2025	Lospalos	Motolori	Business (Individual)
5	8 May 2025	Lospalos	Fuiluro	Business (Individual)
6	8 May 2025	Lautém	Parlamento	Business (Private)
7	8 May 2025	Lautém	Parlamento	Business (Individual)

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 2,5-8,0	> 8,0
Water Quality				
- Temperature (°C)	24-28	22≤24 28-30	20≤22 30-32	< 20 > 32
- Salinity (ppt)	< 10	10-25	25-35	> 10
- pH	6,5-8,5	6,0≤6,5 8,5-9,0	5,5≤6,0 9,0-9,5	< 5,5 > 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 3.000-3.500	< 1.000 > 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

The number of fishing households in Lautém District is recorded at 214 households, distributed across the district. This figure reflects the presence of a community still dependent on fishery resources, particularly fishing as a primary livelihood. Most fishing households are concentrated in Lautém Sub-District, which accounts for nearly 72% of the total fishing households in the region. This high concentration indicates that Lautém Sub-District is the main center for capture fisheries activities, likely supported by geographical factors, accessibility to the sea, and better fishery facilities compared to other Sub-Districts..

Meanwhile, Tutuala Sub-District ranks second with 31 fishing households, or about 14% of the total, indicating that fishing activities are also fairly developed in this area, though not as intensively as in Lautém. Other Sub-Districts such as Lospalos, Iliomar, and Luro show relatively low levels of fishing household involvement. This may indicate that in these areas, people are more reliant on agriculture or other activities, or they have limited access to fishery resources.

These findings provide important insights into the concentration and distribution of fishing households in Lautém District, which can be used as a basis for developing spatial and sustainable fisheries strategies, as well as identifying priority areas for policy interventions, infrastructure development, or strengthening fishermen's capacity. Graphs on the number of fishing households are presented in **Figures 10.2** and **10.3.**

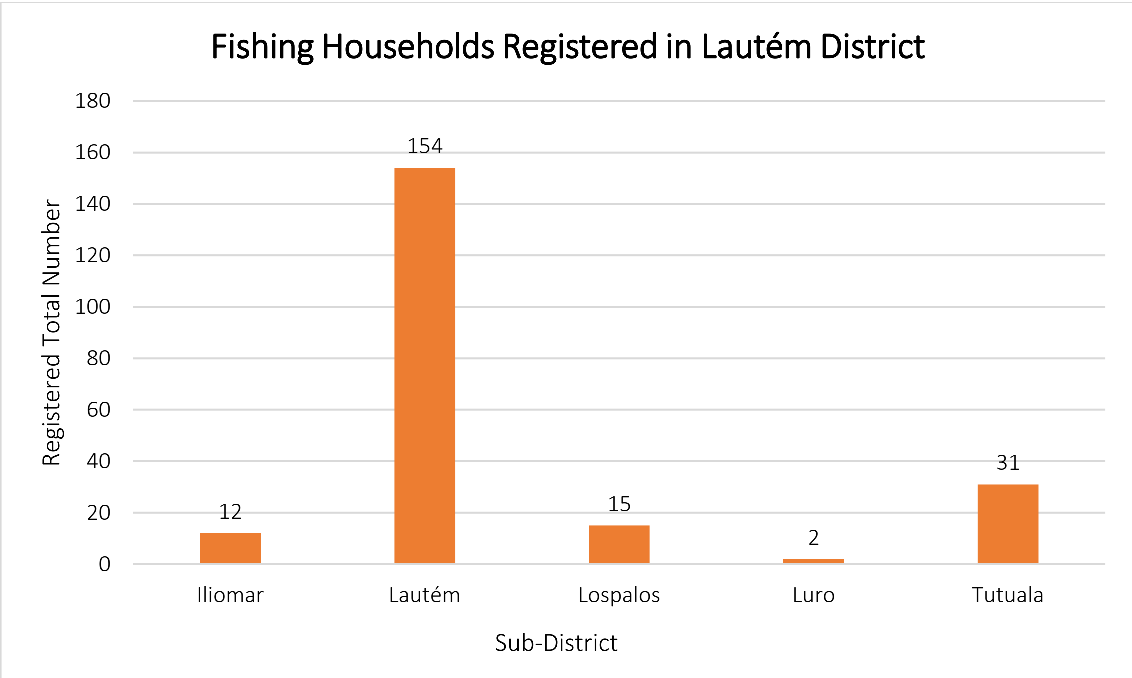

Figure 10.2 Fishing Households in Lautém District
(Source: Timor-Leste Agriculture Census, 2019)

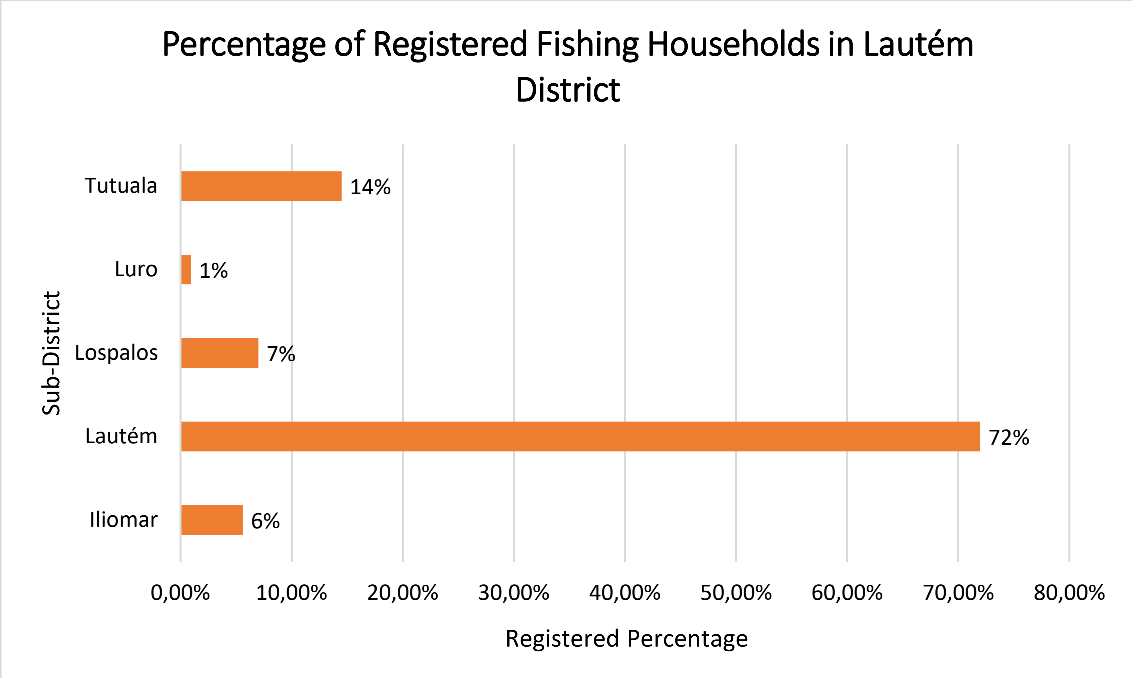

Figure 10.3 Percentage of Fishing Households in Lautém District
(Source: Timor-Leste Agriculture Census, 2019)

2. Households Involved in Fishing Activities

Fishing activities in Lautém District involve various households with different purposes, ranging from personal consumption, social obligations, to commercial economic activities. A total of 218 households are engaged in fishing, with around 66% of households fishing for both consumption and occasional sales. Meanwhile, about 20% of households engage in fishing for direct sale, and the remaining 14% do so for personal consumption and social obligations such as customs or community events.

Spatially, Lautém Sub-District has the highest involvement of households in fishing activities, particularly in sales. Around 74% of the total households fishing for consumption and occasional sales are from this Sub-District, and more than 90% of households selling fish directly to the market are also concentrated in Lautém. This indicates that Lautém Sub-District is the center of fishing activity with substantial commercialization potential.

On the other hand, other Sub-Districts such as Iliomar and Lospalos show characteristics of traditional and subsistence fishing. More than half of the households involved in fishing for personal consumption and social purposes come from these two Sub-Districts. Tutuala Sub-District plays a moderate role, while Luro Sub-District has very low household participation across all categories.

This condition reflects that the potential and characteristics of fishing activities in Lautém District are uneven, with subsistence activities dominating in some areas and significant potential for commercial capture fisheries development in Lautém Sub-District. The number of households involved in fishing activities is presented in **Figures 10.4** and **10.5.**

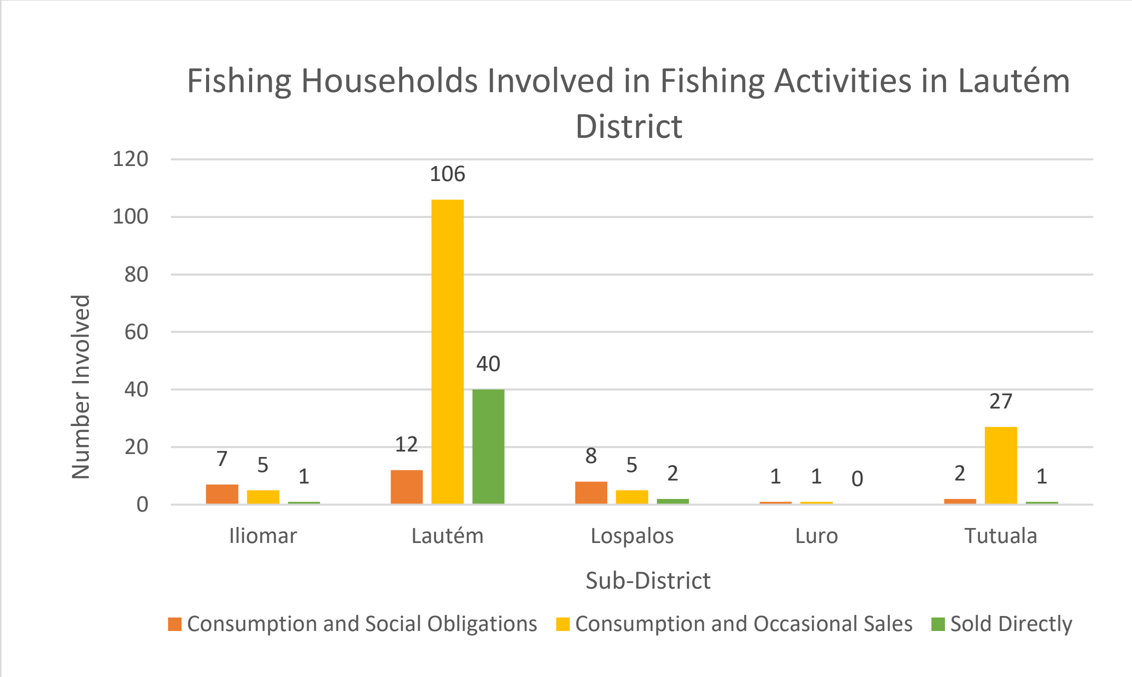

Figure 10.4. Number of Households Involved in Fishing Activities
(Source: Timor-Leste Agriculture Census, 2019)

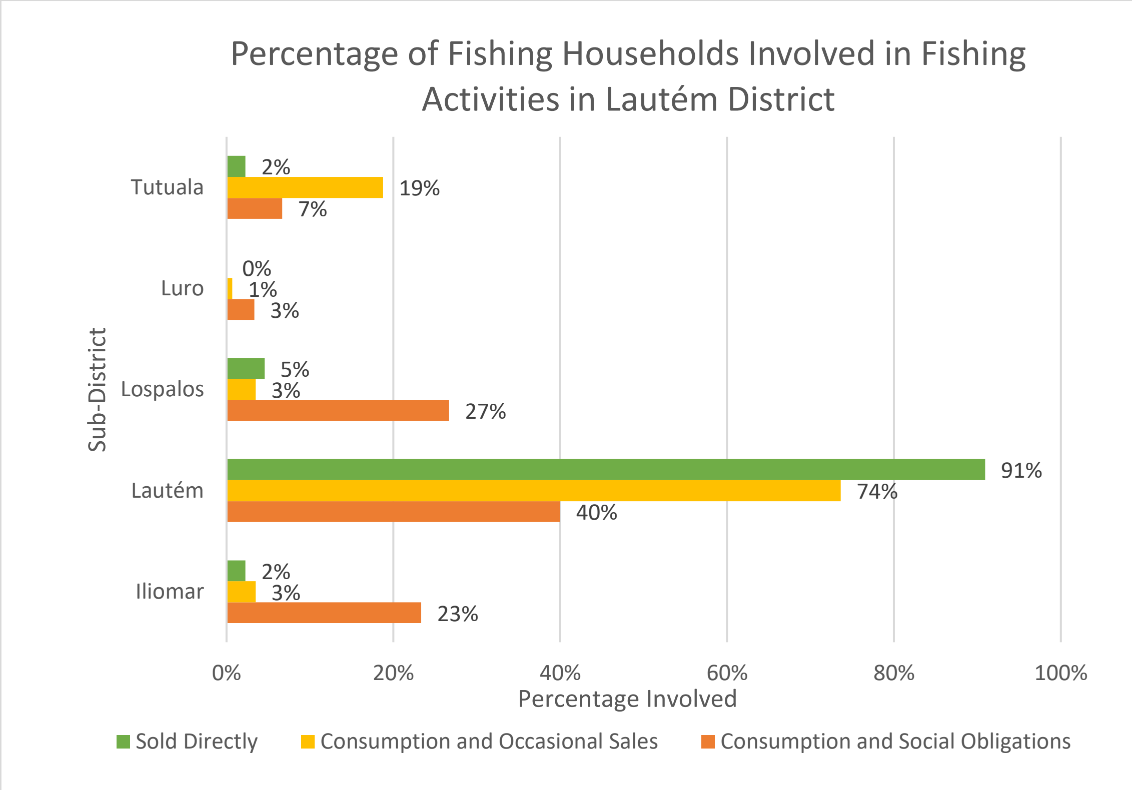

Figure 10.5. Percentage of Households Involved in Fishing Activities
(Source: Timor-Leste Agriculture Census, 2019)

A. Aquaculture

1. Proportion of Land for Aquaculture

The proportion of land used for aquaculture activities in Lautém District shows spatial imbalance across the Sub-Districts. Of the total area of 6.553 hectares used for freshwater and brackish fish farming, Iliomar Sub-District stands out as the most dominant, contributing 57.99%. This figure reflects that more than half of the aquaculture activities in Lautém are concentrated in Iliomar, likely supported by better geographical conditions, water availability, and land infrastructure compared to other Sub-Districts.

Lospalos Sub-District ranks second, contributing 17.96% of the total aquaculture land area, followed by Luro Sub-District (13.87%) and Lautém Sub-District (8.19%). These three regions show active aquaculture activities, although they are still far below the contribution of Iliomar. In contrast, Tutuala Sub-District contributes only 1.98% to the total aquaculture land area, indicating limited utilization of land for aquaculture in this area. Proportions of land for aquaculture are presented in **Figures 10.6** and **10.7.**

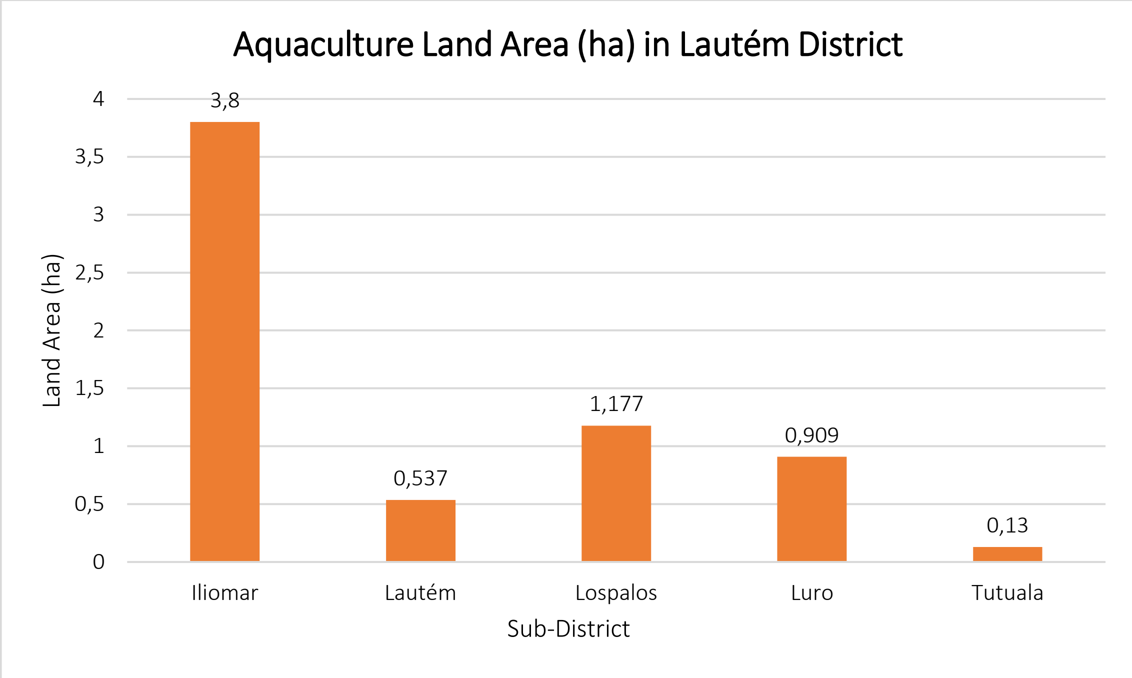

Figure 10.6. Aquaculture Land Area Lautém District
(Source: Timor-Leste Agriculture Census, 2019)

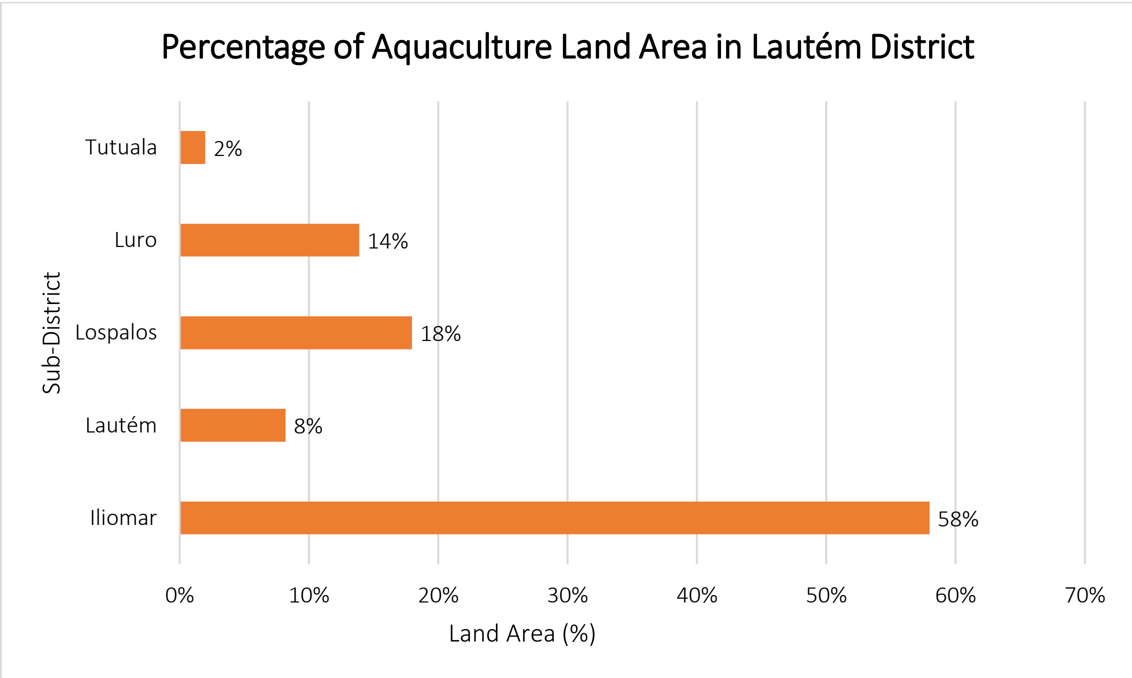

Figure 10.7. Percentage of Aquaculture Land in Lautém District
(Source: Timor-Leste Agriculture Census, 2019)

2. Aquaculture Households

Aquaculture activities in Lautém District show widespread community involvement, with a total of 106 households recorded as fish farmers. This activity is not only concentrated in coastal areas but is also growing rapidly in inland regions. This is reflected in the dominance of Luro Sub-District, which records the highest number of aquaculture households, with 40 households, or approximately 37.74% of the total. This finding is interesting because it shows that Luro Sub-District has sufficient freshwater resources to support aquaculture activities, despite not being located in coastal areas.

Next, Lautém Sub-District and Lospalos Sub-District also play significant roles in aquaculture development, each contributing about 22.64% and 21.70%, respectively. Meanwhile, Iliomar Sub-District ranks mid-level with 15 households (14.15%), and Tutuala Sub-District has the lowest participation, with only 4 households (3.77%).

The distribution of aquaculture households reflects that fish farming has become a promising alternative livelihood for communities in various parts of Lautém District, especially in areas with access to freshwater resources or suitable land. This potential needs to be further developed through technology support, training, and policies that promote sustainability and increased productivity in each region.

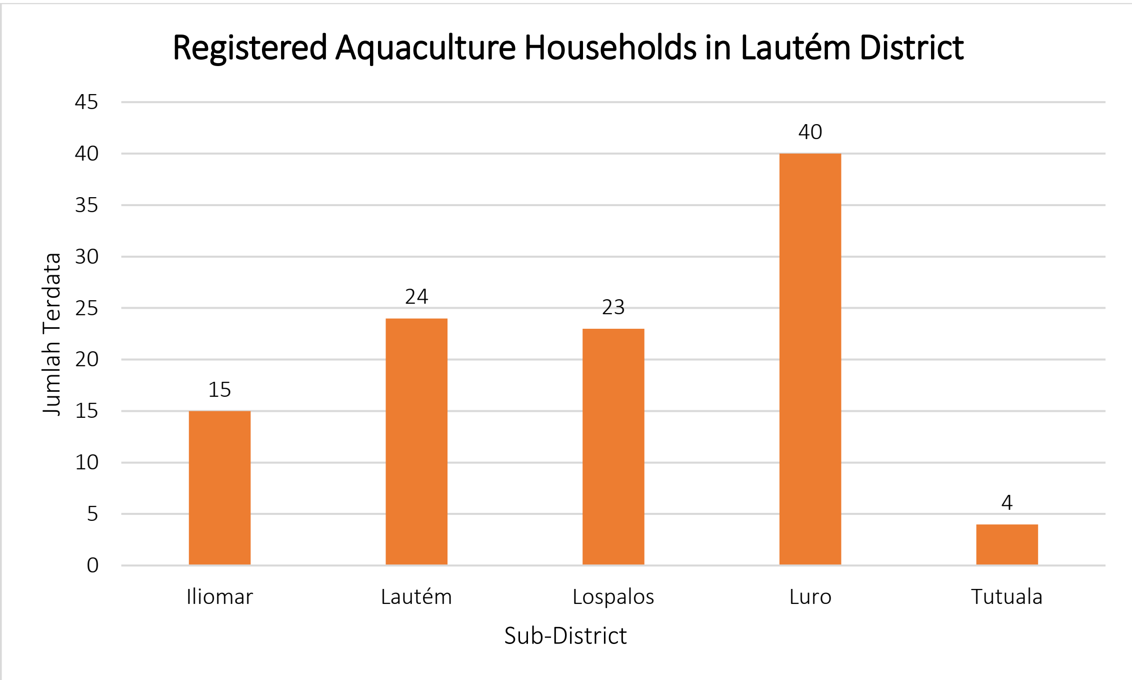

Figure 10.8. Aquaculture Households in Lautém District
(Source: Timor-Leste Agriculture Census, 2019)

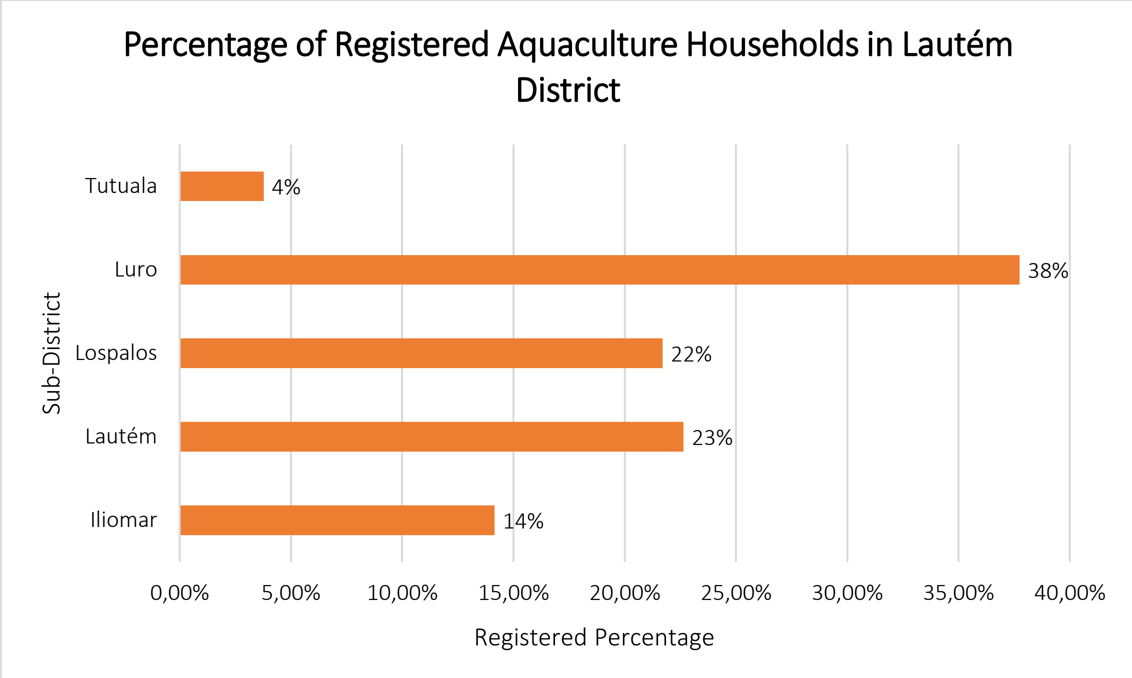

Figure 10.9. Percentage of Aquaculture Households in Lautém District
(Source: Timor-Leste Agriculture Census, 2019)

3. Aquaculture Systems

Aquaculture farming systems in Lautém District show that pond-based fish farming is the most dominant form, with a total of 165 units spread across almost all Sub-Districts. Luro Sub-District contributes the largest portion, accounting for 41.82% of the total ponds, or 69 units. This positions Luro Sub-District as the center for freshwater pond aquaculture in the region. It is followed by Lautém Sub-District and Lospalos Sub-District, each contributing 23.64% (39 units), and Iliomar Sub-District with 10.30% (17 units). In contrast, Tutuala Sub-District has only 1 pond unit, or 0.61%, making it the Sub-District with the lowest pond fish farming activity.

In terms of shrimp ponds and fish cages, the data show that these systems have not yet developed widely. There is only one unit of shrimp pond and one unit of fish cage, both located in Tutuala Sub-District, contributing 100% of the shrimp ponds and fish cages in Lautém District. The presence of these systems provides an initial indication that Tutuala Sub-District has access to and potential for developing shrimp and cage farming systems, though on a very small scale.

The rice-fish farming system is represented by 11 units across four Sub-Districts. Lautém Sub-District leads with 54.55% (6 units), followed by Lospalos Sub-District and Luro Sub-District, each with 18.18% (2 units), and Iliomar Sub-

District with 9.09% (1 unit). This data reflects that Lautém Sub-District is the most promising area for further development of the rice-fish farming system, which integrates agriculture and aquaculture.

Meanwhile, hatcheries are only found in Iliomar Sub-District, contributing 100% of the total hatchery units. This shows that hatchery independence remains a major challenge in most areas, as 80% of the districts do not have hatchery facilities. Graphs showing aquaculture facilities used in Lautém District are presented in **Figures 10.10** and **10.11.**

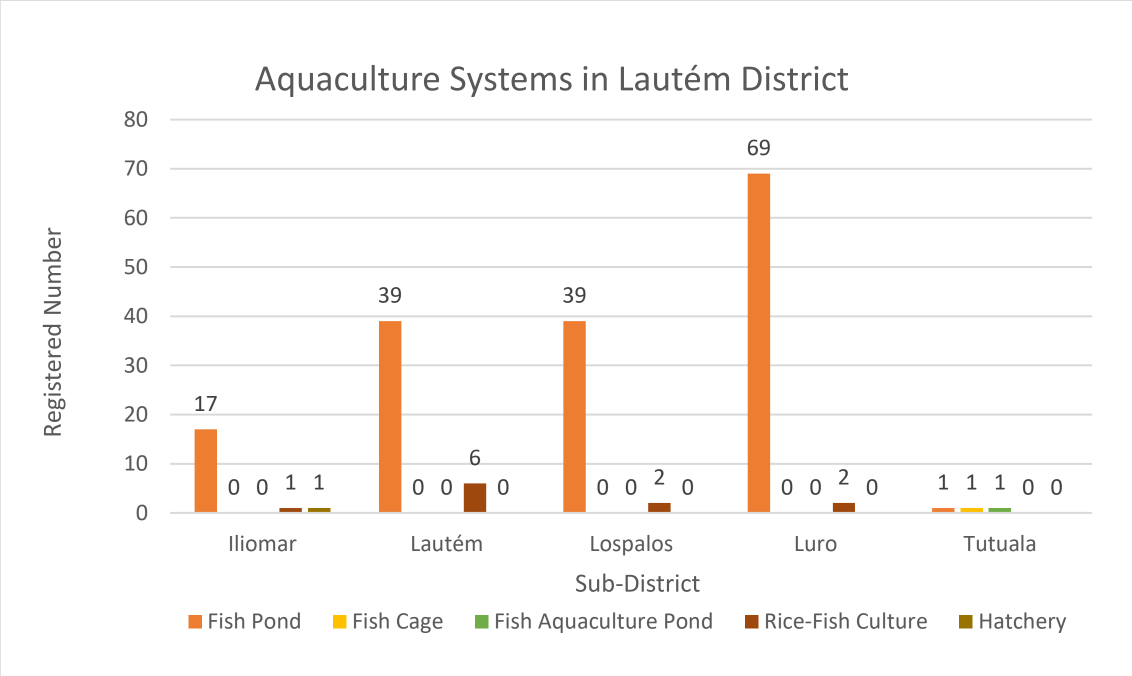

Figure 10.10. Aquaculture Systems in Lautém District
(Source: Timor-Leste Agriculture Census, 2019)

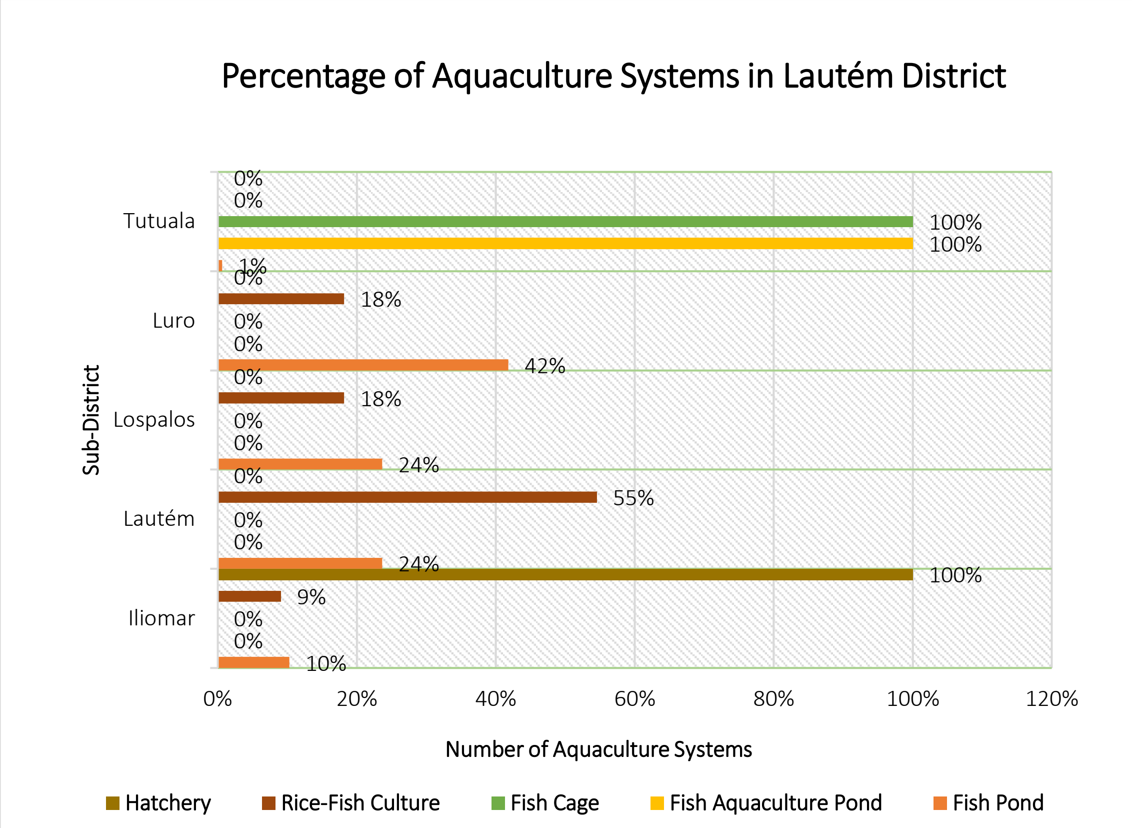

Figure 10.11. Percentage of Aquaculture Systems in Lautém District
(Source: Timor-Leste Agriculture Census, 2019)

B. Field Observation Results

Lautém District has various aquaculture farming systems spread across several observation sites, each with unique characteristics based on water sources, infrastructure, and management techniques. Most ponds are conventional earthen ponds, with the primary water source coming from natural springs, which are channeled directly into the ponds via hoses, pipes, or simple ditches. Aeration systems are generally limited, except in certain locations such as Parlemento Village, where additional aeration has been applied to the seed ponds.

Figure 10.12 Parent and Seed Fish Ponds in Parlemento Village
(Source: Research Documentation, 2025)

At certain observation sites, such as Souro Village and Fuiloro Village, fish farming is done in conventional earthen ponds with varying stocking densities, ranging from 7 fish/m² to thousands per pond. The maintenance cycle ranges from 3 to 5 months, with variable fish survival rates depending on the management system and availability of feed.

Figure 10.13 Conventional Earthen Pond in Souro Village
(Source: Research Documentation, 2025)

Figure 10.14 Conventional Earthen Pond in Fuiloro Village
(Source: Research Documentation, 2025)

In Motolori Village, there is a pond managed by a household group with a survival rate of 90%, showing the effectiveness of a more organized management strategy.

Figure 10.15 Conventional Earthen Pond in Motolori Village
(Source: Research Documentation, 2025)

In addition to earthen pond systems, Lautém District has great potential for fisheries development at Lake Ira Lalaro, the largest lake in Timor-Leste, with abundant water sources and untapped land topography. Although it was once planned as a hydropower project, the project did not materialize due to funding constraints, leaving an open opportunity for lake-based fishery management.

Figure 10.16 Irasiquero River Flow, Lake Ira Lalaro
(Source: Research Documentation, 2025)

In other locations, such as the government demonstration ponds in Motolori Village, a full concrete pond system is applied with inlet and outlet channels, but no aeration. Maintenance at these ponds shows a survival rate of around 48.85%, with the main challenge being feed efficiency.

Figure 10.17 Demonstration Pond in Motolori Village
(Source: Research Documentation, 2025)

Meanwhile, Parlemento Village is the center for tilapia seed production, with a seed production of 1 million fish per year. This location also faces significant challenges, such as high mortality during the dry season and soil texture issues that cause water seepage, leading to frequent pond drying.

Figure 10.18 Tilapia Seed Pond in Parlemento Village
(Source: Research Documentation, 2025)

Additionally, tilapia farming experiments in coastal ponds at Parlemento Village have shown promising results. Initially intended for milkfish farming, these ponds are now used for tilapia growth and have provided satisfactory harvests. This demonstrates the potential for adapting and diversifying commodities within the fisheries system in Lautém.

Figure 10.19 Tilapia Growth Pond in Parlemento Village
(Source: Research Documentation, 2025)

Overall, fisheries in Lautém District present various opportunities and challenges. The utilization of available natural resources, improvements in aeration systems, and adaptations to environmental and seasonal conditions are key factors in optimizing fisheries productivity in the region.

10.4 COMPREHENSIVE LAND SUITABILITY ANALYSIS FOR AQUACULTURE

A. Aquaculture Land Suitability in Lautém District

Land suitability refers to the degree of appropriateness of an area for a specific use, particularly for the aquaculture industry. This concept includes assessing the physical, chemical, and climatic characteristics of the land to determine its support for optimal and sustainable aquatic commodity cultivation. The land suitability evaluation is conducted based on two conditions: actual (current state) and potential (after improvements).

Actual land suitability is determined through field surveys that represent the land's capacity in its natural state without intervention. This evaluation does not consider corrective measures or management to address existing constraints in each land unit. The evaluation process involves identifying limiting factors for each land quality, assigning scores, and calculating the final evaluation score. The results provide a factual picture of the challenges faced.

On the other hand, potential land suitability describes the level of suitability after improvements are made. For example, land that is initially considered marginally suitable (S3) can be upgraded to moderately suitable (S2) or highly suitable (S1) if the main constraints, such as topography or water quality, are addressed. This evaluation focuses on corrective actions to improve limiting factors and significantly increase land suitability.

With the advancement of technology, land with low suitability in its current state can be upgraded to higher suitability classes in its potential state. However, not all land characteristics can be improved with available technology, and some may require intensive management. Therefore, in aquaculture land use planning, potential land suitability serves as the primary reference because it reflects the maximum capacity of the land after improvements. This evaluation supports effective and sustainable land use planning and serves as a basis for determining necessary corrective measures to achieve optimal results.

B. Results of Aquaculture Land Suitability Evaluation Lautém District

Land suitability analysis is a crucial step in designing sustainable land resource management strategies to support aquaculture development. This evaluation adopts an integrated approach that combines geospatial data, field observations, and laboratory analysis of physical and chemical properties of soil and water. This approach allows for the identification of both the potential and limitations of land bio-physical characteristics in supporting the cultivation of various aquatic commodities.

The data collected is analyzed based on the growth requirements of each commodity, both in its actual condition and potential condition after land improvements. These improvements can include topographic modifications, water quality management, or the application of adaptive cultivation techniques. This analysis produces comprehensive information that can be used to prioritize the development of commodities, identify limiting factors, and formulate appropriate technical solutions. This scientific evaluation forms the foundation of the land suitability assessment in Lautém District.

The analysis results provide strategic directions to optimize land productivity while maintaining the sustainability of aquatic resources in the region. All field and laboratory data used in the evaluation are included in the relevant supporting documents. A soil distribution map for aquaculture land in Lautém District is shown in **Figure 10.20.**

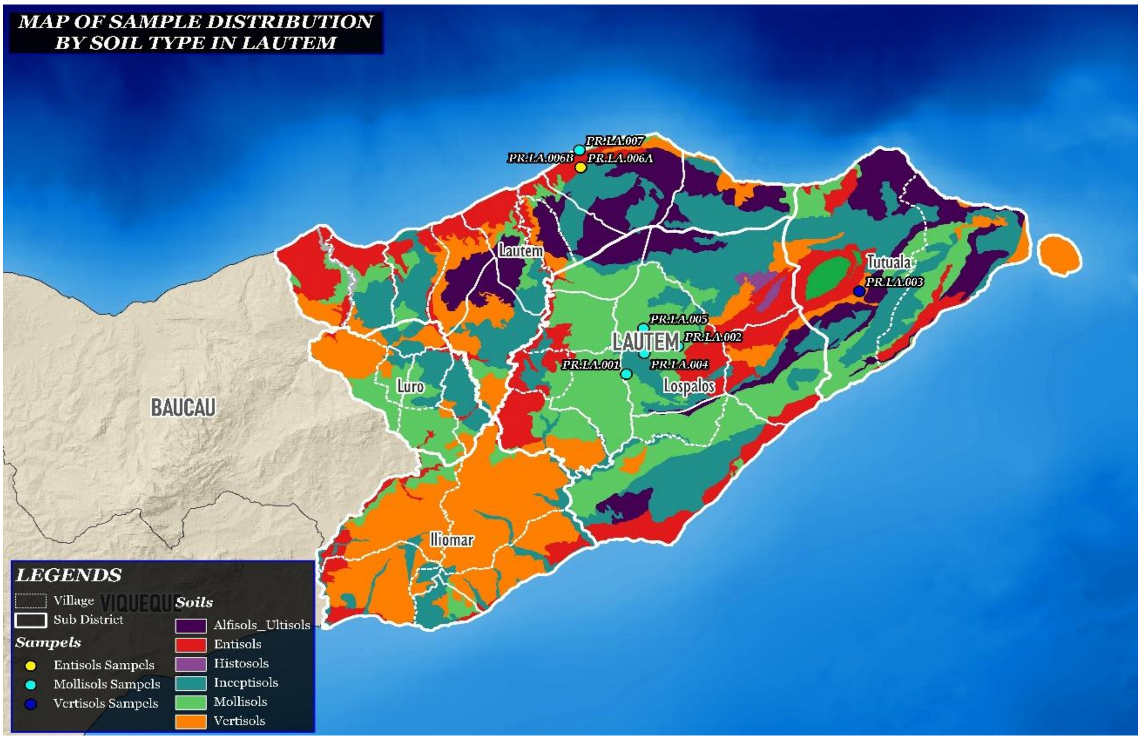

Figure 10. 1 Map of Soil Distribution on Aquaculture Land in Lautém District

a. Land Suitability Evaluation in Lospalos Sub-District

The land suitability evaluation for aquaculture activities in Lospalos Sub-District, Lautém District, shows that this area has potential for both freshwater and brackish water aquaculture. However, several environmental factors act as constraints that limit land suitability, both in actual and potential conditions (as shown in **Table 10.9**). Nonetheless, there are still opportunities for improvement to enhance the potential through interventions based on management difficulty levels.

For freshwater commodities such as gourami (*Osphronemus gouramy*), catfish (*Clarias batrachus*), carp (*Cyprinus carpio*), and tilapia (*Oreochromis niloticus*), the dominant actual limiting factors include high rainfall, prolonged dry seasons, and steep topography. For example, for gourami, in addition to rainfall and the dry season, low water pH is also a limiting factor, classified as S2. However, the pH can be improved through corrective actions such as regular water changes and the use of zeolite, as detailed in **Table 10.10**. These actions are considered to be of low to medium management difficulty and can be carried out by local farmers at relatively low costs.

To address the topography constraint of steep slopes, one recommended technical solution is the implementation of terraced ponds or terracing systems. Although this approach has high management difficulty, it allows pond infrastructure to be built in sloped areas, thus improving actual land suitability to reach potential classes (S3 or S2).

For brackish water commodities such as milkfish (*Chanos chanos*), mangrove crab (*Scylla serrata*), and vannamei shrimp (*Litopenaeus vannamei*), more serious constraints were found. Low salinity is the primary limiting factor, as Lospalos Sub-District has limited access to seawater and is largely dominated by highland or non-coastal areas. This parameter leads to an actual suitability rating of N (not suitable) for mangrove crab. Although methods to increase salinity through conventional seawater mixing or pump systems are available, these methods are highly challenging and require significant resources and infrastructure, making them economically unfeasible in this area.

In general, climatic constraints such as extreme rainfall and long dry seasons cannot be directly improved, as they are natural characteristics of the region. Therefore, while some technical factors can be addressed, climatic parameters remain limiting factors for S2 or S3 suitability classes that are difficult to change. By focusing on local conditions, using appropriate simple technologies, and prioritizing freshwater commodities that are more tolerant of environmental conditions in Lospalos, aquaculture activities can still be developed sustainably. The combination of land improvement techniques, water quality management, and the selection of adaptive commodities will be the key to successful aquaculture sector development in this area.

Table 10. 9 Land Suitability Analysis for Aquaculture Commodities in Lospalos 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 S3: Rainfall, dry months S2: Low temperature, pH	3.2	S3: Rainfall, dry months, slope gradient	3.44
Catfish (*Clarias batrachus*)	N: Slope gradient S3: Rainfall, dry months	3.32	S3: Rainfall, dry months, slope gradient	3.44
Carp (*Cyprinus carpio*)	N: Slope gradient S3: Rainfall, dry months	3.32	S3: Rainfall, dry months, slope gradient	3.44
Tilapia (*Oreochromis niloticus*)	N: Slope gradient S3: Rainfall, dry months S2: Low temperature	3.27	S3: Rainfall, dry months, slope gradient	3.44
Milkfish (*Chanos chanos*)	N: Slope gradient S3: Low salinity, dry months S2: Low temperature, rainfall	3.13	S3: Dry months, slope gradient S2: Rainfall	3.5
Mangrove crab (*Scylla serrata*)	N: Low salinity S3: Slope gradient, dry months S2: Low temperature, rainfall	3.15	S3: Dry months S2: Rainfall, slope gradient	3.62
Vannamei (*Litopenaeus vannamei*)	N: Slope gradient S3: Low salinity, rainfall, dry months S2: Low temperature	3.19	S3: Dry months, rainfall, slope gradient	3.44

C. Aquaculture Land Improvement Efforts

The results of the actual land suitability evaluation in Lautém District show various limiting factors that make most areas unsuitable or only marginally suitable for aquaculture activities. To improve the land suitability classes, corrective efforts or improvements to the limiting factors are required, as far as possible. Land improvement in the context of aquaculture includes all technical interventions aimed at improving the bio-physical conditions of the land and water environment to better meet the optimal needs of the cultivated commodities. These improvements can include habitat modification (e.g., improving pond conditions physically), water quality manipulation, or the provision of supporting infrastructure.

Based on **Table 10.10**, various improvement efforts are available with different management difficulty levels. The management difficulty levels are categorized into three: low, medium, and high. These levels are then used to assess the potential for improving actual land quality to potential suitability, 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. RECOMMENDATIONS

11.1 AGRICULTURE SECTOR

1) Land Potential and Spatial Distribution

Lautém District has diverse land resources for dryland agriculture. Daudare Village, Fuiloro Village, Com Village, Parlamento Village, Euquisi Village, Ailibere Village, Souro Village, Mehara Village, Lacawa Village, and Iliomar Village are suitable for food crop development due to a combination of soil characteristics, topography, and relatively supportive water availability. Intensive grazing areas are found in Parlamento Village, Fuiloro Village, and Cainliu Village, with primary forages including *Elephantgrass* (*Pennisetum purpureum*), *Imperata cylindrica*, and *Gliricidia sepium*.

2) Optimization of Irrigated and Rainfed Rice Fields

The flat alluvial plains of Lospalos Sub-District are strategically important for increasing rice production (both irrigated and rainfed) to meet local food needs. Actions include micro-topography mapping, construction of rainwater reservoirs and small check dams, simple piped distribution systems, improving inlet–outlet channels, and applying alternate wetting and drying to save water.

Idle land should be rehabilitated using integrated packages: soil fertility improvement (mature compost, mulching, cover crops), plot consolidation, access to improved seed and light mechanization, and synchronized planting schedules to increase the cropping index.

3) Coastal Agro-Tourism Potential in the Com Area (Tourism Hub)

The Com area features a coastal landscape with numerous lontar trees (*Borassus flabellifer*) that are ideal for developing a fruit-picking agro-tourism model based on a coastal mixed garden. This model combines wind- and salt-resistant fruit orchards with educational visit paths, product processing kiosks, and a seasonal harvest calendar, thereby enhancing farmers' assets and increasing the destination's marketability.

Recommended fruit crops suitable for the sandy and windy coastal areas include coconut (*Cocos nucifera*), lontar/*siwalan* (*Borassus flabellifer*), cashew (*Anacardium occidentale*), jujube/*bidara* (*Ziziphus mauritiana*), sea pandan

(*Pandanus tectorius*), soursop (*Annona squamosa*), pomegranate (*Punica granatum*), lime (*Citrus aurantiifolia*), mango (*Mangifera indica*), banana (*Musa spp.*), and pineapple (*Ananas comosus*).

For comfort and sustainability, install windbreaks using sea pine (*Casuarina equisetifolia*) or hibiscus (*Hibiscus tiliaceus*), apply mulch and biochar (biochar from pyrolyzed biomass) to improve water retention in sandy soils, and use drip irrigation for horticultural plots. Complete the setup with walking paths, interpretative signs, shaded resting areas, clean harvesting standards, "from tree to product" tour packages (e.g., demonstrations of non-alcoholic lontar sugar, coconut chips, fruit preserves), and a fair profit-sharing scheme between farmers, tourism groups, and the village government.

4) Conservation Boundaries: Tutuala Sub-District–Nino Konis Santana National Park and Jaco Island

In Tutuala Sub-District, the dominant area is the Nino Konis Santana National Park, which serves as a carbon reserve. Agricultural development should not overlap with core zones; cultivation should be directed to buffer zones with biodiversity-friendly agroforestry and wildlife corridors. Jaco Island (the easternmost part of Lautem) is a rocky forest area with very limited water availability, serving as an important habitat for local deer. Interventions should maintain the integrity of the ecosystem and avoid disturbances to wildlife.

5) Water Solutions and Wildlife Safety on Jaco Island

- Wildlife Guzzlers: Rainwater catchment systems based on simple roof structures (frame + roofing sheets) that channel water into ferrocement tanks; equipped with protectors, float valves, and one-way ramps so that deer can drink safely.
- Fog Catchers: Porous polyethylene mesh nets installed upright in windy locations to harvest dew/fog into closed tanks.
- Rock Catchment & Subsurface Dam: Runoff capture in natural stone basins; subsurface dams with geotextiles and impermeable layers to retain seasonal groundwater flow.
- Small Catchment Ponds with Geomembrane Linings in rocky locations that do not interfere with deer roaming paths.
- Solar-Powered Pumps for Shallow Wells, if water quality meets standards; treated as a secondary option after rain/fog harvesting.

- Last Resort: Micro-scale solar desalination (solar still or small reverse osmosis unit) if only brackish/saline water is available—placement must be far from sensitive zones, with safe disposal of concentrated brine. All water points should be partially fenced (to prevent livestock access), equipped with simple level sensors, and monitored by local forest communities to prevent disease transmission and predator disturbance.

6) Key Commodities and Production Clusters

Main food crops (cassava, corn, taro, peanuts, mung beans, sweet potatoes, *porang*; irrigated rice in well-watered areas) are combined with horticultural crops (chili, eggplant, green beans, squash, water spinach, tomato, cucumber, long beans, caisim; fruits such as papaya, banana, orange, mango, soursop, watermelon, durian, pineapple, dragon fruit).

Industry: coconut as a flagship crop across sub-districts. Specific location-based production clusters include: Lospalos (rice–corn), Iliomar and Cotamutu (tubers–legumes), Com–Parlamento (coconut–coastal horticulture), supported by post-harvest activities (grading, packaging) and a simple cold chain.

7) Soil Improvement and Fertility (Based on Soil Test Results)

Develop a balanced fertilization plan according to soil test results; add organic matter (mature compost), mulch, and biochar (biochar from pyrolyzed biomass) to increase water and cation retention capacity. Use agricultural lime on acidic soils (based on pH), and leguminous cover crops for biological nitrogen fixation.

8) Soil and Water Conservation and Erosion Control

Build stable terraces, plant along the contours (contour planting), install stone lines (stone barriers following contours), and construct small gabion dams in runoff channels. Protect riverbanks with vegetative buffers; plant *Leucaena leucocephala*, *Calliandra calothyrsus*, and *Gliricidia sepium* as soil binders and forage sources.

9) Grazing, Feed, and Silvopasture Systems

Implement rotational paddocks, cut-and-carry systems in sensitive zones, forage banks (reserve forage plots for dry seasons), and silvopasture (forage trees

+ grasslands) to enhance ground cover, reduce erosion, and improve livestock productivity.

10) Extension Services, Input Access, and Market Systems

Strengthen extension services on Integrated Pest Management (synchronized planting calendars, monitoring, biological agents), drip irrigation for horticulture, and post-harvest handling. Provide adaptive drought-resistant seeds, light farm tools, and microfinance schemes. Form cooperatives per sub-district for input procurement and marketing contracts, supported by improvements in production roads and collection points.

11) Implementation Stages (Quick Wins to Medium-Term)

- **Quick Wins:** Mapping flat land in Lospalos for rice fields, rehabilitating small irrigation channels, AWD demonstration plots for rice, activating fallow land with mulch and cover crops, installing a wildlife guzzler prototype on Jaco Island, and household rainwater catchment systems.
- **Medium-Term:** Community reservoirs and piped irrigation networks, block-scale terracing in erosion-prone zones, cold chain systems for horticulture, developing communal fog catchers in potential sites, and buffer agroforestry at the Nino Konis Santana National Park boundary (without entering the core zone).

11.2 LIVESTOCK SECTOR

Based on the evaluation of land suitability for forage, and the ecological suitability for livestock, there are two locations that have the potential to become pilot projects for the development of the livestock sector.

1. KTS Pato Center, In line with the national-scale plan for the development of Timor cattle to meet the community's milk needs, the short-term recommendation starts with preparing forage land with high nutritional value to support milk productivity. The government can introduce additional forage varieties, such as Setaria grass and legumes like *Gliricidia sepium*, *Calliandra calothyrsus*, and *Indigofera*. Technically, the forage composition should consist of 60% grass and 40% legumes. Additionally, it is recommended to supplement the diet with additional feed such as rice bran, concentrates, or flushing feed in certain buffalo conditions.

The long-term recommendations include improving reproductive technology, as well as training and education for the workforce. Significant attention must be given to reproduction, which directly affects milk production, through workforce training. Potential challenges include silent heat, a condition that can occur in buffalo. This can be addressed if workers have the necessary education and skills in reproduction, enabling them to detect heat accurately. Training can be further enhanced through certified artificial insemination (AI) courses, with the goal of ensuring that KTS Pato Center adapts to livestock technologies that can improve milk production efficiency. Once the facilities are adequate, the KTS Pato Center can implement sexing methods in livestock breeding as a key step in increasing the chances of female births, which are crucial for breeding stock and milk production.

2. Seiraa, Mehara, Tutuala Sub-District, These areas are recommended as pilot projects for integrated livestock farming, incorporating food crops and brackish water aquaculture. Forage crops such as *Setaria* grass and legumes like *Calliandra calothyrsus*, *Gliricidia sepium*, and *Leucaena leucocephala*, along with cattle and buffalo, can be integrated with food crops such as tubers, tomatoes, and bananas, as well as freshwater aquaculture.

11.3 FISHERIES SECTOR

1. Location-Specific Issues

To improve the effectiveness of aquaculture in several priority areas, technical issues have been identified at the village (administrative village) level, along with recommendations based on local conditions. The table below summarizes the key findings from four locations, including specific constraints faced by fish farmers and technical solutions. The issues in Lautem District are presented in **Table 11.1**.

Table 11. 1 Location-Specific Issues

Location	Main Issues	Technical Recommendations
Parlamento Village	- High mortality during the dry season - Soil texture causing pond leakage	- Add backup water sources during the dry season (rainwater harvesting or shallow well pumps) - Improve pond base structure (waterproofing with tarps/HDPE plastic)
Fuiloro Village	- Conventional system without aeration - Low feed efficiency	- Install simple aeration system (water wheel or manual blower) - Provide training on feed management and fish growth record-keeping
Souro Village	- Simple infrastructure - Unstable irrigation system - Minimal production record-keeping	- Improve water inlet/outlet channels - Provide training on production record-keeping and water quality control system. - Intensive extension services by local fisheries extension officers
Motolori Village	- Concrete ponds without aeration - Low feed efficiency	- Add simple aerators - Use siphon or alternating flow systems to maintain water quality - Provide training on feed efficiency and biologically-based feeding techniques

2. Pilot Project Location Determination

The recommended location for the Aquaculture Pilot Project in Lautem District is Parlamento Village. This area is considered suitable due to its existing capacity to produce up to one million tilapia per year, making tilapia the primary focus for development. Meanwhile, milkfish is better suited for cultivation in the coastal areas of Parlamento Village. The location was chosen based on ongoing aquaculture practices and the ease of replicating this model in other areas. However, improvements in infrastructure are still needed to optimize the aquaculture potential in this location.

3. Policy Recommendations for Local Government (District and Sub-District)

- Provision of government funds or infrastructure grants for concrete ponds, water channels, and aeration systems at priority locations.
- A Revitalization and Rehabilitation Program for Pond Lands, focusing on the improvement of soil pond structures and water use efficiency, especially in village areas with problematic soil textures.
- Provision of initial capital assistance and training for aquaculture groups that wish to produce local seeds or develop new commodities (milkfish, mangrove crabs, *vannamei* shrimp).

Collaboration on applied research and training with universities or technical fisheries institutions to enhance local capacity and ensure the sustainability of the aquaculture program.

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Lautém Municipality

Lautém Municipality is predominantly characterized by dryland areas with strategic potential for the adaptive and sustainable development of agriculture, forestry, livestock, fisheries, and agrotourism. Spatially, protected and conservation forest areas dominate land use, covering 47.49% of the total area, including Nino Konis Santana Protected Forest, the largest protected area in Timor-Leste, which functions as a strategic national asset for greenhouse gas absorption and carbon stock conservation. Agroforestry systems occupy 25.02% of the area, followed by dryland agriculture/mixed gardens (11.47%), rainfed rice fields (7.33%), grazing areas (4.38%), irrigated rice fields (4.22%), and mangrove forest (0.08%).

Based on land suitability evaluation, potential wetland food crop commodities include irrigated rice, while dryland food crops comprise upland rice and corn. The horticultural sector shows strong prospects for fruit commodities such as pineapple and snakefruit, as well as high-value vegetables including chili and bell pepper. For industrial and biopharmaceutical crops, Lautém Municipality has potential for the development of tobacco, cotton, aromatic ginger, and pepper. The forestry sector supports the development of acacia and melaleuca, while grazing systems are suitable for forage crops such as elephantgrass and setaria.

In the livestock sector, Lautém Municipality has significant potential for cattle and pig development, supported by the presence of KTS PATO (Lautem Administrative Post) with an area of approximately 150 ha. The fisheries sector is developing in both coastal and inland waters, particularly in Parlamento Village (Lautem Administrative Post), with tilapia and milkfish as leading commodities. Substantial opportunities also exist in Ilalaro Lake, the largest lake in Timor-Leste, which possesses abundant water resources and extensive land that remains underutilized.

From a biodiversity perspective, Jaco Island represents a high ecological value area that serves as habitat for the endemic Timor deer, although it faces challenges related to limited water availability and natural feed resources. In the tourism sector, the Com area has strong potential for development as coastal agrotourism based on lontar palm (Borassus flabellifer) plantations. In Lautém Municipality, multisector integration can be realized through integrated farming systems and aquaculture intensification, with Fuiloro Village and Parlamento Village recommended as pilot project sites for sustainable integrated agriculture, aimed at strengthening national food security within the context of Timor-Leste's integration into ASEAN.