Land Suitability Evaluation & Regional Potential Mapping

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

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

PERSON IN CHARGE

Eng. Marcos da Cruz, MAgSt
Minister of Agriculture, Livestock, Fisheries, and Forestry
Democratic Republic of Timor-Leste

FOREWORD

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

With gratitude to God Almighty, we are proud to welcome the publication of this book entitled "Land Suitability Evaluation and Mapping of Regional Potential for the Development of Agricultural Commodities in Ermera District, Timor-Leste." This book is 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.

Ermera District is a strategic area located in the highlands of Timor-Leste, comprising five key Sub-Districts, namely Atsabe, Ermera, Hatolia, Letefoho, and Railaco. This area has natural advantages in the form of a cool climate and fertile soils, making it highly suitable for the development of high-value horticultural and plantation commodities, such as coffee, vegetables, fruit crops, and other industrial crops.

In the current global context, food security has become a central issue that demands special attention from many countries, including Timor-Leste. Ermera District has an important role in addressing this challenge due to its considerable natural potential and land resources. In addition, sustainable development of the agricultural sector in this area will support the achievement of the Sustainable Development Goals (SDGs), particularly in addressing hunger (SDG 2), promoting inclusive economic growth (SDG 8), and supporting concrete actions to address climate change (SDG 13).

We believe that this book not only provides clear and measurable recommendations for land resource management, but also serves as a strategic guide for advancing a sustainable agricultural sector in Timor-Leste. Our strong expectation is that this book can be used by various stakeholders, including local government, academics, agricultural practitioners, and the wider community, in formulating agricultural development policies and strategies based on local potential.

Finally, we express our highest appreciation to the entire research team and all parties involved in the preparation of this book. We hope that this work will become an important milestone in the joint effort to realize community welfare through advanced, productive, and environmentally friendly agriculture in Ermera District and Timor-Leste as a whole.

Respectfully,

Eng. Marcos da Cruz, MAgSt
Minister of Agriculture, Livestock,
Fisher, and Forestry
Democratic Republic of Timor-Leste

EXECUTIVE SUMMARY

A. GENERAL OVERVIEW OF THE STUDY AREA

This chapter provides an overview of Ermera District as an important background for evaluating land suitability and the potential for developing agricultural, plantation, horticultural, and forestry commodities. The information presented includes demographics, soil types, geological formations, land use, slope gradients, agroclimatic zones, and existing field conditions, all using a comprehensive data-driven approach.

1. Demographics: Foundation of Human Resource Potential

Ermera District is comprised of several Sub-Districts: Atsabe, Ermera, Hatolia, Letefoho, and Railaco. Geographically, the study area is located at coordinates 8°48'24.8"S and 125°20'47.8"E, with an elevation of 1,195 meters above sea level, and is dominated by agroforestry and mixed gardens (dryland), showing significant potential for agricultural development as a backbone of national food security. With a strong foundation of human resources, Ermera District can play a strategic role in supporting agricultural transformation in Timor-Leste.

2. Soil Types: Basis for Land Suitability Evaluation

Ermera District is predominantly covered by Inceptisols, which make up 66.02 % of the total area, indicating a large potential for agriculture that requires good organic management and irrigation systems. Additionally, Vertisols cover 21.15 % of the area, with high nutrient retention characteristics, making these soils suitable for crops requiring stable water supply throughout the year.

3. Land Use: Ecosystem Dynamics and Human Activities

Ermera District has diverse land use types, reflecting a range of human activities and unique ecosystem dynamics. The dominant land use is forest, covering an area of 36,786 ha, or about 4.87 % of the total district area. Atsabe Sub-District has the largest forest area (19.31 %). This forest functions not only as an important natural resource but also as an ecosystem buffer, supporting biodiversity conservation, microclimate regulation, and water source protection. Commercial agricultural land covers 34,704 ha, or 45.17 % of the total area, making it the primary foundation for the local economy and agricultural potential of Ermera District. Hatolia Sub-District has the largest area of commercial agricultural land (14.38 %). With the dominance of plantation crops like coffee, this area significantly contributes to national exports and the well-being of local communities. Agricultural activities in Ermera District are also closely linked to ecosystem management, where sustainable farming practices are key to minimizing land degradation and increasing productivity.

4. Slope Gradient: Risks and Potential

The slope gradient in Ermera District predominantly ranges from 25% to 45%. Slope data indicates the complexity of the area, influencing erosion risks and land degradation. Areas with steep and very steep slopes require conservation approaches, such as terracing and cover cropping, to support stability and ecosystem sustainability.

5. Agroclimatic Zones: Regional Potential Grouping

Ermera District's agroclimatic zones are divided into three regions: A, B, and C. Generally, the district is dominated by zone B (5-6 wet months) and zone C (6-7 wet months). These conditions offer great potential for developing sustainable and productive dryland agriculture. With fairly stable rainfall during the wet season, the land in this area is ideal for cultivating a variety of food and horticultural crops.

6. Field Conditions: Issues and Potential

Land degradation issues (erosion, landslides, and critical land), lack of irrigation infrastructure, and suboptimal land management are the main barriers to land management. However, the significant potential for developing industrial crops presents opportunities that can be optimized through conservation-based approaches and community empowerment.

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

Ermera District, with its rich biodiversity, faces a major challenge related to the invasion of *Chromolaena odorata*, a weed often seen as harmful. One major opportunity for utilizing this plant is as a raw material for organic fertilizers. The nutritional content in its leaves and stems, when properly processed through composting, can become an inexpensive and environmentally friendly natural fertilizer for local farmers. This also aligns with efforts to maintain soil fertility in Ermera, a region highly dependent on the agricultural sector.

B. RESEARCH METHOD

This study used a survey approach, including field observations, interviews, and laboratory analyses, to evaluate land suitability comprehensively. The analysis was based on Homogeneous Land Units as the basis for delineating the area, using thematic maps such as land use, soil type, geology, and slope gradient. Data analysis was supported by Geographic Information Systems (GIS) to produce accurate and informative map visualizations.

Research Procedures

1. Soil Sampling
   a) Composite soil samples were collected at the following depths:
      - **0–30 cm** for annual crops.
      - **0–60 cm** for perennial crops.
2. Laboratory Analyses
   The physical and chemical soil parameters analyzed included:
   a) C-organic *(%)*: Walkley dan Black Method.
   b) N-total *(%)*: Kjeldahl Method.
   c) Soil Texture: pipet Method.
   d) Soil pH: potensiometer Method *(H_2O 1:2.5)*.
   e) Available-P & Available-K (ppm):
      - Bray-1 Method for pH < 7 (with conversion ke mg/100 g).
      - Olsen Method for pH > 7 (with conversion ke mg/100 g).
   f) Salinity: *dS/m* using a potensiometer *(H_2O 1:2.5)*.
   g) Cation Exchange Capacity (*cmol/(mg/100g)*) and Base Saturation (%) *dengan NH_4OAc 1N pH7*.
   h) Total P (mg/100 g) using the 25 % HCl method.
   i) Total K (mg/100 g) using the 25 % HCl method.
   j) Soil Fertility status determined: according to the PPT (1995) Method.
   k) Erosion Haazard: assessed through field observations and the Universal Soil Loss Equation (USLE).

Stages of Land Suitability Classification

1. Actual Land Suitability:
   Initial classification was carried out to assess land suitability under existing conditions without improvement.

2. Land Improvement Reccommendations:
   Improvement measures were identified to address limiting factors, including input management such as fertilization and soil and water conservation techniques.
3. Potential Land Suitability:
   Suitability was re-evaluated after considering improvements, in order to maximize land potential.
4. Zoning of Commodity Development Potential:
   Zoning was determined by integrating the agroecological zones of Ermera District, based on land suitability and specific agroecosystem conditions.

C. CHARACTERISTICS OF AGRICULTURE AND FOREST LAND

1. Temperature

Air temperature is a key parameter in land suitability evaluation, with analysis based on the integration of field measurement data and the Digital Elevation Model (DEM) SRTM using the Braak approach. Temperature distribution varies across Ermera District. The region is predominantly characterized by temperatures ranging from >18-21°C (38%) and >21-24°C (37%), making it highly suitable for horticultural crops such as coffee, tea, and cool-season vegetables.

2. Rainfall

Ermera District shows significant variation in rainfall across its Sub-Districts. Atsabe, Ermera, and Letefoho Sub-Districts all experience annual rainfall of >2000 mm, while Hatolia Sub-District has 40% of its area with rainfall >2000 mm, and the remaining 60% falls in the range of 1500–2000 mm/year. Railaco Sub-District mainly receives rainfall in the range of 1500–2000 mm/year (80%), with the remainder (20%) receiving 1000–1500 mm/year. These differences in rainfall affect water availability, highlighting the need for optimized water resource management to support improved agricultural development.

3. Dry Month

The distribution of dry months reflects variations in water stability. Ermera District exhibits varying characteristics of dry months across its Sub-Districts. Ermera and Letefoho Sub-Districts are entirely dominated by 3-4 dry months. Atsabe Sub-District has a similar pattern in 95% of its area. Meanwhile, Hatolia Sub-District is dominated by 2-3 dry months in 53% of its area. Railaco Sub-

District records that 80% of its area has 3-4 dry months. Overall, the average district-wide dry period is 3-4 months, which significantly affects water availability, necessitating effective water management strategies.

4. Drainage

Ermera District shows variation in drainage characteristics across its Sub-Districts. Ermera and Letefoho Sub-Districts have fully good drainage. Atsabe Sub-District has good drainage in 71% of its area, while 24% is impeded, and 5% is somewhat impeded. Hatolia Sub-District has good drainage in 67% of its area, with 27% having impeded drainage and 7% somewhat impeded. Railaco Sub-District has good drainage in 80% of its area, with the remaining 20% having somewhat impeded drainage. Overall, good drainage is the dominant characteristic in Ermera District, influencing soil oxygen availability and supporting optimal water distribution for plants.

5. Soil Texture

Soil texture in Ermera District varies across its Sub-Districts. Ermera Sub-District entirely has moderate texture. Atsabe Sub-District has 43% of its area with somewhat fine texture, 33% fine texture, and 24% moderate texture. In Hatolia Sub-District, 40% of its area has fine texture, 33% moderate texture, and 27% somewhat fine texture. Railaco Sub-District is dominated by somewhat fine texture (60%), with 20% each having moderate and fine textures. Letefoho Sub-District predominantly has somewhat fine texture (71%), with the remaining 14% each having fine and moderate textures.

6. Coarse Fragments

Analysis of coarse material content in Ermera District shows considerable variation. Land with less than 5% coarse material dominates (37%) and has relatively fine texture, supporting plant growth with good root systems. Areas with 5-10% (19%) show low texture but are still ideal for agricultural activities. Areas with medium coarse material content, namely 10-15% and 15-20%, each cover 6% and 10% of the area and may affect groundwater availability. High coarse material content, in the 20-25% and 25-35% range, covers only 8% and 4%, respectively, thus limiting agricultural activities. Very high coarse material content, 35-50% and >50%, covers 10% and 6%, requiring special land management to maintain productivity. This variation shows great potential for agricultural development based on the soil texture characteristics of each Sub-District.

7. Slope Gradient

Slope characteristics in Ermera District show significant variation. Atsabe Sub-District is dominated by steep slopes, covering 57% of its area, while Ermera Sub-District is entirely characterized by steep slopes. Hatolia Sub-District has 66% of its area with moderately steep and steep slopes. In Letefoho Sub-District, 57% of its area is steep, while Railaco Sub-District has 60% of its area with steep slopes. Steep slopes present opportunities for the development of high-value crops.

8. Surface Rock

Analysis of surface rocks in Ermera District shows that most areas have low rock content. As much as 59% of the district has surface rock content of 0-5%, indicating soils that are relatively free from rocks, which strongly supports agricultural activities. Areas with more dominant surface rocks, in the 20-50% range, cover 19% and may affect soil fertility and land use.

9. Rock Outcrops

Analysis of rock outcrops in Ermera District indicates that most areas have low outcrop levels, with 63% of the district having 0-5% outcrops. This condition supports agricultural activities, settlement, and other development. Areas with moderate rock outcrops, categorized as 5-10% and 10-20%, cover 10% of the area, and these can still be managed using soil conservation techniques.

D. SOIL FERTILITY STATUS

Soil fertility analysis in Ermera District shows that the majority of the area (69.39 %) has low fertility, which limits agricultural productivity without proper management. Land with moderate fertility covers 18.37 %, while high fertility areas make up only 12.24 %. To address the dominance of infertile soils, strategic measures such as sustainable farming, organic fertilizer use, efficient irrigation, and soil conservation techniques are necessary. Optimizing more fertile lands can support food security and improve farmers' welfare.

1. Effect of Sampling Time

Soil sampling was conducted during the dry season (July–August 2024) in Ermera District. This condition may strengthen the findings of low soil fertility status because, during the dry season:

a) Availability of Organic Matter: Reduced due to minimal natural inputs from vegetation and lack of organic matter return/added organic matter.

b) Water and Nutrient Retention: Drastically reduced in coarse-textured or predominantly sandy soils.
c) Environmental Stress (Climate, Ustic Moisture Regime/Drought): Increased, accelerating the degradation of soil chemical properties.

2. Spatial Distribution of Soil Fertility

a) Atsabe Sub-District: Dominated by low soil fertility (57.14 %), due to the prevalence of Vertisols, which face drainage issues.
b) Ermera and Railaco Sub-Districts: Entirely have low soil fertility (100 %), making them challenging for agriculture as they struggle to store water and nutrients and have poor drainage.
c) Hatolia and Letefoho Sub-Districts: Dominated by low fertility (73.33 % and 71.43 %, respectively) due to a combination of steep slopes, high erosion, and suboptimal soil fertility management.

3. Limiting Factors

a) Slope Gradient: Steep slopes in Ermera District accelerate erosion, removing the upper soil layers rich in organic matter and nutrients.
b) Soil Type: The dominance of Inceptisols typically results in a young, limited soil profile, leading to suboptimal availability of essential nutrients. The unstable soil structure and low organic matter content limit nutrient retention capacity and water storage efficiency.
c) Low Agricultural Inputs: Low use of organic and inorganic fertilizers exacerbates the lack of essential nutrients such as nitrogen, phosphorus, and potassium.

E. EROSION AND AGROFORESTRY-BASED CONSERVATION

1. Soil Erosion

Soil erosion plays a crucial role in evaluating land suitability and the sustainability of land use. In Ermera District, factors such as steep slopes, low vegetation cover, granular soil structure, and minimal conservation efforts accelerate erosion rates. Analysis indicates that over 70% of Ermera District experiences very heavy and heavy erosion. The dominant steep slopes and limited vegetation cover are the primary causes of erosion, leading to the loss of fertile soil and sedimentation in waterways and flat areas.

The main causes of erosion in this area include:

a) **Topography:** Dominant steep slopes, especially in Ermera, Railaco, and Hatolia Sub-Districts.
b) **Soil Type:** Inceptisols and Vertisols are prone to erosion, particularly on slopes >15 %, due to their loose particles and susceptibility to surface runoff.
c) **Rainfall**: High rainfall intensity leads to heavy to very heavy erosion.
d) **Low Vegetation Cover**: Contributing to the loss of the topsoil layer due to surface runoff.
e) **Anthropogenic Factors:** Poor management practices that do not consider conservation principles accelerate erosion.

Spatial data shows that Ermera District has 38.02 % of areas with very heavy erosion, 33.53 % with heavy erosion, 22.58 % with moderate erosion, and 5.58 % with light erosion. This condition emphasizes the need for ecological conservation approaches to manage land and minimize soil degradation.

2. Agroforestry-Based Conservation

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

a) **Increasing vegetation cover:** to reduce surface runoff and maintain soil moisture.
b) **Improving soil fertility:** through organic matter inputs from litter and roots.
c) **Managing water sustainably:** by retaining water within the soil profile through deep root systems.

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

a) **Erosion mitigation:** Trees and crops act as natural barriers that protect soil from surface runoff.
b) **Improved water infiltration:** Tree root systems increase the capacity of soil to absorb water.
c) **Enhanced biodiversity:** Combinations of food crops and trees create more diverse and stable ecosystems.
d) **Increased agricultural productivity:** Through agroforestry components that support diversified yields.

3. Implementation of Agroforestry in Timor-Leste

Agroforestry systems implemented in Ermera District vary according to the agroecological zones. Examples of effective agroforestry-based conservation systems include:

a) **Alley cropping:** Planting crops between tree rows on steep slopes to control erosion.
b) **Live hedgerows:** Using erosion-tolerant plants such as vetiver to stabilize slopes.
c) **Live stakes:** Using perennial plants such as Leucaena to control erosion, combined with pepper and other climbing crops.
d) **Multistrata planting:** Combining trees, shrubs, and ground cover crops to hold soil and reduce runoff.
e) **Silvopastoral systems:** Integrating forest vegetation with livestock to manage erosion in grazing areas.

4. Conservation Recommendations

a) **Scaling up agroforestry** practices in erosion-prone zones.
b) **Spatial data-based management** to identify priority locations for conservation interventions.
c) **Capacity building for farmers** through training and adoption of modern agroforestry techniques.
d) **Strengthening soil conservation policies** by integrating agroecological approaches into spatial planning.

F. LAND SUITABILITY FOR AGRICULTURE

Ermera District, known as a major coffee production center in Timor-Leste, holds great potential for agricultural and forestry development. Key commodities in Munisípiu Ermera, such as rice, maize, mung beans, coffee (Arabica and Robusta), and horticultural crops (chili, tomato, pineapple), face challenges including steep slopes, shallow soil depth, erosion, and low nutrient availability.

1. Land Suitability Evaluation Atsabe Sub-District

a) **Food Crops:** This Sub-District has potential for the development of wheat and peanuts (S2) on flat land. However, crops like upland rice, maize, wheat, soybean, and cassava are moderately suitable (S2), with temperature limitations affecting suitability.

b) **Industrial Crops:** Arabica coffee is suitable for development in Baboi Craic and Paramin Village, while Robusta coffee in Batumanu Village and Leimea Leten Village, and tobacco, also have potential in areas with lower elevation.

c) **Horticultural Crops:** Vegetables like chili, cucumber, and tomato are moderately suitable (S2), while fruit crops like pineapple are highly suitable (S1) in Batumanu and Obulo Village, with avocado and salak being marginally suitable (S3).

2. Land Suitability Evaluation Ermera Sub-District

a) **Food Crops:** The development of maize, cowpea, and cassava is suitable with moderate land suitability.

b) **Horticultural & Industrial Crops:** There is significant potential for the development of horticultural crops and coffee, with Robusta coffee suitable in lowland areas and Arabica in highland areas. Vegetables like chili and tomato are moderately suitable, while fruits like pineapple have high potential for development.

c) **Spices:** Vanilla is highly suitable (S1) for development in this region.

3. Land Suitability Evaluation Hatolia Sub-District

a) **Food Crops:** The development of upland rice and maize is moderately suitable, with permanent limiting factors such as low temperature and erosion risk.

b) **Horticultural Crops**: Crops like chili, tomato, and cucumber are marginally suitable (S3) in areas with slopes >15%. For fruit crops, pineapple and avocado are moderately suitable (S2) with improvements in planting distance and planting hole construction.

c) **Forestry:** The development of forestry species such as teak, mahogany, Agathis, Albizia, and pine is marginally suitable (S3). However, species like Acacia, Leucaena, Eucalyptus, and Melaleuca are more suitable (S2) for development.

4. Land Suitability Evaluation Letefoho Sub-District

a) **Food Crops**: Crops like upland rice, maize, sorghum, wheat, and soybean are suitable for marginal land (S3), while sweet potato has the highest potential as a tuber crop (S2).

b) **Plantation & Horticultural Crops**: Coffee has good potential for development (S2). Horticultural crops like potatoes and chili are moderately suitable (S2) in Suco Ducurai and Catrai-Craic. Fruit crops like avocado and grapes are marginally suitable (S3).

c) **Spices:** Spices like turmeric, galangal, and aromatic ginger can also be developed through integration with annual crops in agroforestry systems.

5. Land Suitability Evaluation Railaco Sub-District

a) **Food Crops**: Crops such as maize, soybean, peanuts, and cassava are moderately suitable for development (S2).

b) **Plantation & Horticultural Crops**: Robusta coffee and tobacco are moderately suitable (S2). Horticultural fruits like breadfruit and pineapple are also moderately suitable (S2), with improvements needed in planting hole construction and organic material use.

c) **Spices**: Turmeric and galangal have moderate suitability (S2).

d) **Forestry**: The development of forestry species such as teak, mahogany, Agathis, Albizia, Acacia, Leucaena, Eucalyptus, Melaleuca, and pine is marginally suitable (S3).

G. LIVESTOCK POTENTIAL IN ERMERA DISTRICT

This study aims to evaluate the potential and land suitability for livestock development in Ermera District, Timor-Leste, as part of efforts to support food security and improve local economic development. The main challenges facing the livestock sector in Ermera include limited forage availability, traditional management practices, low knowledge and technology among farmers, limited market access, and inadequate infrastructure. These factors have led to suboptimal livestock productivity across cattle, buffalo, goats, pigs, and poultry.

Proposed solutions include utilizing land for forage production through the planting of legumes and quality grasses, implementing controlled housing systems, strengthening farmers' capacity through modern management training, and providing government support such as access to credit and improvements to marketing infrastructure. Additionally, integrated poultry farming is recommended as a pilot project due to its ecological potential, regional accessibility, and strong local market. Based on geospatial analysis and ecological suitability, Ermera District is well-positioned to become a livestock development hub, focusing on optimizing livestock forage, improving breeding management, and developing an integrated modern poultry industry from upstream to downstream. The implementation of these strategies is expected to increase productivity, strengthen food security, and foster sustainable local economic growth.

H. FRESHWATER FISHERIES POTENTIAL IN ERMERA DISTRICT

Ermera Sub-District has potential for freshwater aquaculture development, though it faces biophysical constraints such as steep slopes and prolonged dry periods. Topographic constraints can be mitigated by using terraced ponds, improving suitability to S3 (marginally suitable), while water limitations can be addressed through rainwater harvesting reservoirs. Secondary factors such as unstable pH, low temperatures, and limited rainfall can relatively be managed using simple techniques. Conversely, brackish water aquaculture is not recommended due to low salinity and the distance from coastal areas. Therefore, aquaculture development should focus on adaptive freshwater species like tilapia, catfish, and Nile tilapia.

I. AGRICULTURAL COMMODITY DEVELOPMENT ZONING IN TIMOR-LESTE

Ermera District has significant land resource potential to support agricultural, forestry, and livestock development. Based on land suitability evaluation, regional zoning has been systematically designed through field observation, laboratory analysis, and agroclimatic mapping. This zoning aims to maximize land management efficiency, support food security, and improve community welfare.

1. Irrigated Rice Fields (0.01% of total area)
   - **Area:** 0.4 km^2, at low elevation (0–100 meters above sea level) with a slope of 0–8%.
   - **Main Area:** Hatolia Sub-District
   - **Strategy:** Expansion of irrigation networks such as piped irrigation and pump systems in areas with low rainfall.
2. Rainfed Rice Fields (9.49% of total area)
   - **Area:** 72.89 km^2, at an elevation of 100–500 meters above sea level with a wet season of 4–6 months.
   - **Main Areas:** Atsabe, Ermera, Hatolia, and Railaco Sub-Districts
   - **Strategy:** Construction of rainwater reservoirs, piped irrigation, pump systems, and water management to improve yields.

3. **Dryland Farming (25.69% of total area)**
   - **Area:** 197.35 km², at an elevation of 100–500 meters above sea level with slopes of 8–25%.
   - **Main Areas:** Entire observation area Sub-Districts
   - **Key Commodities:** Maize, cassava, peanuts (food crops); vegetables, fruits, flowers (horticulture); coffee, cacao, and spices (industrial crops).
   - **Strategy:** Soil conservation practices such as strip cropping and crop rotation.
4. **Grazing Areas (0.28% of total area)**
   - **Area:** 2.18 km², dominated by grasslands and savannah.
   - **Main Areas:** Letefoho and Atsabe Sub-Districts
   - **Strategy:** Pasture rotation systems combined with agroforestry for ecological and economic benefits.

J. FORESTRY POTENTIAL IN ERMERA DISTRICT

1. **Agroforestry (56.22% of total area)**
   - **Area:** 431.94 km², at an elevation of 500–1,000 meters above sea level with slopes of 25–45%.
   - **Proportion:** 30–40% agricultural crops (coffee, cacao), 60–70% forest trees (teak, Albizia, mahogany).
   - **Strategy:** Integration of small-scale livestock farming to diversify income.
2. **Protected and Conservation Forest Areas (8.32% of total area)**
   - **Area:** 63.91 km², at an elevation of >1,000 meters above sea level with slopes >45%.
   - **Purpose:** Soil and water conservation, biodiversity preservation.
   - **Strategy:** Reforestation and ecosystem restoration to reduce land degradation.

K. RECOMMENDATIONS FOR RESEARCH

1. **Land Zoning Management**
   - **Irrigated and Rainfed Rice Fields:** Optimizing land in Hatolia Sub-District is expected to make it the primary rice granary of Ermera District. With the expansion of irrigation networks, focused soil management for fertility enhancement, and the application of sustainable farming technologies.

- **Agroforestry and Forestry:** The agroforestry and protected forest zones in Ermera District, covering 64.54% of the area, support economic diversification through high-value commodities such as coffee, cacao, and horticulture, while enhancing soil, water conservation, and climate change mitigation. Protected forests safeguard ecosystems and biodiversity, while production forests like teak, mahogany, and Albizia provide economic value and support sustainable management.
- **Grazing Areas:** Implement pasture rotation systems to improve livestock productivity, combined with agroforestry for ecological and economic benefits. Grazing areas are distributed in Letefoho and Atsabe Sub-Districts.

2. Productivity Enhancement Strategy
    - **Improvement of Land Limiting Factors:** Apply technologies like liming for acidic soils, sulfur-based fertilizers for alkaline soils (high pH), addition of organic matter, drainage, and site-specific fertilization to address soil fertility issues.
    - **Utilization of Invasive Weeds:** Use Chromolaena odorata as organic fertilizer, biochar, or pharmaceutical material to support sustainable land management.
3. Soil and Water Conservation
    - **Erosion Mitigation:** Implement terracing, cover cropping, crop residue mulching, and check dam technologies to protect land from erosion on steep slopes.
    - **Rainwater Harvesting:** Construct reservoirs, infiltration wells, and drainage systems in agricultural areas to ensure year-round water availability.
4. Community Empowerment
    - **Training and Education:** Provide training in soil and fertility conservation, agroforestry, and weed utilization technologies for farmers in collaboration with universities.
    - **Farmer Commitment:** Activities to enhance land productivity.
    - **Multi-sector Partnerships:** Engage government, academics, and the private sector to support research and technology development.
5. Policy and Incentives
    - **Economic Incentives:** Subsidies and microcredit for farmers adopting environmentally friendly technologies.

- **Zoning Regulations**: Establish land-use regulations according to zoning results to ensure sustainable natural resource management.

6. Monitoring and Evaluation
   - **GIS Technology:** Use GIS to monitor the effectiveness of land management strategies, land cover changes, and land capabilities in Timor-Leste.
   - **Local Participation:** Involve local communities in the evaluation and planning to ensure program sustainability.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

I. INTRODUCTION

New Context: ASEAN, SDGs, and High Value Agriculture

Timor-Leste is now officially a member of the Association of Southeast Asian Nations (ASEAN). This announcement was confirmed during the 47th ASEAN Summit held in Kuala Lumpur, Malaysia.

In this new era, Timor-Leste faces a dual challenge: achieving food self-sufficiency while managing its natural resources sustainably. The development of the agricultural sector, particularly export-worthy commodities, is a top priority. This aligns with the Sustainable Development Goals (SDGs), especially SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), and SDG 13 (Climate Action).

In this roadmap, Ermera District plays a strategic role, not as a producer of staple foods, but as a hub for high-value economic commodities.

Regional Focus: The Heart of Coffee in Timor-Leste

Ermera District is the heart of the highlands in Timor-Leste, comprising five Sub-Districts: Atsabe, Ermera, Hatolia, Letefoho, and Railaco. This region is renowned for its premium coffee, specifically coffee Letefoho, which has gained international recognition.

Its geographic advantages—cool climate and fertile soils—make Ermera a key production center for premium quality coffee, horticultural products, and other industrial crops. However, this potential comes with significant challenges: the topography is dominated by steep and very steep slopes. Therefore, a land management strategy based on conservation is essential to maintain productivity and environmental sustainability.

Technical Foundation: Fertile Land on Slopes

Ermera's greatest asset, enabling it to be a coffee hub, is the quality of its soils. Despite being on sloped land, Ermera's soils are highly diverse and fertile:

a) **Inceptisols (66.02%):** Dominates the region, these soils have great potential for well-managed agriculture, especially with organic matter additions.
b) **Vertisols (21.15%):** With high water retention, these soils are suitable for crops that require a stable water supply.

c) **Mollisols (12.49%):** Known as "premium" soils, these are naturally very fertile, making them ideal for horticulture and intensive agriculture.

This soil diversity presents significant opportunities for diversifying agricultural commodities, not just coffee, but also highland vegetables and fruit crops.

Opportunities for Integrated Sector Development (Four Pillars)

To optimize Ermera's potential sustainably, an integrated four-pillar approach is essential:

1. **Agriculture and Plantation Sector:** This is the main pillar. The focus is on developing premium coffee as the primary export commodity. Additionally, developing horticulture (vegetables and fruits) will diversify farmers income and reduce imports.
2. **Forestry Sector**: Given the dominance of steep land, the forestry sector (through agroforestry systems) is crucial. This system serves as a conservation base to prevent erosion and can be directly integrated with plantations (e.g., shade-grown coffee), aligning with global demand for sustainable agricultural products.
3. **Livestock Sector:** There is significant potential for developing cattle and goat farming through natural grazing. This system can be integrated with agriculture, where agricultural waste is used as feed, and manure is utilized to improve soil fertility.
4. **Freshwater Fisheries Sector**: In line with water management (SDG 6) and conservation needs in the highlands, the potential for freshwater aquaculture (such as ponds or rainwater reservoirs) can be developed. This would provide an additional source of animal protein for local communities and can be integrated with agricultural systems.

Management Challenges and the Objectives of This Book

Despite its great potential, Munisípiu Ermera faces significant challenges. Land degradation due to erosion on steep slopes is a primary issue. Additionally, inadequate infrastructure and limited market access hinder the distribution of premium agricultural products like coffee.

Therefore, the research underpinning this book aims to evaluate land suitability and map the potential for development in Munisípiu Ermera. The primary focus is **on the agricultural and plantation sectors**, with exploration into the **forestry sector (agroforestry), livestock, and freshwater fisheries** as integrated supporting sectors.

This book is expected to provide strategic recommendations for the government, academics, and other stakeholders to design sustainable development policies to support national food security and strengthen inclusive economic growth in Timor-Leste in the new ASEAN era.

History and Administrative Evolution of Ermera District

During the Portuguese administration in Ermera District, the Portuguese authorities resided in the Urgisu area, which means two Ai-Ru trees intertwined when blown by the wind, within the customary territory of the Leobesi Hularema community. When the Portuguese requested permission from the Leobesi Hularema community, they stated that all authority had been entrusted to the Lisan Mayjor community, which controlled the area. Lisan Mayjor then accompanied the Portuguese to meet Liurai Dom Miguel in Hatmautei, Suku Estadu. At that time, the Portuguese government requested that Liurai Dom Miguel provide a name for the District, and Liurai Dom Miguel affirmed that the area was named Ermera. From that point onward, the Portuguese government changed the name Urgisu to Ermera. Recognizing that Liurai Dom Miguel held greater traditional authority in the area, the Portuguese also designated Hatmautei as ESTADO, which is now known as Suku Estadu in Ermera District.

Ermera is one of the 14 Districts in Timor-Leste. Its former capital was established by the Portuguese in Vila Ermera and was later relocated to Gleno in 1983 during the Indonesian administration. The area is known for its cool climate, which is suitable for horticultural crops and coffee, making it a producer of organic coffee exported to various countries. In addition, Ermera has strong community traditions, originating from two main ethnic groups, namely Mambae and Kemak. The cultural identity of Ermera is reflected in social life supported by cultural practices such as relationships between women and men and kinship ties, which form the basis of social cohesion in Ermera.

II. GENERAL OVERVIEW OF THE AREA

2.1 DEMOGRAPHY

Ermera District consists of several Sub-Districts, namely Atsabe Sub-District, Ermera Sub-District, Hatolia Sub-District, Letefoho Sub-District, and Railaco Sub-District. Geographically, the study area is located at coordinates 8°48'24.8"S 125°20'47.8"E, with an elevation of 1,195 meters above sea level (Figure 2.1).

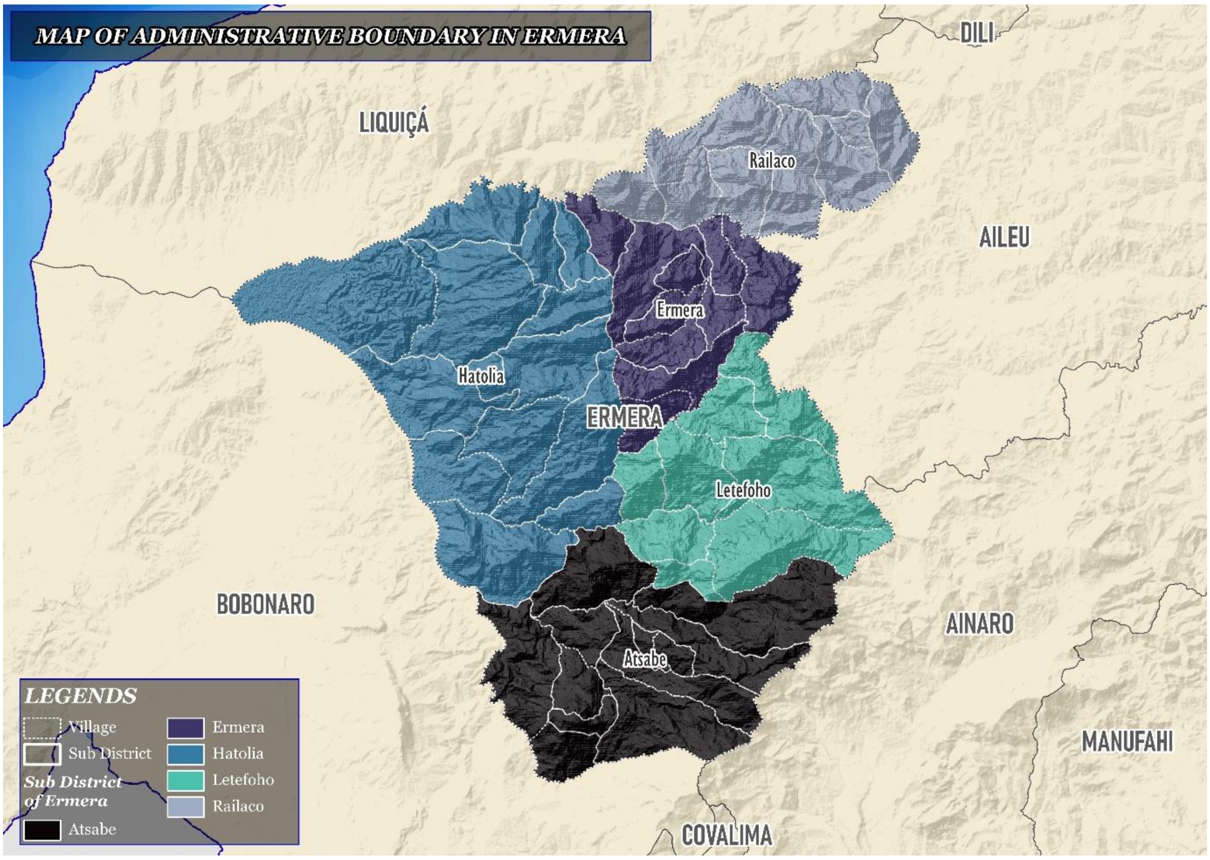


Figure 2.1 Administrative Area of Ermera District

The population in the study area is 177,333 (Administrasaun Munisípiu Ermera, 2025). According to the Timor-Leste Agriculture Census (TLAC) 2019, several data points were obtained, such as population data, the number of farmers, and data by Sub-District. These data are presented in Table 2.1.

Table 2.1 Demographic Data of Ermera District

Sub-district	Area (ha)
Atsabe	16.736,12
Ermera	9.337,91
Hatolia	27.350,43
Letefoho	12.868,21
Railaco	10.540,07

2.2 SOIL TYPE

Soil information in Timor-Leste has been classified using the Soil Taxonomy (1992). This classification only extends to the Great Group/Soil Type/Soil Group level. There are 7 soil orders; 16 sub-orders; and 22 Great Groups (Soil Types/Groups).

Ermera District predominantly covered by the Inceptisols order, occupying an area of 49,583.57 ha (66.02%) **(Figure 2.2),** distributed throughout the entire study area **(Figure 2.3).** Other soil orders include Vertisols, covering 15,886.19 ha (21.15%), Mollisols covering 9,382.81 ha (12.49%), and Entisols covering 253.43 ha (0.34%).

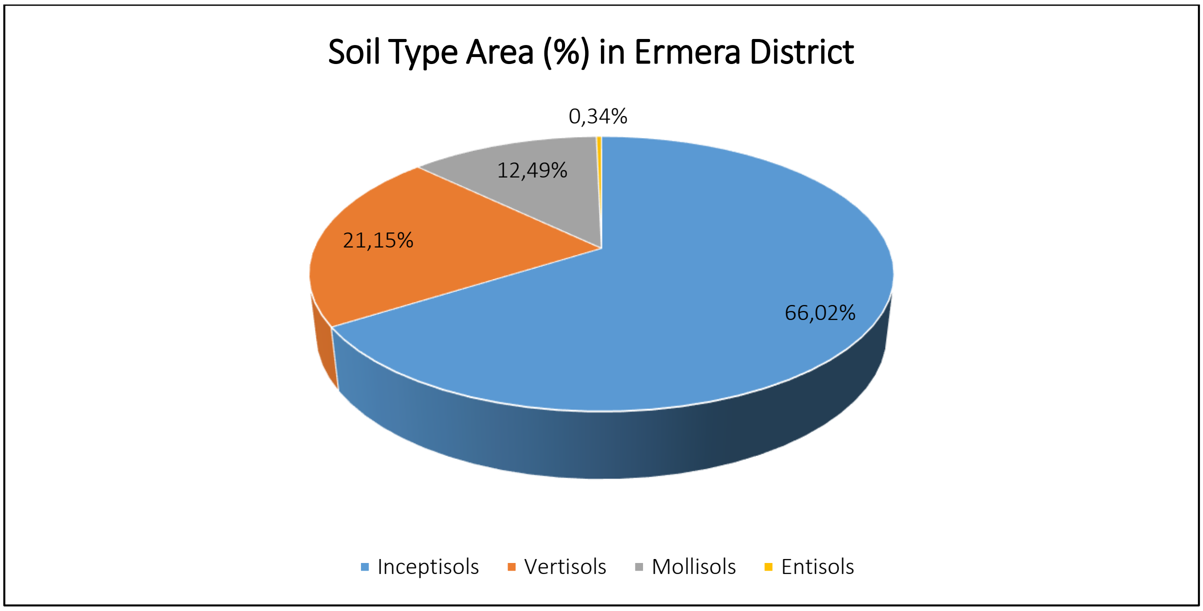


Figure 2.2 Area Distribution Based on soil Type

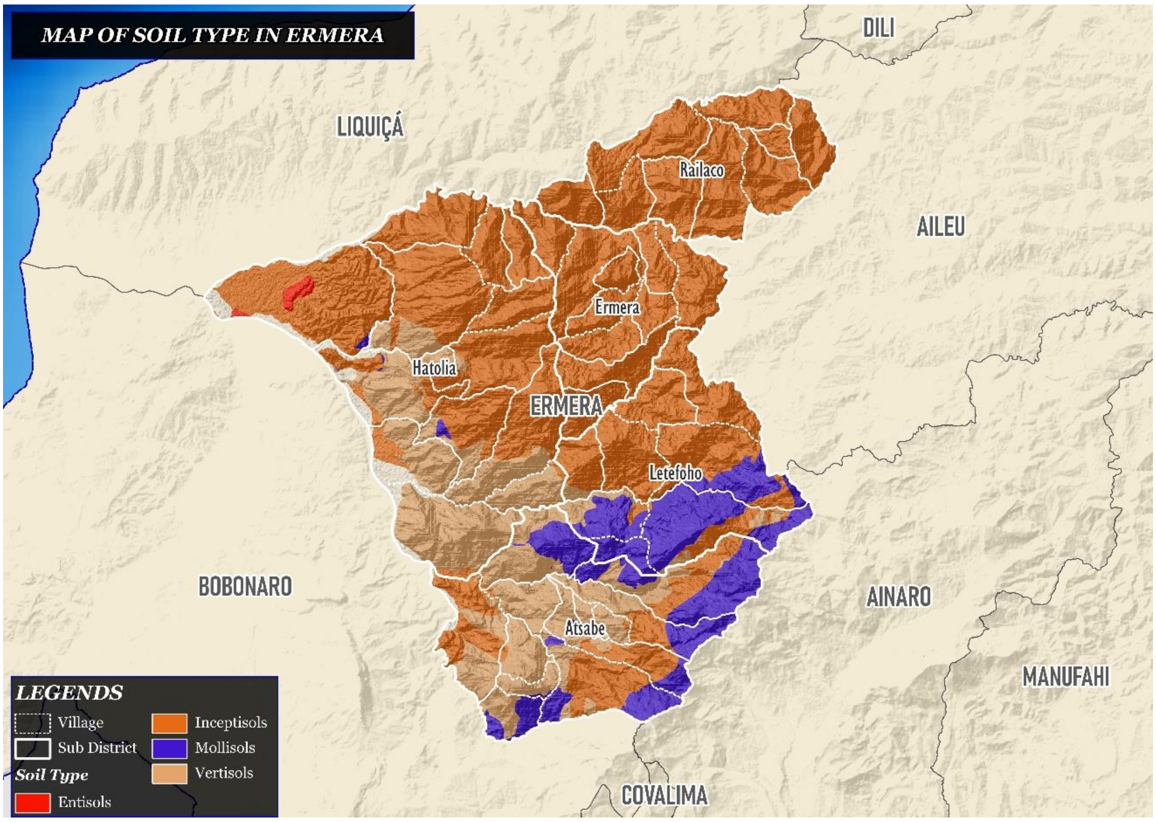


Figure 2.3 Soil Type Map of Ermera District

2.3 LAND USE

The Ermera District, Timor-Leste, has a variety of land use types that provide a critical foundation for the development of agricultural and forestry commodities. The dominant land use in Ermera District is forest land, covering 36,786 ha (47.87%), followed by commercial agricultural land covering 34,704 ha (45.17%). Other land uses include settlement areas with 1,751 ha (2.28%), agricultural land with 1,680.43 ha (2.19%), unused dryland areas with 1,472.23 ha (1.92%), and industrial areas covering only 438.48 ha (0.57%). Land use by region within Munisípiu Ermera is shown in **Figure 2.4**.

Atsabe Sub-district has the largest forest area in Ermera District, covering 19.31% of the total area, followed by agricultural land at 5.43%. Commercial agriculture in Atsabe is more dispersed, covering 2.55%, and the unused dryland area is 0.17%. The total river area in this region is only 0.06%. The potential for land development in Ermera lies in optimizing both forest and agricultural lands.

Ermera Sub-district has 1.8% of its area covered by forest land and 0.23% by agricultural land. The settlement and industrial areas in this region make up only 0.27%, while the river area covers 0.22%. The commercial agricultural land in Ermera is larger than other land uses, accounting for 9.63%.

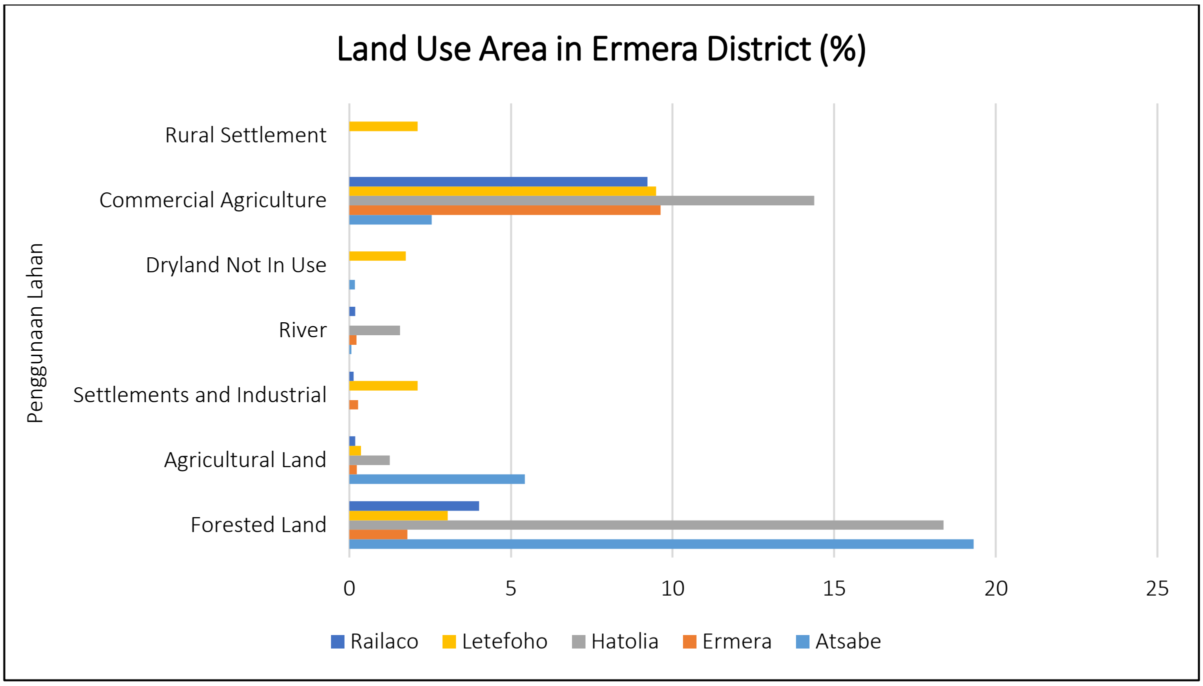


Figure 2.4 Land Use by Type (%) in Ermera District

In Hatolia Sub-district, the forest area covers 18.38% of the total area, making it the second-largest forest area after Atsabe Sub-district. Agricultural land in Hatolia Sub-district covers only 1.25%, with a total river area of 1.57%. The commercial agricultural land in this region is 14.38%. The large forest area in Ermera presents significant opportunities for developing sustainable forest commodities, which can support environmental conservation and provide long-term economic benefits.

Letefoho Sub-district has an interesting land use profile, with only 0.36% agricultural land and 1.75% unused dryland. This region has 3.04% forest coverage, with settlement and industrial areas covering just 2.11%. Commercial agriculture accounts for 9.49%, while rural settlements in this area also cover 2.11%.

In Railaco Sub-district forest land makes up only 4.01% of the total area, with agricultural land covering just 0.18% and the total river area at 0.18%. The commercial agricultural land in this area is 9.22%, while settlement and industrial areas cover 0.13% **(Figure 2.5).**

Overall, land use in Ermera District presents both challenges and significant opportunities. The dominance of forest land offers the potential to develop sustainable forest commodities, while the dispersed agricultural land requires strategies for sustainable intensification. Support from the Ministry of Agriculture, Fisheries, Livestock, and Forestry of Timor-Leste is crucial, and integrated, data-driven planning is needed to ensure the optimization of land use, improve agricultural productivity, and support national food security in a sustainable manner.

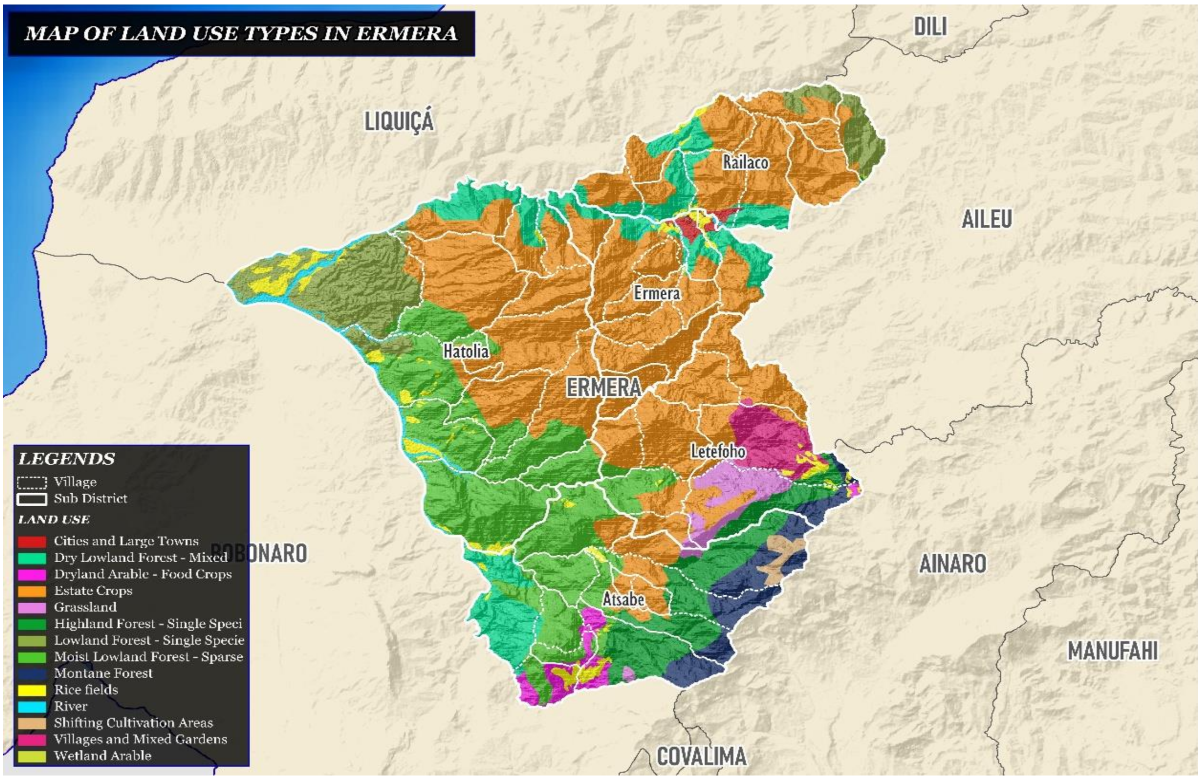


Figure 2.5 Land Use Map of Ermera District

2.4 EXISTING CONDITIONS

In Ermera District there are several key issues related to land management and agricultural production. One significant issue is the presence of sloping land with minimal ground cover, where vegetation is very limited. This condition increases the risk of severe soil erosion, which can exacerbate environmental damage.

Factors such as soil quality, inadequate maintenance, and potentially suboptimal agricultural practices contribute to low yields. Although many areas have started growing potatoes, the results remain limited, with small tubers, indicating issues in agronomic management or the quality of the soil used. Efforts to improve agricultural productivity in Ermera require special attention to improving land management techniques, enhancing crop quality, and monitoring and adjusting agricultural practices to better suit local conditions.

Figure 2.6 Land Conditions in the Field
(Source: Researcher Documentation, 2024)

However, the Ermera region also possesses various development potentials that can be optimized. One of these is the presence of numerous rivers with year-round water flow, although the discharge is small. This water source can be utilized for irrigation systems that support agricultural activities. In addition, there is a high potential for developing industrial crops such as coffee and eucalyptus in this area. The development of food crops like ganyong (kontas) and potatoes in the highlands also has the potential to yield better results if managed effectively. With the implementation of good management practices and the addition of appropriate inputs, this potential can be maximized to enhance productivity and agricultural sustainability.

2.5 Chromolaena odorata

Chromolaena odorata **(Figure 2.7)**, commonly known as *Siam weed,* is a flowering weed in the family *Asteraceae* that grows vigorously in tropical and subtropical regions. This species is native to North America, Mexico, and the Caribbean, and has subsequently spread widely to other regions, including Asia, Africa, and Australia. Its dispersal occurs through human activities as well as natural factors such as wind and water, which facilitate its invasion into new ecosystems (Day *et al.*, 2013).

In developing countries such as Timor-Leste, the presence of Siam weed has significant impacts on the environment and local economies. This plant is frequently found from lowland areas up to elevations of 500 m above sea level, particularly in open habitats such as coconut and rubber plantations, home gardens, and grazing land (Peniwiratri & Arbiwati, 2021). Its rapid and aggressive growth leads to competition with native plants, hampers forest regeneration, and reduces the productivity of agricultural and plantation land.

Figure 2.7 Plants of *C. odorata* in Ermera District
(Source: Researcher Documentation, 2024)

Morphologically, *C. odorata* has cylindrical, hairy stems, simple leaves with serrated margins, and compound flower heads that are bluish when young and turn brown when mature. In addition, this species contains various active compounds such as flavonoids, tannins, alkaloids, saponins, and essential oils (Jamatia *et al.*, 2024). These chemical constituents provide potential for Siam weed to be used as a raw material for traditional medicines to treat various diseases, including diabetes, burn wounds, hypertension, and skin infections.

Despite its pharmacological benefits, the invasion of Siam weed remains a serious challenge for land management and ecosystem sustainability. Therefore, appropriate control strategies are required to reduce its negative impacts, whether through mechanical and biological methods or through the sustainable utilization of this species.

III. RESEARCH METHOD

This research was conducted in Ermera District, Timor-Leste, which has significant potential for agricultural development, particularly in horticulture and plantation sectors. The study aims to evaluate land suitability to support optimal and sustainable land use. Data collection was carried out through field surveys, laboratory analysis, and the use of geospatial technology. The research was conducted from July to August 2024, with the main focus on direct land condition observations, soil sampling, interviews with local farmers, and Geographic Information System (GIS)-based mapping. All stages were conducted systematically to obtain accurate information to support land management planning that is efficient and sustainable.

3.1 RESEARCH DESIGN

A. Methodological Approach

This research methodology combines both quantitative and qualitative approaches. The quantitative approach was applied to analyze numerical data, while the qualitative approach was used to explore insights and experiences of farmers in the study area (Trigunasih, 2016). The techniques employed in this research included field surveys and laboratory analysis, including soil sampling and interviews with local farmers.

B. Determination of Sample Points

Sample points were determined using the Homogeneous Land Unit approach, which was obtained through the overlay of thematic maps such as Land Use Map, Soil Type Map, Geological Map, and Slope Map. Analysis and delineation of land units were carried out using QGIS 3.10 software (Trigunasih et al., 2023). Soil samples were collected randomly and compositely using soil boring methods. Each land unit was represented by one composite soil sample, which was taken at depths of 0-30 cm for annual crops and 30-60 cm for perennial crops. Each soil sample weighed 1 kg for further laboratory analysis.

C. Soil Morphological Observations

During soil sampling, morphological characteristics of the soil were observed to understand its physical conditions directly in the field. Parameters observed included soil color, texture, structure, consistency, and drainage system. To support more in-depth analysis, ring samples were used in the collection of intact soil samples to measure bulk density (BD) and soil porosity, which play a crucial role in determining water retention capacity and soil fertility (Sukarman et al., 2017).

D. Interviews and Questionnaires

In addition to physical land observations, structured interviews and questionnaires were administered to the farming community. The respondent selection used purposive sampling or judgmental sampling methods, based on the experience and expertise of farmers in land management (Sekaran & Bougie, 2013). The data collected included cropping patterns, agricultural challenges, and the land management systems applied in the study area.

E. Land Suitability Evaluation

Data from field surveys, climate data, and laboratory analysis were processed and evaluated using an agroecosystem land suitability assessment system based on the criteria of Ritung et al. (2011). The land suitability classification applied follows the FAO (1976) system using the matching method, which involves comparing land characteristics with the growth requirements of the crops being analyzed. The agricultural commodities evaluated in this study include food crops, horticulture, and high-value plantation crops, forestry, livestock feed commodities, and fisheries.

3.2 RESEARCH PROCEDURE

A. Literature Review

The initial stage of the research begins with a literature review to gather secondary data that supports the analysis. The collected data includes administrative maps of the study area, geographic conditions, the extent of agricultural land, and agricultural commodity production data. The climate data reviewed includes temperature, rainfall, dry months, and humidity. Additionally, references from various previous studies related to land suitability evaluation are examined to strengthen the scientific foundation of this research.

B. Homogeneous Land Unit Analysis

The purpose of the homogeneous land unit analysis is to determine land units as the basis for field observation planning. The homogeneous land units derived are used as a reference in soil sampling and land suitability mapping. The Land Unit analysis process includes:

a) Interpretation of Digital Elevation Model (DEM) maps to analyze landforms and slope gradients.
b) Satellite imagery analysis to verify the actual land use pattern, particularly in areas that have undergone land use changes such as rice fields, settlements, and plantations.
c) Utilization of supporting data in the form of slope gradient maps, geological maps, and soil type maps to strengthen the delineation of land units.
d) Overlaying of various thematic maps to produce homogeneous land units, which will serve as the basis for soil sampling.

C. Field Survey

A field survey is conducted to validate the suitability of homogeneous land units with actual conditions in the field. If discrepancies are found between the map analysis results and field reality, the delineation is revised according to the actual conditions. Sampling points are determined based on the results of the homogeneous land unit analysis and the current field conditions.

During the field survey, interviews are also conducted with local farmers to gather additional information about farming practices and challenges faced in land management. Observations also include environmental factors affecting agricultural productivity, such as soil drainage, effective depth, erosion risk, flood risk, and surface rock content (Ritung et al., 2011).

Soil samples are taken using the boring method at depths of 0-30 cm for annual crops and 30-60 cm for perennial crops. The obtained soil samples are further analyzed in the laboratory to determine the physical and chemical properties of the soil that can influence land productivity. 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 shown in **Table 3.1**, while the land suitability distribution map is presented in **Figure 3.1.**

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

No	Parameter	Data Acquisition		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	√		Hasil laboratorium
7	Coarse Fragments	√		Field survey
8	Effective Soil Depth	√		Field survey
9	Cation Exchange Capacity	√		Laboratory Results
10	Base Saturation	√		Laboratory Results
11	Soil pH	√		Laboratory Results
12	Soil Organic Carbon	√		Laboratory Results
13	Total N	√		Laboratory Results
14	P_2O_5	√		Laboratory Results
15	K_2O	√		Laboratory Results
16	Salinity	√		Laboratory Results
17	Alkalinity	√		Laboratory Results
18	Slope Gradient	√		Field survey
19	Erosion Hazard (eh)	√		Field survey
20	Flood Hazard (fh)	√		Field survey
21	Surface Rock	√		Field survey
22	Rock Outcrops	√		Field survey

D. Soil Laboratory Analysis

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

a. Organic carbon using the Walkley and Black method (%).
b. Total nitrogen using the Kjeldahl method (%).
c. Soil texture using the pipette method.
d. Soil pH using the potentiometer method (H2O 1:2.5).
e. Available phosphorus (ppm) and available potassium (ppm) using the Bray-1 method for soils with a pH below 7 and the Olsen method for soils with a pH above 7, with unit conversion (mg/100 g).
f. Salinity (dS/m) using the potentiometer method (H2O 1:2.5).
g. Cation exchange capacity (CEC) (cmol) and base saturation (KB) (%) using

the NH4OAc 1N 7pH extraction method.

h. Total P (mg/100 g) using the 25 % HCl method.
i. Total K (mg/100 g) using the 25 % HCl method.
j. Soil fertility status determination based on the method of PPT (1995).
k. Erosion hazard using the Universal Soil Loss Equation (USLE).

E. Land Suitability Evaluation

The results of the field observations and laboratory analyses are then tabulated into data on the characteristics/quality of the agroecosystem land units. The agroecosystem land suitability evaluation is carried out by matching (matching) the land characteristics/quality data with the growth requirements of crops such as bamboo, teak, mahogany, pine, coffee, cacao, and coconut. This allows for the determination of land suitability classes based on the criteria of Ritung et al. (2011). The land suitability classification is analyzed at the land unit level.

Land suitability classes are classified into actual and potential suitability. The actual land suitability for each homogeneous land unit is obtained by matching the land characteristics/quality with the growth requirements of crops without any improvements to limiting factors. The potential land suitability is obtained by considering inputs and management actions applied to each homogeneous land unit, assuming improvements are made to the limiting factors.

F. Planning for Agricultural Commodity Development

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

G. Land Use Guidelines

Land use guidelines are developed at the land unit level, based on the highest land suitability class, followed by lower suitability classes, addressing limiting factors, and improvement efforts for each homogeneous land unit in the Districts of Timor-Leste. The creation of digital maps using geographic information systems (GIS) greatly facilitates the interpretation of information.

These maps provide data on agroecosystem land suitability, land use guidelines, and agricultural commodity zoning. Land suitability maps are created based on homogeneous land units and agroecosystem land suitability classifications.

The land suitability classification results are mapped for each evaluated crop commodity group. The land suitability for crop commodities is presented in a commodity zoning map, while the land use planning is presented in a land use guideline map. The research flow diagram is systematically presented in **Figure 3.1.**

H. Data Analysis with Geographis Infromation System Technology

The land suitability information system combines spatial and attribute data to generate land suitability maps using QGIS 3.10. The information produced includes land suitability classes for food crops, horticulture, and plantations. These maps are created based on data and land suitability criteria, considering crop variety development, cultivation technology, and land management practices. Land use planning maps are generated based on land suitability classification and commodity zoning.

The land use planning maps are thematic digital maps that provide land use guidelines for various crop commodities, horticulture, and plantations. Digital maps are the result of converting primary and secondary data and information in raster and analog form into digital data. The advantages of digital maps include the ease of correcting errors, easy copying, long-term storage, and the ability to measure distances and areas directly on the screen, eliminating the need for time-consuming and costly field measurements (Nugroho and Yarianto SBS, 2010). The resulting maps are digital in analog form or hard copy in *.jpeg format, which can be printed, and digital maps in *.dbf or shape file format (*.shp) that are integrated, easily copied, and informative. The map legend displays the map name, followed by the name of the creator, scale bar, and information about the homogeneous land units, study area, soil type, slope, and land use, including the source, coordinate positions (latitude and longitude), and the datum system used.

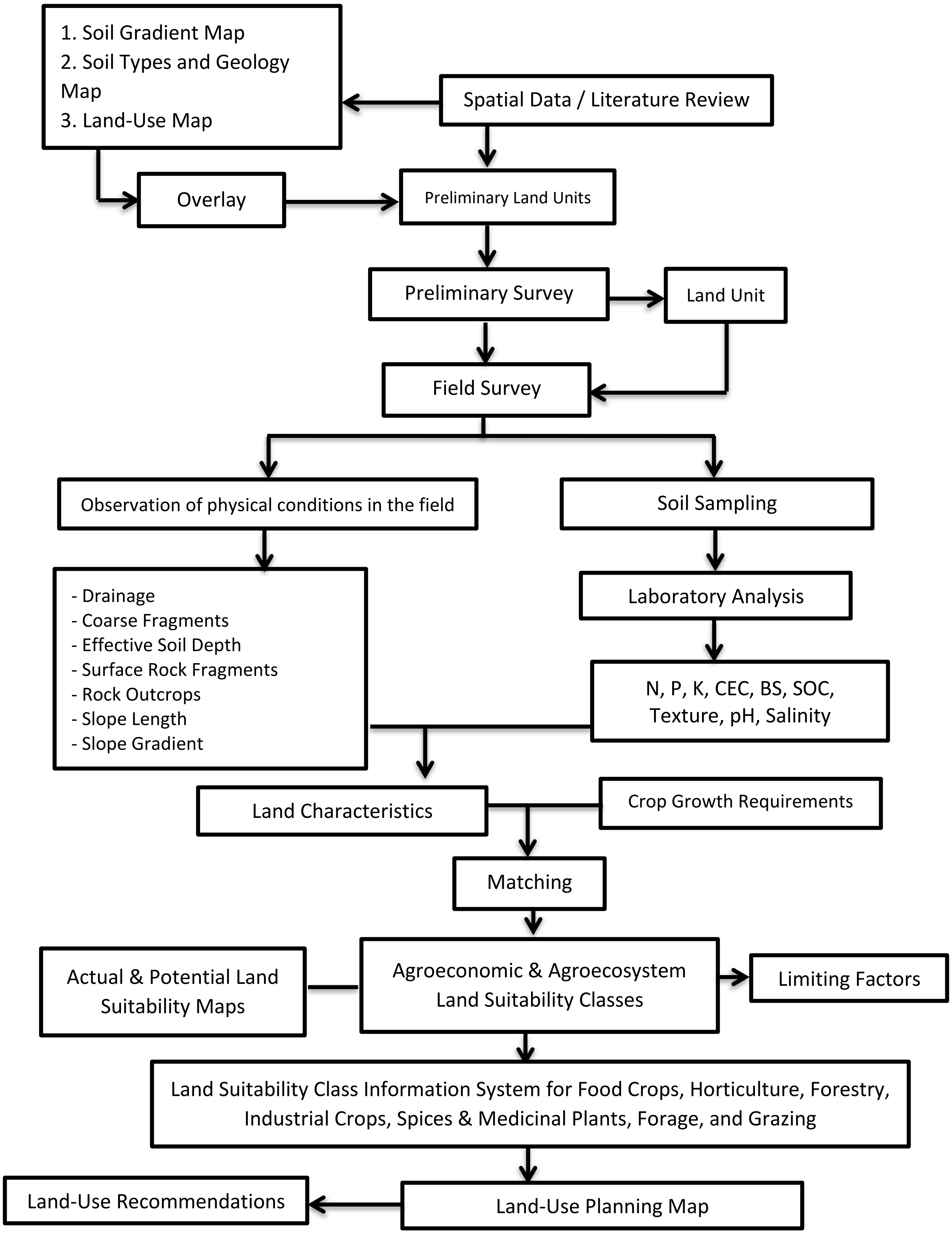


Figure 3.1 These Research Flow Diagram

3.3 GEOGRAPHIC INFORMATION SYSTEM TECHNOLOGY

Geographic Information System (GIS) is a system that contains spatially referenced data, which 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 within a certain area that meet predefined criteria.
3. Exploring the relationships between different data sets within a specific area.
4. Facilitating the selection and distribution of data for specific analytical application models that can predict the impact of an alternative on the conditions of a given area.
5. Presenting a specific area graphically and numerically, both before and after analysis (Murai, 2006).

From various definitions of GIS, several common key terms emerge, such as: geographically referenced data, data analysis (spatial and attributes) 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 from a geographical perspective. This is particularly relevant in development planning, as development planning is carried out within the context of a specific area or region.

The term "Geographic" is part of the spatial concept (space). These terms are often used interchangeably, leading to the emergence of a third term, "geospatial." All three terms convey the same meaning within the context of GIS. The use of the term "Geographic" refers to matters concerning the Earth: its two- or three-dimensional surface (Prahasta, 2005).

The term "geographic information" refers to information about locations on the Earth's surface, knowledge about the position where an object is located on the Earth's surface, and information about the attributes found on the Earth's surface, with their position being either given or known (Prahasta, 2005).

GIS is a formal system consisting of various physical resources related to objects on the Earth's surface. It is also a type of software used to input, store, manipulate, display, and output geographic information along with its attributes (Prahasta, 2005). **Figure 3.2** shows the components of GIS.

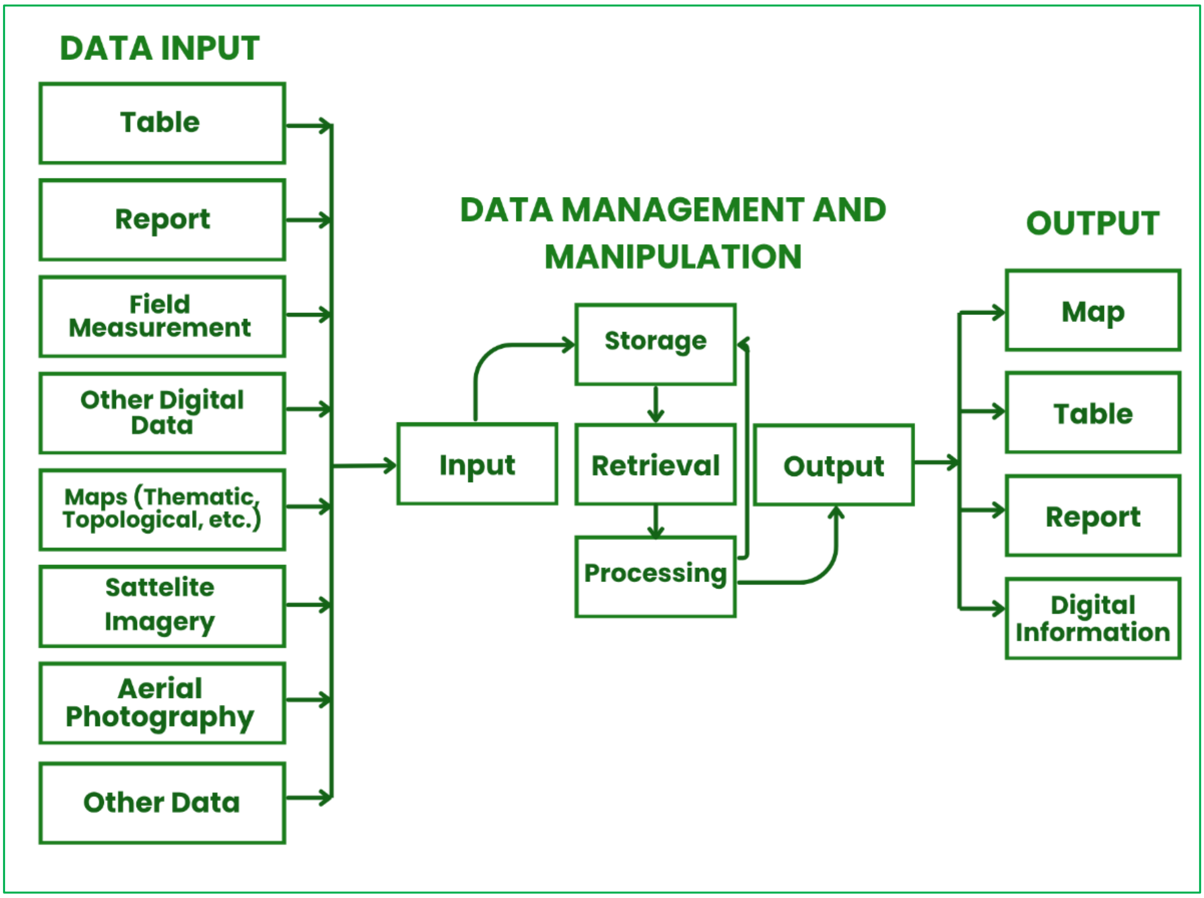


Figure 3.2 Components of GIS
(Source: Prahasta, 2005)

Geographic Information Systems can be applied to various fields. Some capabilities of this system include (Prahasta, 2005):

1. Cartographic Capacity

   This allows users to create maps and technical drawings effectively and efficiently. Cartographic capability includes digitization, graphical visualization, interactive line manipulation, and plotting processes.

2. Data Management Capability

   GIS has the ability to store, process, and manipulate geographically referenced data. This management capability also includes processing attribute data, which refers to the ability to store and display specific attribute data related to certain geographic features.

3. Analytical Capability

   Analytical capability refers to the ability to interpret and study collected data and information for specific purposes. This includes: engineering function analysis, predictive/forecasting capabilities, computational operations, demographic analysis, socio-cultural analysis, analysis of various regions and districts (Munisipiu), graphical and tabular presentation, overlay analysis, logical analysis, and selection analysis.

4. **Integration of GIS and Multimedia**

   The ability to integrate GIS with multimedia is a creative outcome developed by the local talents of Bali. Through the integration of multimedia systems with GIS, the final output of GIS analysis becomes more visually appealing, making it easier to read and understand the results.

A. GIS Processes and Components

A Geographic Information System (GIS) fundamentally performs six processes, as outlined by Prahasta (2005):

1. Data Input

Before geographic data can be used in GIS, it must be converted into a digital format. This process is known as digitizing. In this thesis, the digitizing process used is referred to as "on-screen digitizing," where data conversion is carried out using scanning technology.

2. Data Transformation

The data types used in GIS may need to be transformed or manipulated in several ways to be compatible with the system. For example, if there is a difference in scale, the data must be transformed into the same scale before being entered and integrated. This transformation can be temporary for display purposes or permanent for analytical processes.

3. Editing

The editing stage involves digital correction. Corrections may include adding or removing arcs or features, such as editing excess arcs (overshoot) or adding missing arcs (undershoot). Editing is also performed to manually add arcs, such as creating polygons, lines, or points.

4. Data Management

After spatial data is inputted, the next process involves handling descriptive data, including annotation (adding text to coverage), labeling (adding information to maps), and attributing. At this stage, each label ID resulting from the labeling process is assigned additional attributes that provide information about the polygon or arc it represents.

5. Query dan Analisis

A query in GIS is essentially an analysis process, but it is conducted through tabular processes. Fundamentally, analysis in GIS relies on spatial analysis. GIS has many advantages in spatial analysis, but two critical aspects are:

a) *Proximity Analysis*

This is a geographical analysis based on the distance between layers. Questions like "How many houses are located in a watershed?" are examples of proximity analysis. In GIS, proximity analysis uses a process called buffering (creating a supporting layer around a layer at a specific distance) to determine the closeness of relationships between the properties of existing features.

b) *Overlay Analysis*

The process of integrating data from different layers is referred to as overlay. In simple terms, it can be described as a visual operation; however, analytically, this operation requires more than one layer to be physically combined. For example, an overlay or spatial join involves the integration of soil data, slope gradient, and vegetation, or land ownership, with assessed land tax values.

6. Visualization

For certain types of geographical operations, the best final results are presented in maps or graphs. Maps are highly effective for storing and providing geographic information.

B. Components of GIS

In general, a Geographic Information System (GIS) operates based on the integration of five components: hardware, software, data, people, and methods, which can be explained as follows (Budianto, 2010):

1. Hardware

Hardware refers to the computers on which the GIS operates. Currently, GIS can run on a wide range of hardware, from centralized server computers to desktop computers used as stand-alone systems or in network configurations.

2. Software

GIS software provides the functions and tools necessary to create, process, analyze, and display geographic information. Examples include:

a. Tools for data input and manipulation.
b. A database management system (DBMS).

c. Tools that support query, analysis, and geographic visualization.
d. A graphical user interface (GUI) for accessing the tools.

3. Data

Data is a crucial component in GIS. Fundamentally, GIS works with two types of geographic data models: vector data models and raster data models. The vector data model displays, places, and stores spatial data using points, lines or curves, or polygons along with their attributes. The raster data model displays, 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, at the center, or elsewhere). The accuracy of this data model depends heavily on the resolution or pixel size (grid cell) on the Earth's surface.

4. Human

GIS technology would not be useful without the people who manage the system and develop plans that can be applied according to real-world conditions. Like other information systems, GIS users have varying levels of expertise, from technical specialists who design and maintain the system to end-users who utilize GIS to assist with their daily tasks.

5. Methods

A good GIS system aligns well with a solid design plan and real-world rules. The methods, models, and implementation will vary for each problem.

C. Data Processing in GIS

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

1. Digitizing Base Maps

Digitizing is performed on the Indonesian topographic maps at a scale of 1:25,000, which will serve as the foundation for conducting surveys and digitizing maps, including data updating. The data conversion into digital format is done layer by layer, each complemented with topology.

2. Data Import

Data import is carried out for satellite images that have a format different from the processing software. This format conversion is an initial process often performed in image processing tasks.

3. Geometric Correction of Images

Geometric correction is required to ensure that satellite images have a map coordinate reference system. This geometric correction can be performed using three methods: image-to-image (where the image has been previously corrected), image-to-ground (where map coordinates are measured directly in the field using GPS—Global Positioning Systems), and image-to-map.

4. Digital Image Processing

Satellite images are digitally processed to improve the spatial resolution from the standard 25 m in multispectral bands to 15 m in color. This is done using an image data fusion processing model with the Brovey transformation method. This process is carried out for the purpose of visual interpretation of planimetric objects such as transportation networks, rivers, and other planimetric features in the area.

5. Satelite Image Classification

Another process carried out is digital classification, using a knowledge base approach for extracting spatial information on land use. This classification process will use a supervised classification method along with filtering processes. The digital classification model, which has higher clustering accuracy than human interpretation, will be complemented by visual data interpretation from the Brovey transformation results. The digital classification model works by grouping identified objects as samples (sampling areas). The image processing software automatically searches for pixel patterns similar to those of the sample areas, creating distinct classes. The classified image is then field-tested to check for discrepancies and to identify uncertain pixels. Any discrepancies from the field tests should not exceed 3% of the test area. The results of this clarification are used to update the Indonesian topographic maps that have been digitized using the digital light table effect and raster-vector overlay methods.

6. Spatial Information Updating

Spatial information updating of maps will be performed using raster-vector overlay methods, complemented by the light table effect for interpreting and analyzing spatial information on land use. The update of planimetric spatial information will be conducted through raster-vector overlay. This integration model is applied with digital image classification and visual image interpretation to obtain accurate updated spatial data. Specific objects that are deemed important to map but are not clearly visible in the images will be mapped using GPS tools during field surveys. The final result of this update work is digital land use spatial data in GIS.

7. Field Survey

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

8. Re-interpretation dan Editing

This task is performed to correct inaccuracies in image interpretation based on fieldwork results. It is conducted in the laboratory digitally to obtain the final updated spatial information.

9. Edge Matching

Edge matching will be performed to ensure that the alignment between adjacent map sheets is consistent. This process will be done digitally across all layers and adjacent sheets.

10. Digital Cartography and Map Production

Cartography will be performed fully digitally to produce standardized map layouts following established cartographic principles. The cartographic model used in this task will refer to the thematic map model issued by the Geospatial Information Agency.

11. Database Structuring and Modeling

Database structuring will be carried out on all spatial GIS data from the work outputs, including land use spatial data, attribute data, and generated thematic maps.

IV. LAND CHARACTERISTICS

4.1 TEMPERATURE

Air temperature is one of the key factors in land suitability evaluation because it significantly affects the sustainability of natural resource management and the potential for regional development. In this study, temperature distribution was analyzed using the integration of field measurement data and geospatial data based on the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM), with the Braak formula approach. This analysis provides a comprehensive overview of temperature variability, reflecting the complexity of topography, elevation, and microclimates in Timor-Leste.

The air temperature analysis results for Ermera District show a temperature distribution that varies, with a tendency towards moderate to warm temperatures. According to **Figure 4.1**, temperatures in the range of 18-21°C have the largest percentage, at 38%, indicating that most of the area experiences a relatively cool climate suitable for various agricultural activities.

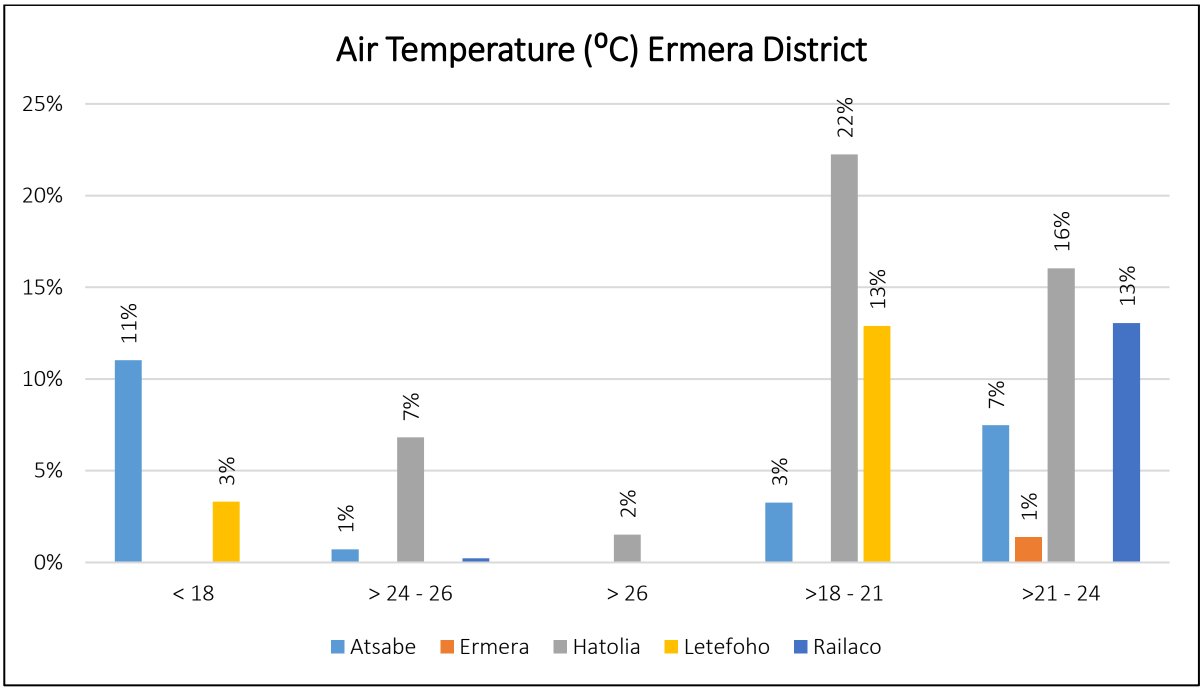


Figure 4.1 Air Temperature Data for Ermera District

The temperature in the 21-24°C category covers 37%, indicating that most of the area experiences temperatures that are still quite comfortable and support the growth of crops that require moderate temperatures. Next, temperatures in the <18°C and 24-26°C categories cover 14% and 8%, respectively, showing that there are some areas that experience cooler or warmer temperatures compared to other regions. Meanwhile, temperatures in the >26°C category cover 2%, indicating that only a small portion of the area has higher temperatures. This temperature distribution impacts the agricultural sector in Ermera District. Areas with dominant temperatures of 21-24°C and 18-21°C are highly suitable for horticultural agriculture such as coffee, tea, and highland vegetables that require cooler temperatures. Higher temperatures (>24°C) have the potential to increase evaporation rates and necessitate better irrigation systems to maintain soil moisture. Therefore, water resource management strategies and the selection of plant types suited to the temperature conditions are essential to improving agricultural productivity sustainably in Ermera District.

4.2 RAINFALL

The land characteristics in Ermera District, based on field observations, include rainfall, the number of dry months, drainage, soil texture, slope, and erosion hazards. According to rainfall observations in the field, Atsabe Sub-district, Ermera, and Letefoho all have a uniform annual rainfall of >2,000 mm, covering the entire region (100%). In Sub-district Hatolia, 40% of the area experiences rainfall of >2,000 mm per year, while 60% has rainfall between 1,500 and 2,000 mm per year. In Sub-district Railaco, 80% of the area receives rainfall between 1,500 and 2,000 mm per year, and 20% experiences rainfall between 1,000 and 1,500 mm per year. The differences in rainfall characteristics across the regions result in varying water availability, so each area must be able to maximize its resources to support the development of better agricultural practices **(Figure 4.2).**

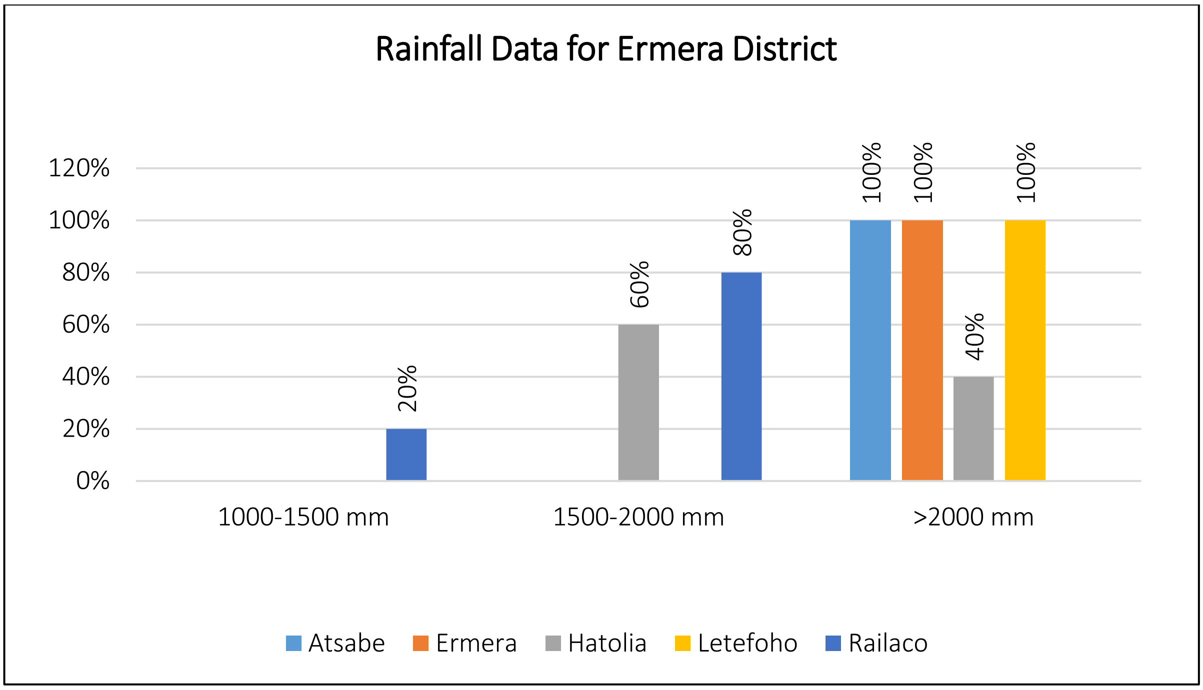


Figure 4.2 Rainfall Data for ermera District

4.3 DRY MONTH

The land characteristics based on dry months in Munisípiu Ermera also show variation and differences across the regions. Postu Ermera and Letefoho have the most dominant dry months, with 3-4 dry months covering the entire area. In Postu Atsabe, 95% of the area experiences 3-4 dry months. Postu Hatolia has 2-3 dry months dominating 53% of its area. Meanwhile, in Postu Railaco, 80% of the area experiences 3-4 dry months. These dry month characteristics indicate that, on average, the Sub-Districts in Munisípiu Ermera predominantly experience 3-4 dry months, which will impact water availability **(Figure 4.3).**

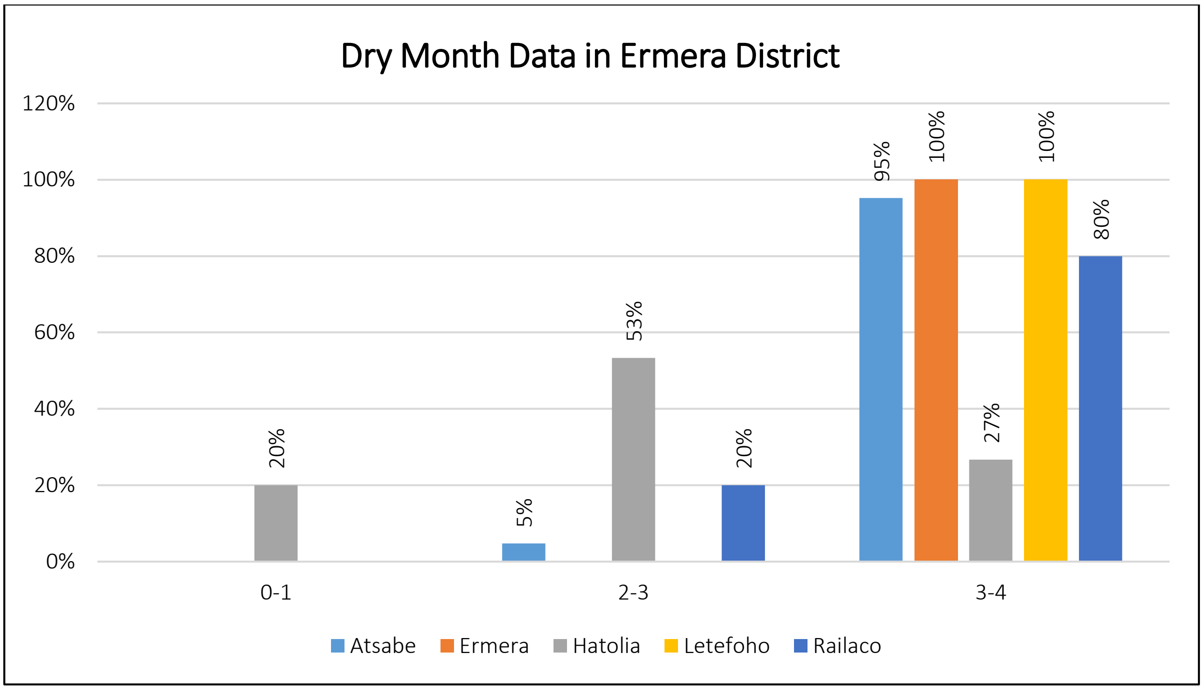


Figure 4.3 Graph of Dry Month in Ermera District

4.4 DRAINAGE

The land characteristics based on drainage show variation and differences across the regions. Ermera and Letefoho Sub-district have good drainage throughout their entire areas. In Atsabe Sub-district, 71% of the area has good drainage, 24% has somewhat poor drainage, and 5% has excessively poor drainage. In Hatolia Sub-district, 67% of the area has good drainage, 27% has somewhat poor drainage, and 7% has excessively poor drainage. Meanwhile, Railaco Sub-district has good drainage in most of the area (80%) and somewhat poor drainage in some regions (20%). The most dominant drainage class in Ermera District is good drainage. This drainage class will influence the availability of oxygen in the soil, allowing water to be efficiently distributed to meet the water needs of crops **(Figure 4.4).**

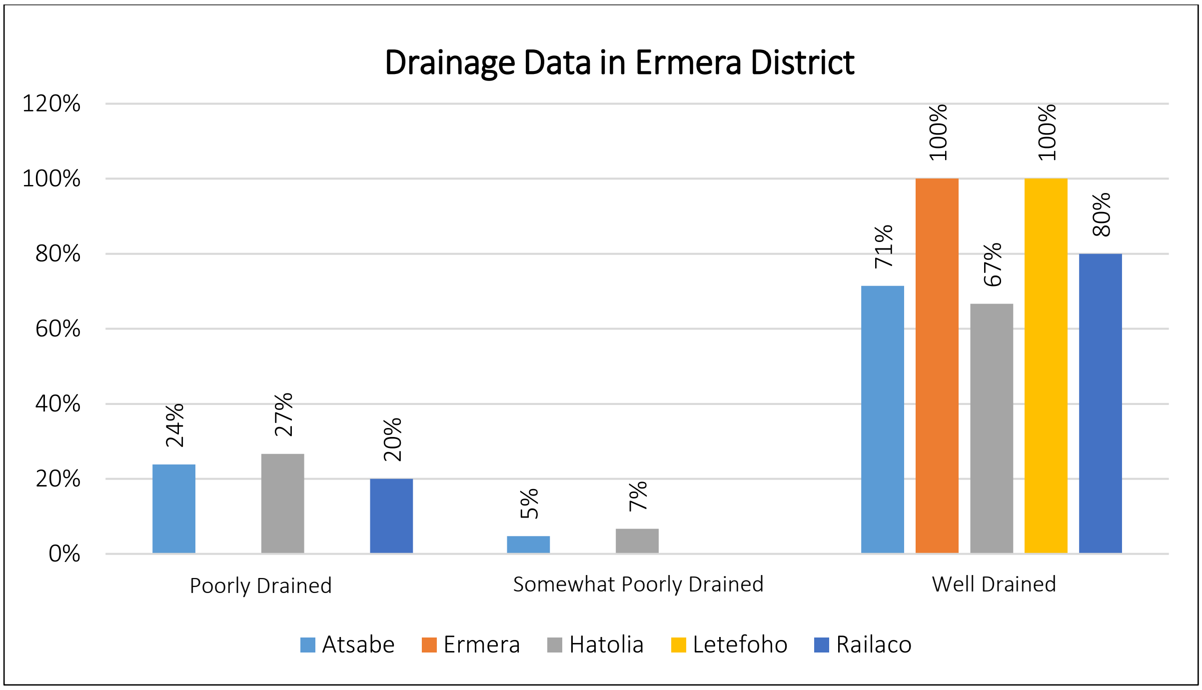


Figure 4.4 Drainage Data in Ermera District

4.5 SOIL TEXTURE

The soil texture characteristics in each area of Ermera District show variations in soil texture classes. In Ermera Sub-District, the texture is moderately fine across the entire area. In Atsabe Sub-District, 43% of the area has a slightly fine texture, 33% has a fine texture, and 24% has a moderate texture. In Hatolia Sub-District, 40% of the area has a fine texture, 33% has a moderate texture, and 27% has a slightly fine texture. In Railaco Sub-District, 60% of the area has a slightly fine texture, 20% has a moderate texture, and 20% has a fine texture. In Letefoho Sub-District, the majority of the area (71%) has a slightly fine texture, 14% has a fine texture, and 14% has a moderate texture. Finer soil textures affect the availability of organic matter and improve water retention, while coarser textures enhance soil aeration **(Figure 4.5)**.

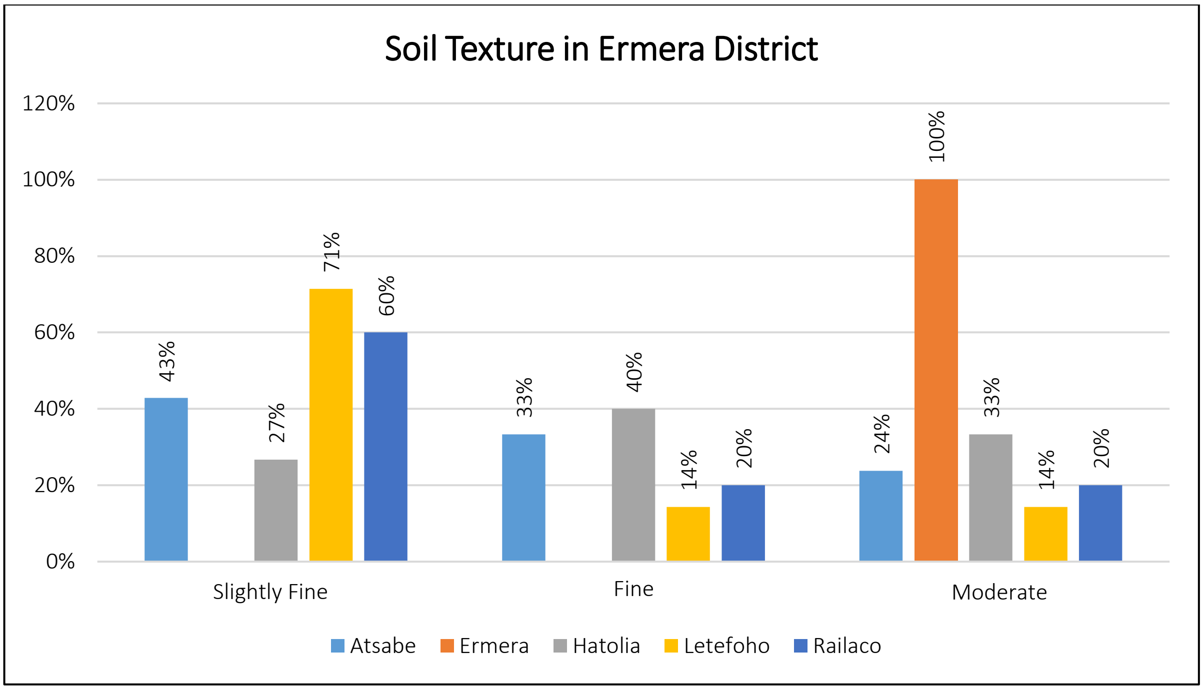


Figure 4.5 Soil Texture in Ermera District

4.6 COARSE FRAGMENTS

The characteristics of coarse fragments in the soil are an important factor in determining land suitability for agriculture, as coarse fragments affect the soil's ability to retain water, manage infiltration, and support plant roots. The analysis of coarse fragment percentages in Ermera District shows a wide variation in the content of coarse fragments **(Figure 4.6).** The largest category, with a percentage of less than 5%, covers 37%, indicating that most of the soil in this area has a relatively fine texture, which supports plant growth with better root systems. The 5–10% category covers 19%, indicating that most of the area still has low coarse fragment content and is suitable for agricultural activities. The 10–15% and 15–20% categories cover 6% and 10%, respectively, suggesting that some areas have moderate coarse fragment content, which may affect soil water availability. The 20–25% category covers 8%, while the 25–35% category covers only 4%, indicating that the areas with high coarse fragment content are relatively limited.

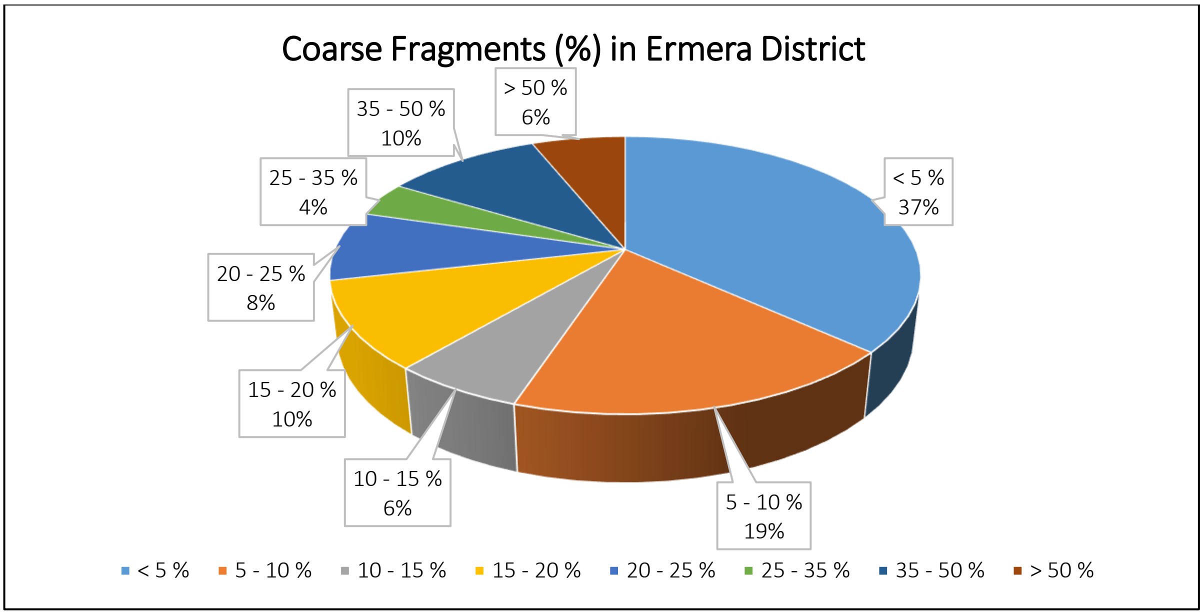


Figure 4.6 Coarse Fragments Data (%) in Ermera District

The category with higher coarse fragment content, 35–50%, covers 10%, while areas with coarse fragment content greater than 50% cover 6%, indicating that there are some areas with coarser soil texture that may require special land management techniques. The distribution of coarse fragments has implications for the agricultural sector in Ermera District. Areas with low coarse fragment content (<10%) are highly suitable for horticultural crops such as coffee, vegetables, and other food crops because the soil can better retain water and nutrients. Conversely, areas with high coarse fragment content (> 35%) may have low water retention capacity and be vulnerable to erosion, thus requiring improved soil conservation techniques, such as terracing or cover crop usage. Therefore, proper land mapping and management are crucial for enhancing agricultural productivity sustainably in this region.

4.7 SLOPE GRADIENT

The slope characteristics in each area of Ermera District show variations in slope classes. In Atsabe Sub-District, steep slopes dominate nearly the entire area (57%), while the entire area of Ermera Sub-District has steep slopes. In Hatolia Sub-District, 66% of the area has moderately steep to steep slopes. In Letefoho Sub-District, 57% of the area has steep slopes, and in Railaco Sub-District, 60% of the area has steep slopes. Flat to undulating slopes are generally directed toward the development of agricultural commodities, while moderately steep to steep slopes are allocated for high-value crop development. Very steep slopes pose significant limitations and challenges for agricultural land development **(Figure 4.7).**

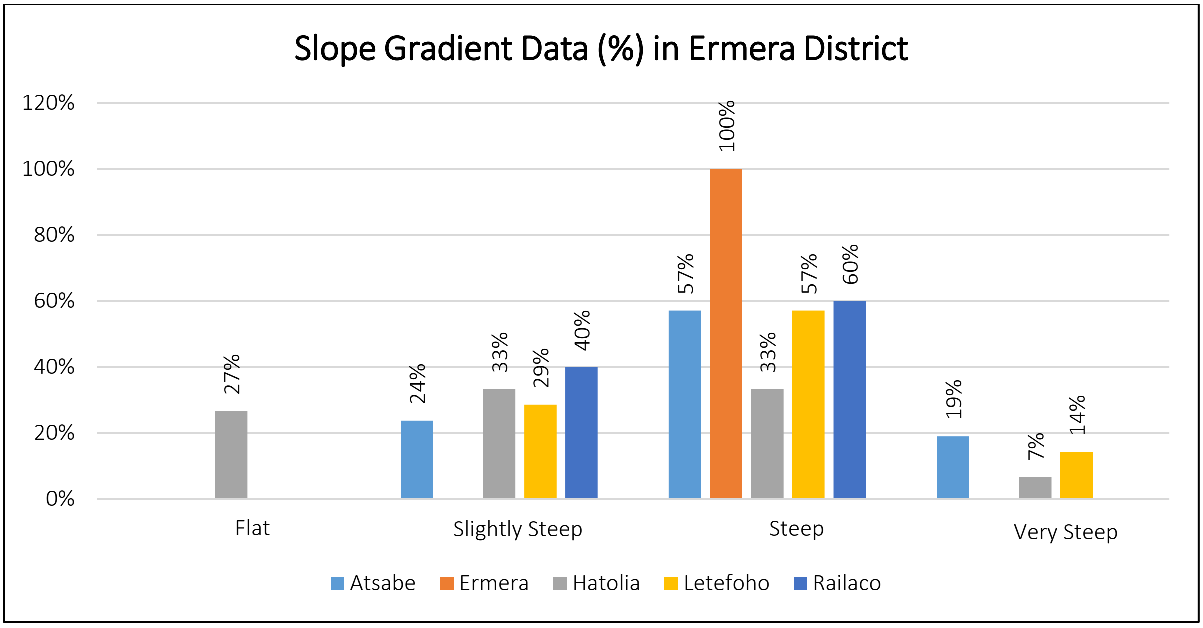


Figure 4.7 Slope Gradient in Ermera District

4.8 SURFACE ROCKS

The condition of surface rocks is an important parameter in determining land potential and management challenges. The presence of surface rocks affects land suitability for agriculture, as high levels of surface rocks can hinder soil cultivation activities and reduce soil fertility. The analysis of surface rock percentages in Ermera District shows that most areas have low surface rock content, with 59% of the area having surface rock content in the range of 0–5% **(Figure 4.8).** This indicates that most of the area is relatively free from surface rocks, thus supporting agricultural activities and other land uses.

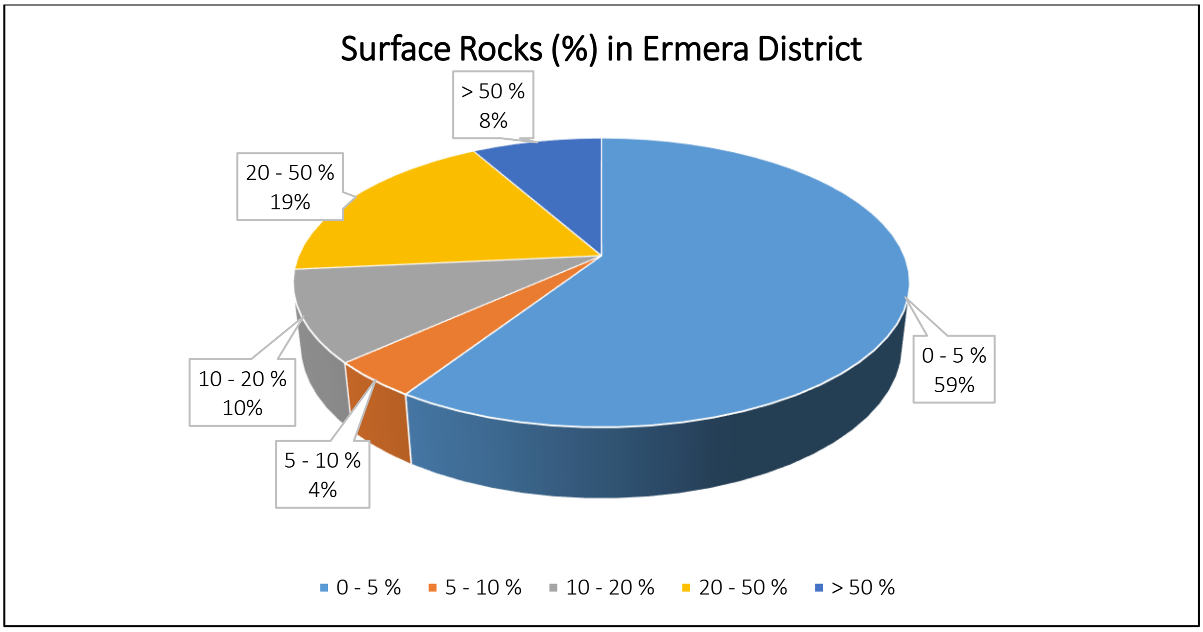


Figure 4.8 Surface Rocks Data in Ermera District

The 5–10% category covers only 4%, while the 10–20% category covers 10%, indicating that a small portion of the area has slightly higher surface rock content but is still manageable for various purposes. The 20–50% category covers 19%, indicating that nearly one-fifth of the area has more dominant surface rocks, which may affect soil fertility and optimal land use. Areas with surface rock content greater than 50% cover 8%, indicating that some areas are dominated by surface rocks, which may be more suitable for conservation or other uses such as forestry and ecotourism rather than intensive agriculture.

This distribution of surface rocks has important implications for land utilization in Ermera District. Areas with low surface rock content (< 10%) have high potential for intensive agriculture, especially for food crops and horticulture such as coffee and vegetables. On the other hand, areas with higher surface rock content (> 20%) may be more suitable for plantations or require soil conservation techniques such as terracing to prevent erosion. Therefore, appropriate land management strategies need to be implemented to ensure the sustainability of agricultural productivity in this region.

4.9 ROCK OUTCROPS

Rock outcrops are an important indicator in assessing geological conditions and land suitability. The presence of rock outcrops can affect soil physical properties, water retention capacity, and erosion levels. The analysis of rock outcrop percentages in Ermera District shows that most areas have low rock outcrop levels **(Figure 4.9)**. The largest category, 0–5%, covers 63%, indicating that most of the area has relatively rock-free surfaces, making it more suitable for agriculture, settlement, and other development activities. The 5–10% and 10–20% categories each cover 10%, indicating that a small portion of the area has moderate rock outcrops, which may still allow for land cultivation but would require soil conservation techniques. Furthermore, the 20–50% category covers 17%, indicating that some areas have more dominant surface rock outcrops, which could become obstacles in agricultural land development or other land uses.

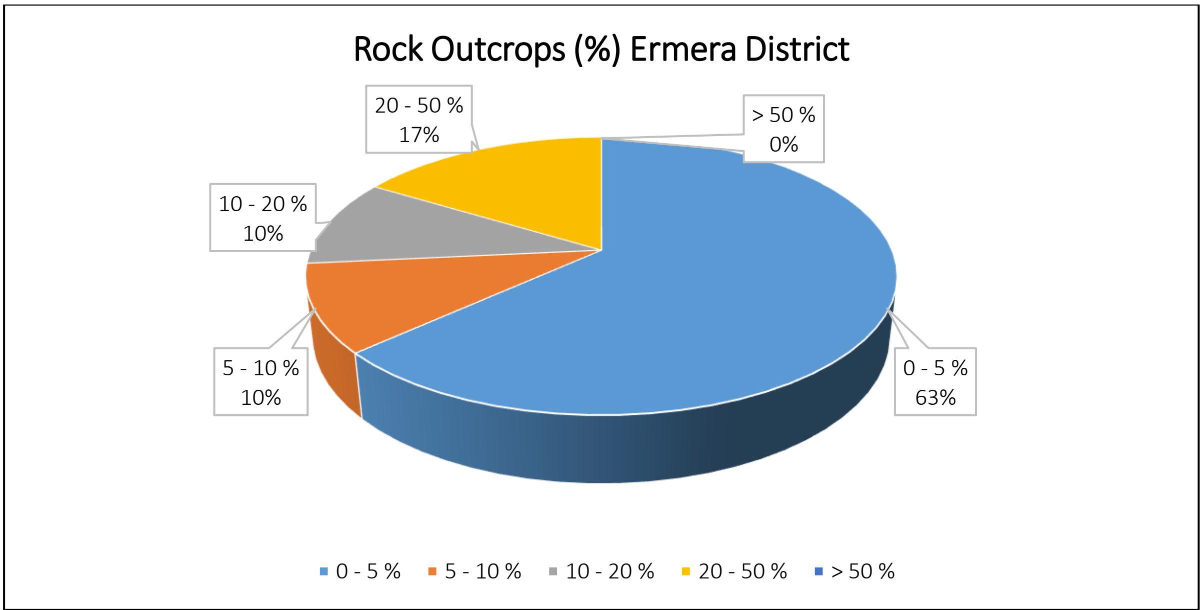


Figure 4.9 Rock Outcrops Data (%) in Ermera District

No areas were found with surface rock outcrop content greater than 50% (0%), indicating that there are no areas fully dominated by exposed surface rocks. This distribution of surface rock outcrops has important implications for land use in Ermera District. Areas with low surface rock outcrops (< 5%) have significant potential for intensive agriculture, particularly for commodities such as coffee and vegetables, which require fertile soil. Meanwhile, areas with higher surface rock outcrops (> 20%) may be more suitable for protected forests, ecotourism, or conservation activities. Therefore, appropriate land management strategies need to be applied to ensure optimal and sustainable land use in this region.

V. SOIL FERTILITY STATUS

Soil fertility is the ability of the soil to provide optimal and balanced amounts of nutrients in an environment suitable for plant growth (Yuwono, 2007). The goal of soil fertility is to achieve high productivity in plants, including fruits, seeds, leaves, flowers, tubers, and so on. Soil fertility varies depending on the soil-forming factors, including parent material, relief, organisms, and time that dominate the location. Soil itself is the primary focus of soil fertility, while plants serve as the main indicator of soil fertility quality (Yuwono, 2007).

Soil fertility status evaluation is essential to determine the types and amounts of nutrients to be used. This evaluation is carried out by diagnosing nutrient issues in the soil and providing fertilization recommendations. The diversity of soil characteristics or chemical properties can support plant life as agricultural commodities and the availability of nutrients in the soil, thus distinguishing fertile soils from infertile ones (Utomo et al., 2016). Evaluating soil fertility status is important for assessing and monitoring soil fertility to identify nutrient limitations that affect plant growth. The determination of soil fertility status aims to assess soil characteristics and identify major fertility constraints, and soil fertility status is determined based on the criteria set by the Soil Research Center (PPT, 1995).

The evaluation of soil fertility status in Ermera District uses several parameters, including Cation Exchange Capacity, Base Saturation, soil organic carbon content, soil P_2O_5 content, and soil K_2O content. The results of the soil fertility evaluation in Ermera District show three criteria: low fertility status (red), followed by moderate (yellow), and high (green) fertility status. The data is presented in **Figure 5.1.**

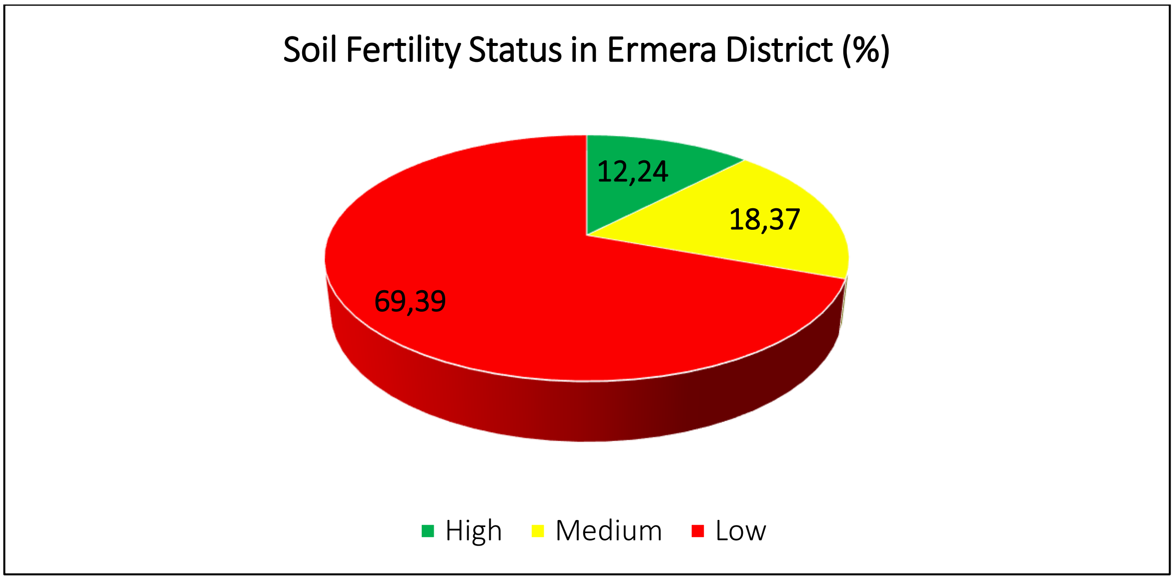


Figure 5.1 Soil Fertility Status in Ermera District

Based on the soil fertility status analysis in Ermera District, it is evident that the majority of the area has low fertility, accounting for 69.39% **(Figure 5.1)**. This indicates that most of the land in this region has limitations in supporting agricultural productivity without proper land management interventions. Meanwhile, soil with moderate fertility covers 18.37% of the total area, while high fertility soils make up only 12.24%. With the dominance of less fertile soils, efforts to improve soil fertility are necessary, such as the adoption of sustainable farming methods, the use of organic fertilizers, and more efficient irrigation systems. Additionally, land management using soil conservation techniques is also a crucial factor in enhancing agricultural productivity in this region. Areas with moderate and high fertility can be optimally utilized to support food security and improve farmers' welfare.

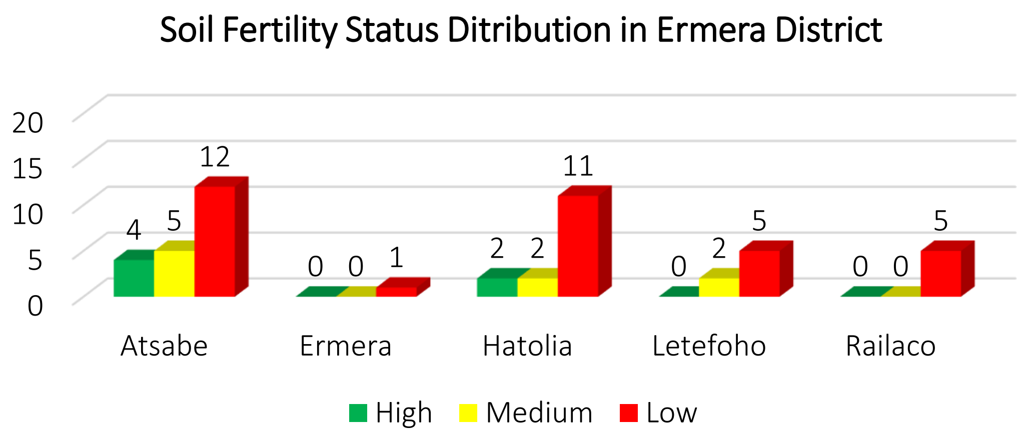


Figure 5.2 Distribution Chart of Soil Fertility Status in Ermera District

Based on the Soil Fertility Status Distribution data in Ermera District **(Figure 5.2)**, it is apparent that the majority of the area has low soil fertility, with a dominance of red-colored land units in various Sub-Districts. Atsabe Sub-District has the highest number of low fertility land units, with 12 units, followed by Hatolia with 11 land units. This indicates that the majority of the land in these two Sub-Districts is infertile and requires better land management interventions. Letefoho and Railaco Sub-Districts also have low fertility levels, with 5 land units in each falling into this category. Meanwhile, Ermera Sub-District is in slightly better condition, with only 1 land unit classified as low fertility. In terms of better soil fertility, Atsabe has 4 land units with high fertility and 5 units with moderate fertility, making it one of the areas with relatively good agricultural potential. In contrast, Hatolia has only 2 land units with high and moderate fertility, which indicates a limited amount of fertile land in this area.

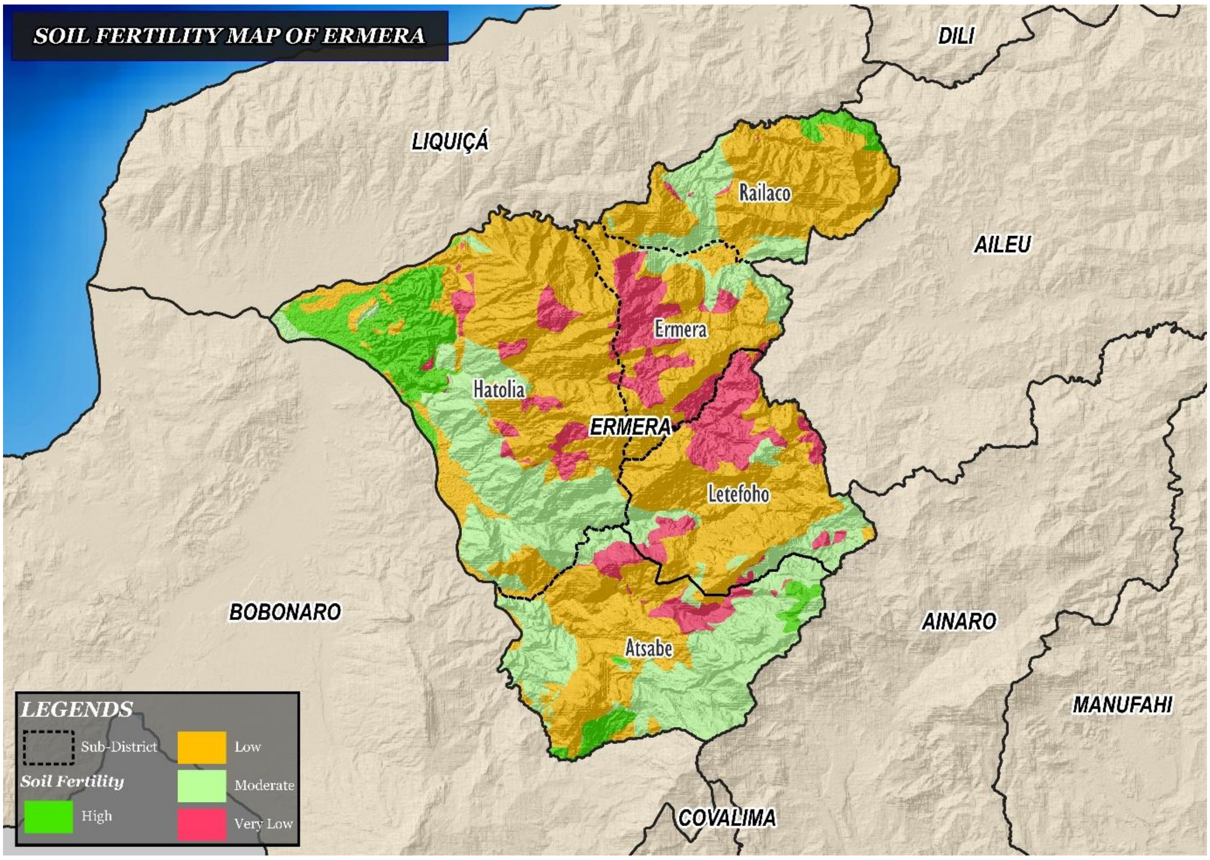


Figure 5.3 Soil Fertility Status Map in Ermera District

According to the Soil Fertility Status map of Ermera District **(Figure 5.3)**, Timor-Leste, it is evident that most of the district has low soil fertility, as indicated by the dominance of red. Sub-Districts such as Ermera, Railaco, Letefoho, and most of Atsabe are areas with low soil fertility, signaling the need for interventions in land management to improve fertility and agricultural productivity. Some areas, particularly around Hatolia, a small portion of Atsabe, and the western part of the district, have moderate fertility (yellow), indicating that these regions have better agricultural potential with appropriate land management techniques. High fertility areas (green) are found only in a few limited locations, such as around Hatolia and the western part of the district, highlighting that fertile land in Ermera District is quite rare.

VI. EROSION AND CONSERVATION

6.1 SOIL EROSION

Soil erosion analysis plays a critical 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 the soil's capacity to retain nutrients and water. In the context of agricultural land management, erosion analysis serves as a foundation for designing appropriate soil conservation strategies to mitigate negative impacts and ensure sustainable land use.

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

Ermera District exhibits a very high erosion rate of 38.02%, a high erosion rate of 33.53%, a moderate erosion rate of 22.58%, and a light erosion rate of 5.58%. More than 70% of Ermera District area experiences very high and high erosion rates. The dominant steep slopes and minimal vegetation cover are the main factors contributing to erosion in this region, leading to the loss of fertile soil and sedimentation in water channels and flat areas. Erosion data for Ermera District is presented in **Figure 6.1.** The soil erosion distribution map for Ermera District is presented in **Figure 6.2**.

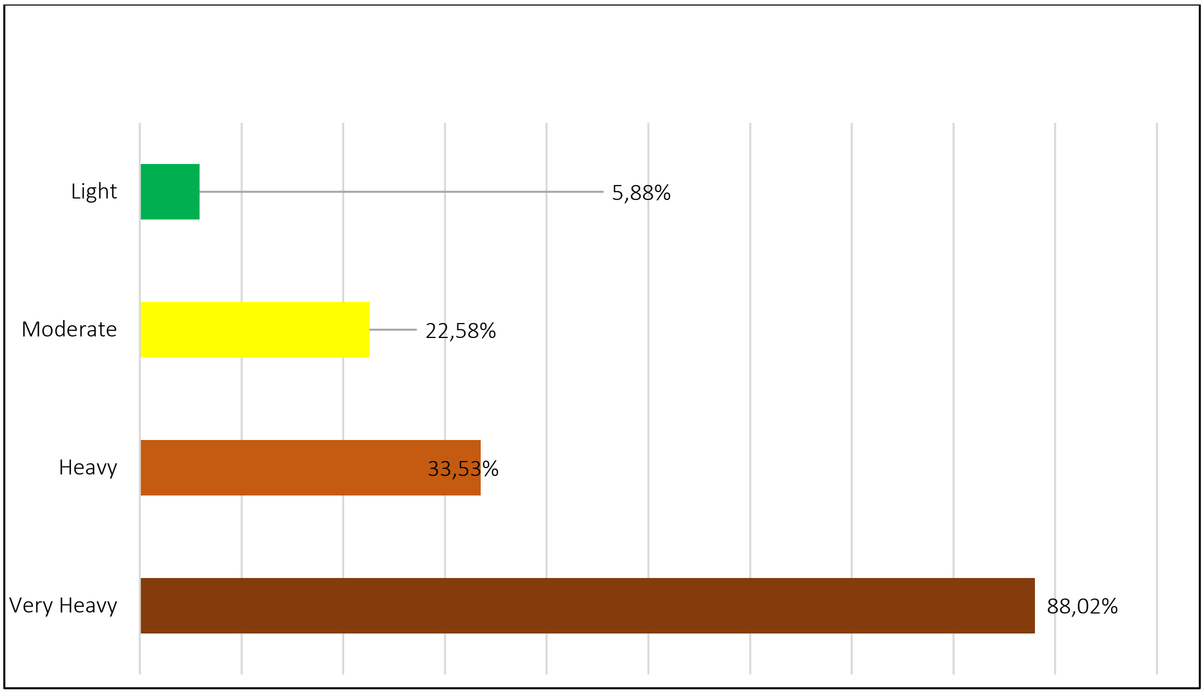


Figure 6.1 Soil Erosion Levels in Ermera District

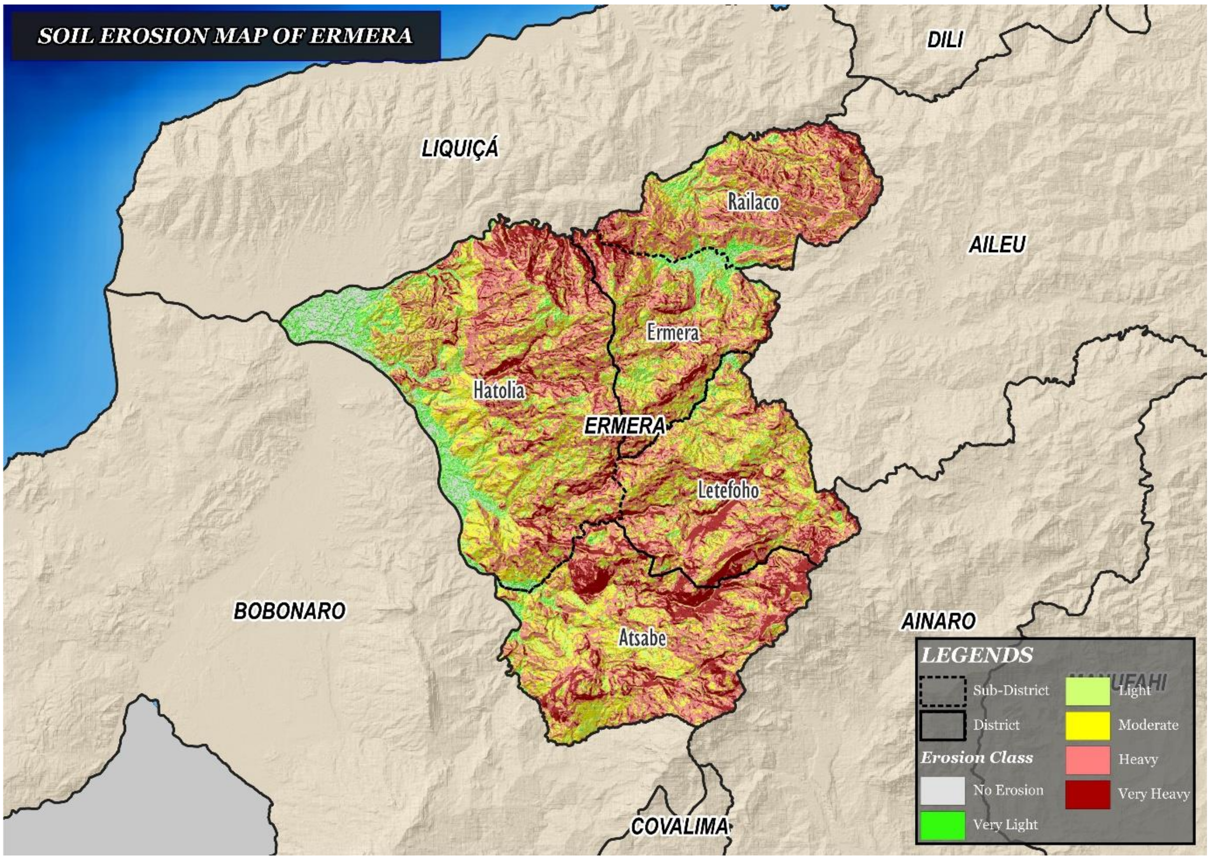


Figure 6.2 Soil Erosion Distribution Map in Ermera District

6.2 SOIL AND WATER CONSERVATION

Conservation refers to the long-term management of natural resources aimed at maintaining soil quality and productivity. Conservation plays a crucial role in protecting soil from degradation, rehabilitating degraded soils, improving infiltration, and maintaining soil fertility.

Soil and water conservation efforts in Ermera District are based on varying slope gradients, dominated by steep to very steep slopes. The Sub-Districts with steep (25-45%) to very steep (>45%) slopes are Atsabe and Letefoho, while the Sub-Districts with gentle (8-15%) to steep (25-45%) slopes are Ermera, Railaco, and Hatolia.

Slopes with steep to very steep gradients pose a high risk of soil erosion, requiring appropriate conservation measures. One strategy that can be implemented is optimizing agroforestry by combining main crops, such as coffee, with trees like vanilla, cocoa, and agarwood. This system helps reduce erosion while improving soil fertility. In addition, terracing can slow water flow and prevent soil erosion. Another measure is planting cover crops, such as vetiver, to stabilize the soil vegetatively and minimize erosion. The construction of water reservoirs also serves as a strategic step to reduce surface runoff and store rainwater. The use of perennial plants in agroforestry systems, alongside subsistence crops like corn and cassava, can improve land productivity. The Slope Map of Ermera District is shown in **Figure 6.3**, and the Slope Data for Ermera District is presented in **Table 6.1**.

Table 6.1 Slope Data in Ermera District

Sub-district	Slope	Potential Class	Areas (ha)	Areas (%)
Atsabe	15-25%	Moderately Potential	1850,87	2,41
Atsabe	25-45%	Agroforestry	13785,02	17,94
Atsabe	8-15%	Potential	80,66	0,1
Atsabe	>45%	Agroforestry	908,65	1,18
Atsabe	0-8%	Highly Potential	110,92	0,14
Ermera	15-25%	Moderately Potential	3580,5	4,66
Ermera	25-45%	Agroforestry	4882,53	6,36
Ermera	>45%	Agroforestry	550,18	0,72
Ermera	0-8%	Highly Potential	324,69	0,42
Hatolia	15-25%	Moderately Potential	9405,56	12,24
Hatolia	25-45%	Agroforestry	11315,78	14,73
Hatolia	8-15%	Potential	911,2	1,19
Hatolia	>45%	Agroforestry	3702,95	4,82
Hatolia	0-8%	Highly Potential	2014,94	2,62

Letefoho	15-25%	Moderately Potential	3115,65	4,06
Letefoho	25-45%	Agroforestry	9244,36	12,03
Letefoho	>45%	Agroforestry	508,2	0,66

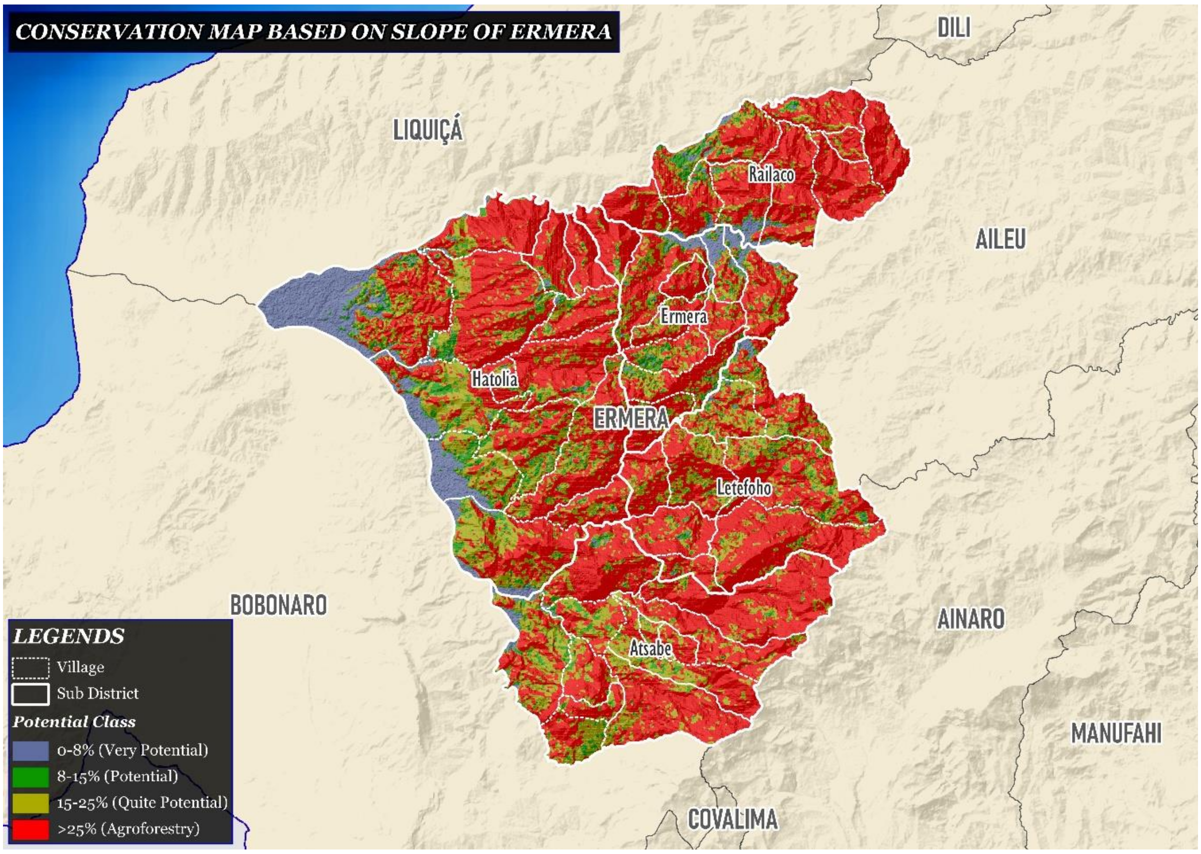


Figure 6.3 Slope Map of Ermera District

Ermera District, which consists of Sub-Districts Atsabe, Ermera, Hatolia, Letefoho, and Railaco, has slopes greater than 45%, with the following areas: 908.65 ha (1.18%), 550.18 ha (0.72%), 3,702.95 ha (4.82%), 508.2 ha (0.66%), and 776.88 ha (1.01%), with the largest area in Sub-District Hatolia. This indicates that areas with very steep slopes can only support the cultivation of perennial crops. The land in Ermera District with gentle slopes (0-8%) covers 2,564.34 ha (3.33%), slopes of 8-15% cover 991.86 ha (1.29%), slopes of 15-25% cover 18,302.02 ha (23.83%), and slopes greater than 25% cover 54,974.52 ha (71.55%) **(Table 6.1).** This shows that the highly suitable land in Ermera District is less than the land used for agroforestry.

The implementation of agroforestry systems in this area can also contribute to biodiversity conservation and maintaining ecosystem balance. The combination of food crops with woody plants not only increases land productivity but also plays a role in stabilizing the soil, reducing the risk of erosion, and maintaining groundwater availability. With layered vegetation resembling the structure of natural forests, this system can create an environment that supports ecological and socio-economic sustainability for local communities.

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

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

1. Agrosilvicultural System: integration of trees and specific food crops on the same land.
2. Silvopastoral System: a combination of tree cultivation and livestock forage grasses to support livestock farming.
3. Agrosilvopastoral System: 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 the intensive cultivation of annual and seasonal crops, typically consisting of vegetables, cereals, fruit trees, grasses, and livestock.
5. Other Systems: includes multipurpose tree cultivation, beekeeping, as well as aquaculture and forestry, all of which can be utilized for various agricultural and non-agricultural purposes. The agroforestry conservation model is presented in Figure 6.4.

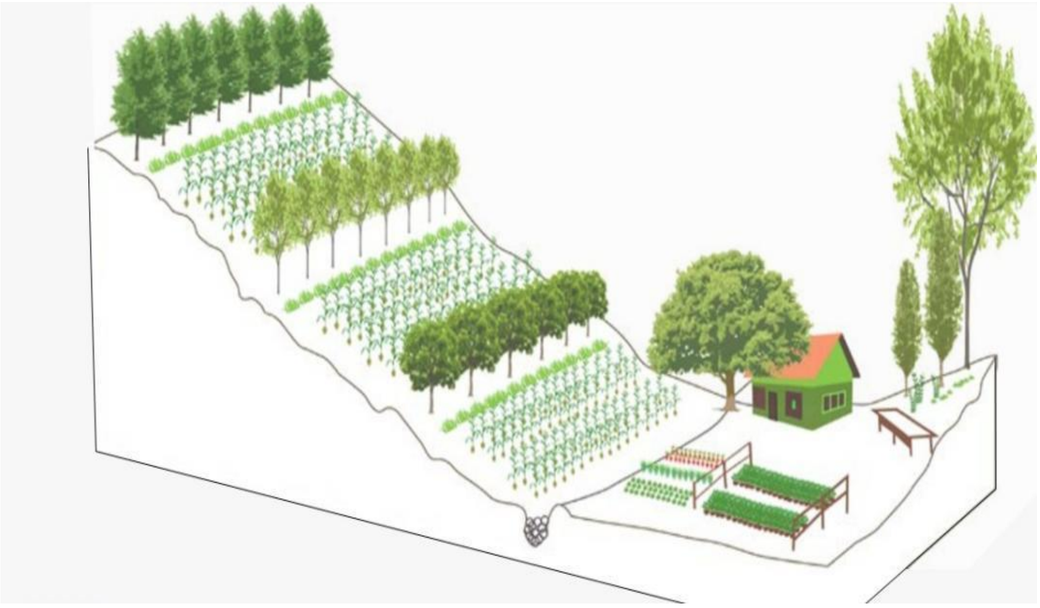


Figure 6.4 Agroforestry Conservation Model
(Sumber: La *et al*., 2016)

A. Important of the Agroforestry Concept

Agroforestry plays a crucial role in the production of both local commodities (firewood, timber, fruits, and livestock feed) and global commodities (coffee, tea, cocoa, rubber, and resin). Agroforestry also has a strategic role in helping countries through poverty eradication, food security, and environmental sustainability. Agroforestry enhances farmers' resilience and increases household income by providing diverse crops harvested at different times throughout the year. The combination of trees, food crops, and livestock helps reduce environmental risks, creates permanent soil cover that combats erosion, minimizes flood damage, and enhances water storage that benefits crops and pastures.

Agroforestry offers a variety of benefits, including:

1. Enhancing Food Security and Nutrient Enrichment

Agroforestry provides a diversity of plant species to produce various types of food that contribute to improving food security. The integration of various agroforestry components enhances agricultural productivity and improves nutritional diversity for consumers.

2. Resilient Livelihoods

The integration of trees, food crops, and livestock can reduce the vulnerability of production to climate disasters and market shocks. Furthermore, agroforestry can also suppress pest attacks on monoculture systems by creating better microclimates. Agroforestry influences climate impacts that hinder agricultural systems, creating more resilient livelihoods.

3. Mitigation and Adaptation to Climate Change

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

4. Environmental Protection

Agroforestry systems help regulate climate and environmental services. Perennial plants contribute to improving air and water quality. Tree litter can be used as organic material to reduce the use of chemical fertilizers. Deep root systems support nutrient cycling. Agroforestry components also support biodiversity by creating an environment suitable for the habitats of flora and fauna in agricultural landscapes.

5. Poverty Alleviation

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

B. Agroforestry and Agro-Ecology in Ermera District

The most successful agroforestry systems in Ermera District generally involve mixed cultivation of fruit trees and timber-producing trees alongside spices. Key fruit crops selected include jackfruit, banana, mango, pineapple, and orange. Timber trees commonly planted alongside fruit crops include mahogany, sandalwood, moringa, and albizia. Agroforestry has adopted a modern approach focused on techniques that emphasize crop rotation, intercropping, and agro-silvopasture.

Paudel *et al*. (2022) describe a common agroforestry model applied in Ermera District.

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

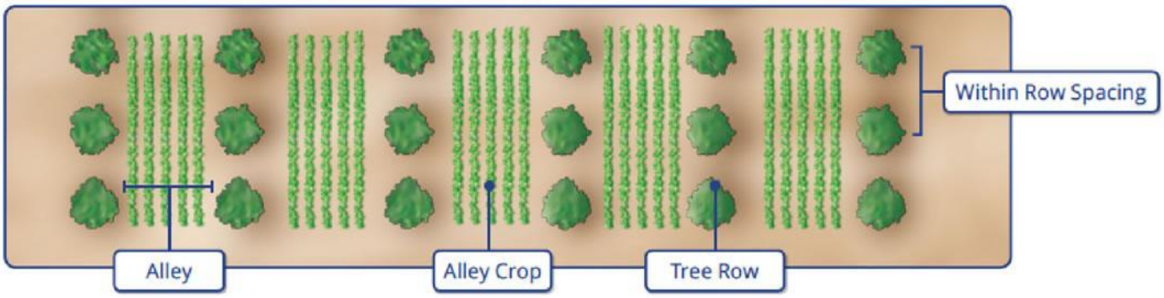


Figure 6.5 Alley Cropping Planting System Concept
(Sumber: https://www.fs.usda.gov/nac/practices/alley-cropping.php)

2. Fence planting creating boundaries or fences using trees or shrubs. This is commonly applied in steep hill areas to conserve soil. The concept is presented in **Figure 6.6**.

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

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

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

4. Alternating Row Planting regularly spaced planting rows with seasonal crops planted between rows on flat and extensive land. An example of an agroforestry model that can be established in Covalima District is vanilla (wood + fruit + spices + staple food), with vanilla as the main crop and supporting crops such as casuarina, albizia, wild pepper, jackfruit, cassava, mango, banana, and cocoa. This agroforestry model can be applied at elevations between 500 - 1500 m with an average annual rainfall of 1500–3000 mm/yr.

Cogné & Lescuyer (2024) combined agro-ecological and socio-technical data to identify the types of Agroforestry Systems (AFS) in Ermera District. These include home gardens that integrate perennial crops, spices, and small livestock; the integration of crops and barren land for developing food crops and trees with specified spacing; planting perennial crops (papaya, banana, chili, etc.) combined with timber trees (palms); forest gardens typically located near water sources; and silvopastoral systems that integrate trees, shrubs, and grazing livestock on the same land.

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

Table 6.2 Agro-Ecological Zone Data and Main Crops

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

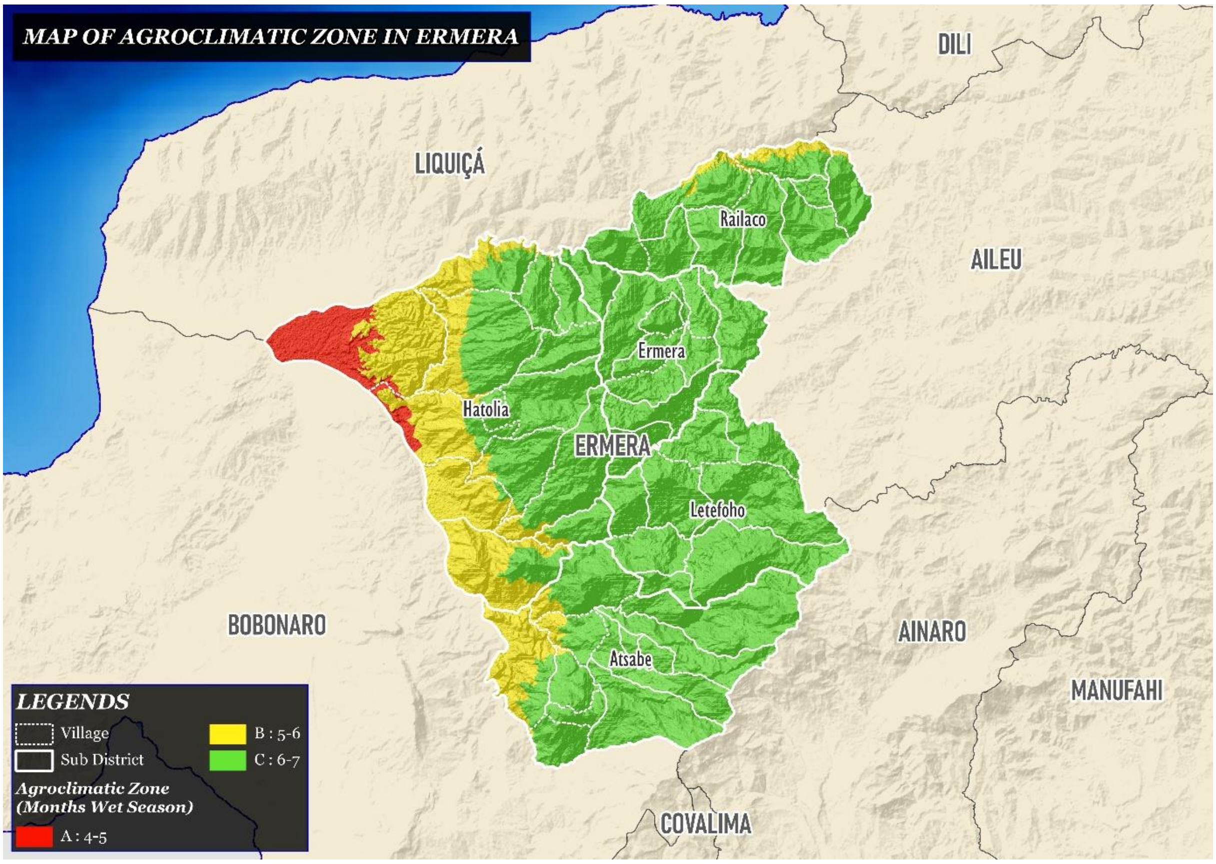


Figure 6.8 Agroclimatic Zone Map in Ermera District

Here is the translation of the recommendations for agroforestry implementation based on agro-ecological zones in Ermera District:

1. Zone A

Appropriate conservation practices include check dams, gabions, ridge terraces, biopore holes, riverbank protection, rainwater reservoirs, and drainage systems. Suitable crops include mahogany, sandalwood, teak, and forest trees, all of which also have high economic value.

2. Zone B

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

3. Zone C

Soil conservation techniques that can be applied include terraces with drainage channels, bench terraces, rainwater reservoirs, drainage systems, grass planting, and check dams. Crops that can be developed include mahogany, sandalwood, ebony, coffee, vanilla, and clove.

C. Conservation Techniques in Ermera District

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

1. Check Dam

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

a. **Brushwood**, A brushwood dam is made from wood or branches and is typically used in small river channels. It usually has an effective height of around 1 m above the ground surface, and the minimum foundation depth for the posts is 0.75–1 m. The brushwood conservation model is shown in **Figure 6.9**. Steps in building a brushwood dam*:*
   1) Dig a trench about 5 cm wide, and insert wooden posts (150-200 cm) to a depth of about one-third to half the length of the post, with a distance of 30-50 cm between each post.
   2) The center should be made lower than the sides to create a gap used to hold the maximum water flow.
   3) Branches from trees (mahogany, rosewood, sesbania) and shrubs are woven between the wood to reach the desired height.

4) The ends of the tied materials must extend into the riverbed at least 30 cm.
5) The back of the check dam should be filled with soil.
6) The edges of the brushwood, about 1.5-2.0 times the height of the dam, should be protected from erosion and reinforced with galvanized wire.
7) Side walls should be built to direct water flow toward the dam.
8) Correct the steep gradient of the riverbed head.

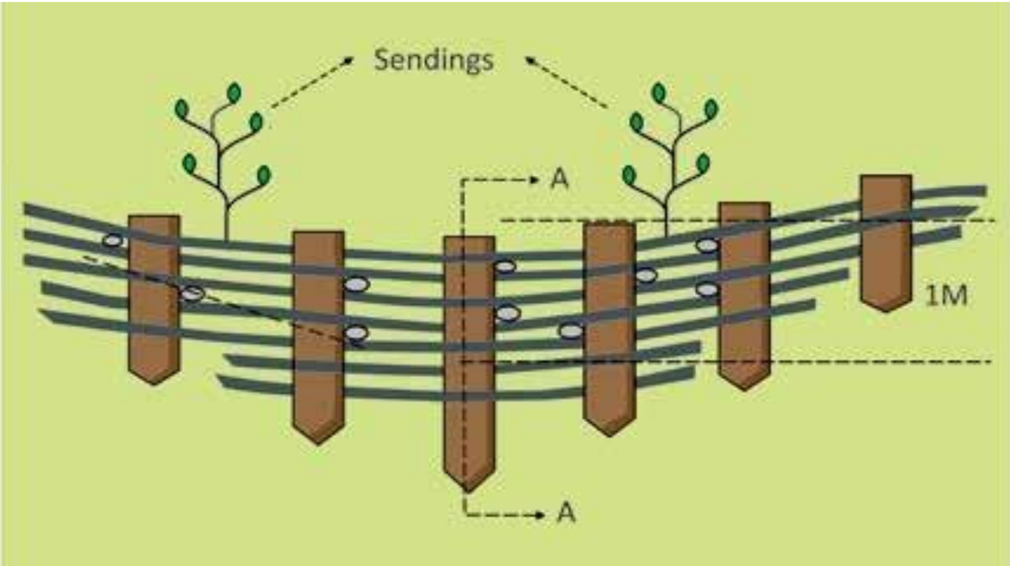


Figure 6.9 Brushwood Check Dam
(Source: Godinho *et al.*, 2023)

b. **Loose Stone**, The loose stone dam is made from loose rocks to block small to medium-sized river channels, while the boulder dam uses large rocks as the barrier, following the same principle as the loose stone dam. Typically, this dam has an effective height of 1–2 m, a minimum foundation depth of half the effective height, and the thickness of the dam at the spillway is between 0.5–1 m. The loose stone model is shown in **Figure 6.10**. Steps in building a loose stone or boulder dam:
   1) Clear the site and mark the construction line using a rope.
   2) Cut the riverbed slope with a 1:1 gradient. The foundation of the wing walls should be >0.5 m. The height of the wing walls should match the depth of the spillway.
   3) The foundation of the dam should be longer than the spillway.
   4) For larger dams, build two wing walls with foundations that match the height to direct the water flow into the spillway or gap and prevent damage to the riverbed edges.

5) Boulder stones are used at the gap and downstream side of the spillway. The center section should be kept lower for the spillway.
6) If there is a large volume of water flow, concrete may need to be used at the gap and the top of the dam or cover everything with wire mesh.
7) An apron made of stones should be built under the dam.
8) Large stones should be placed at the bottom of the dam, with stones about 50 x 30 cm used throughout the dam.
9) On the upstream side, the dam should receive soil filling to increase its stability.

Figure 6.10 Loose Stone Check Dam
(Source: Flickr Loose Stone Check Dam)

c. **Gabion**, A gabion dam is constructed using hexagonal or square wire baskets filled with stones. The general specifications for gabions include a maximum effective height of <5 m, a maximum foundation depth of half the effective height, and a dam thickness at the spillway of <1 m. The gabion conservation concept is shown in **Figure 6.11.** Steps in building a gabion dam:
   1) The structure must extend at least 0.5 m into the riverbed and must be protected from floodwaters with wing walls.
   2) Wing walls with suitable foundations must be built on top to direct the water flow into the spillway or gap and prevent damage to the riverbed edges. The space between the dam and wing walls should be filled with soil.
   3) The foundation of the retaining dam should be longer than the spillway.

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

Figure 6.11 Gabion Check Dam
(Source: Pinterest Gabion Check Dam)

2. Terracing

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

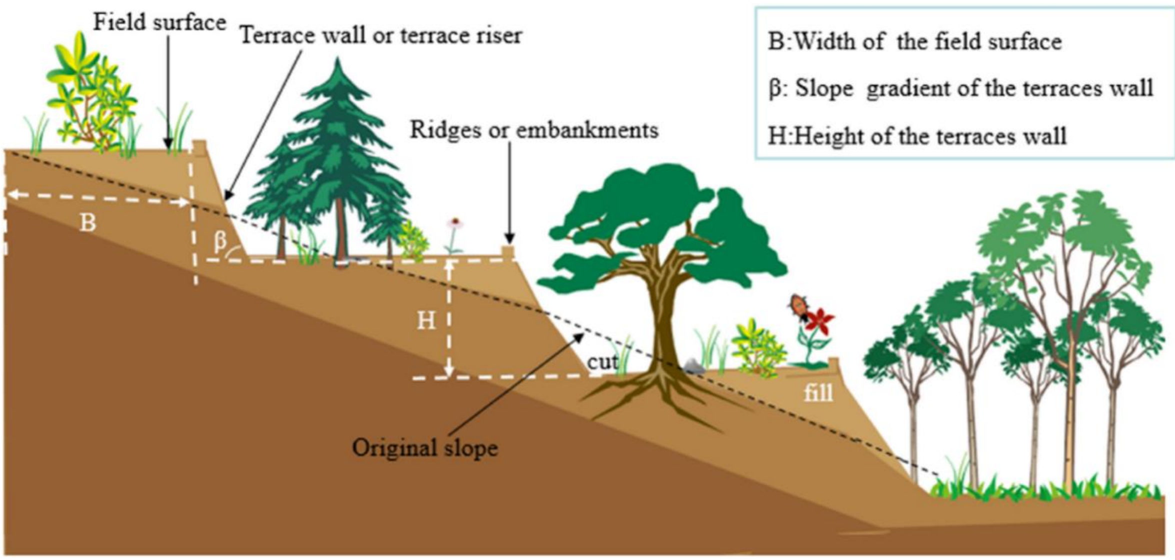
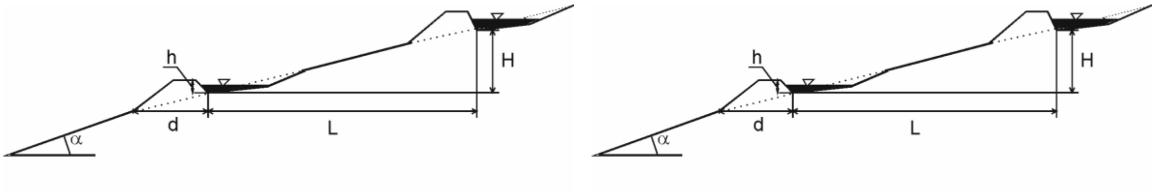


Figure 6.12 Terracing Conservation Concept
(Source: Deng *et al*., 2021)

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

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

terraces have surface or subsurface drainage. For subsurface drainage, water is discharged through wells or underground pumps into ditches, rivers, or reservoirs. These terraces are used in areas with high precipitation and on soils with low water absorption capacity. The concept of ridge terrace division is shown in **Figure 6.13.**



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

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

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

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

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

1) Terrace Length: Typically a maximum of 100 m in one direction of the drainage channel for humid tropical climates. Terrace length is limited by the size and shape of the land, degree of cutting, and soil type.
2) Terrace Width: The optimal width ranges from 2.5 - 5 m (manual construction) and 3.5 - 8 m (machine/tractor construction). The width is

adjusted according to soil depth, land preparation tools, plant types, and other needs.

3) Terrace Gradient: The horizontal gradient of the terrace ranges from 0.5 - 1%, depending on the climate and soil type.
4) Height and Slope of Subterraces: Subterraces are made from compacted soil and protected with grass or stones. The height of the sub-terraces should not exceed 2 m. The Vertical Interval (VI) between two successive terraces can be calculated using the following formula:

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

Descriptions:
S = Slope (%)
Wb = Bench Width (m)
U = Slope of the sub-terrace (m)

Figure 6.14 Application of Terracing Conservation
(Source: Freepik)

3. Biopore Infiltration Holes

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

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

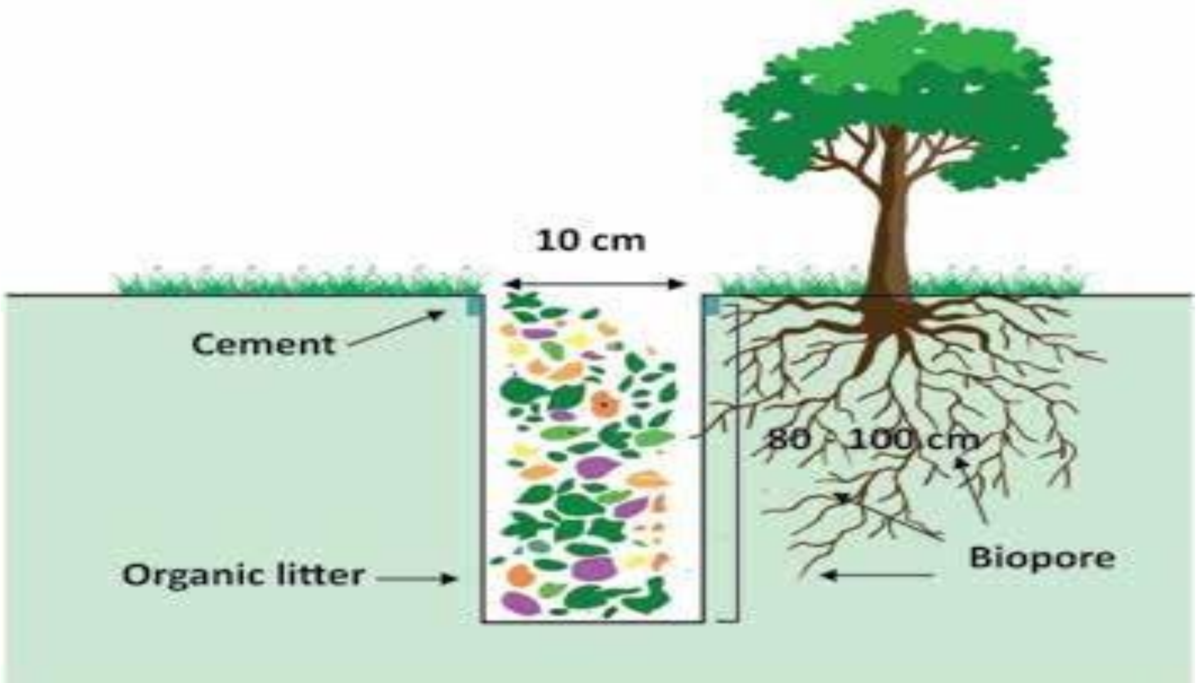


Figure 6.15 Biopore Infiltration Holes
(Source: Godinho *et al*., 2023)

4. Riverbank Protection

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

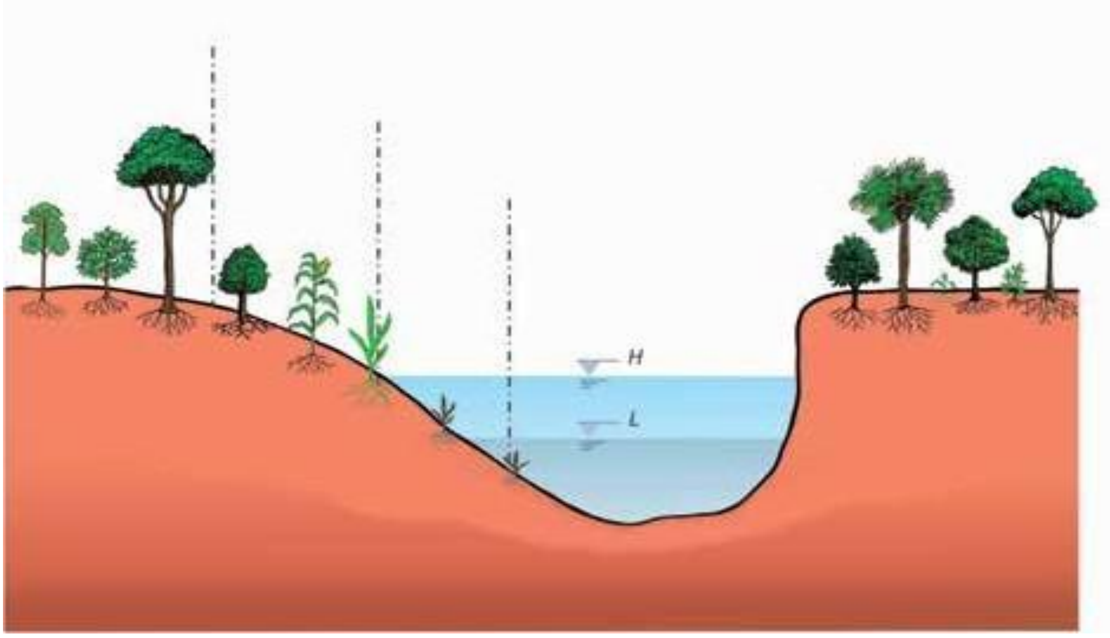


Figure 6.16 Riverbank Protection with Various Layers of Trees, Shrubs, and Grasses (Source: Godinho *et al*., 2023)

5. Grass Planting

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

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

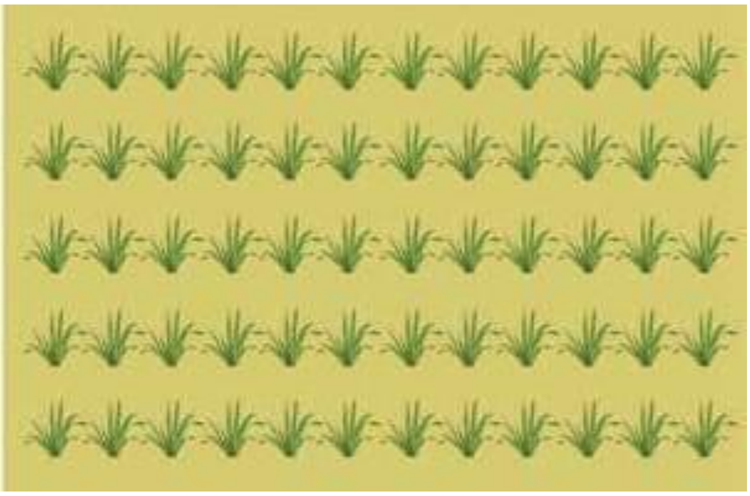


Figure 6.17 Horizontal Grass Planting
(Source: Godinho *et al*., 2023)

b. Vertical and Downward Grass Planting, This method can be applied to slopes <65 degrees in moist areas. The recommended planting distance is 10 cm between plants and 50 cm between rows. The concept of vertical and downward grass planting is shown in **Figure 6.18.**

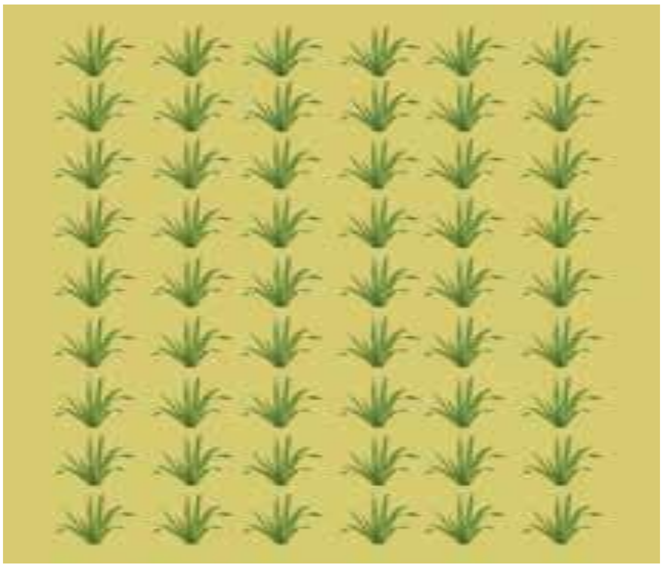


Figure 6.18 Vertical Grass Planting
(Source: Godinho *et al*., 2023)

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

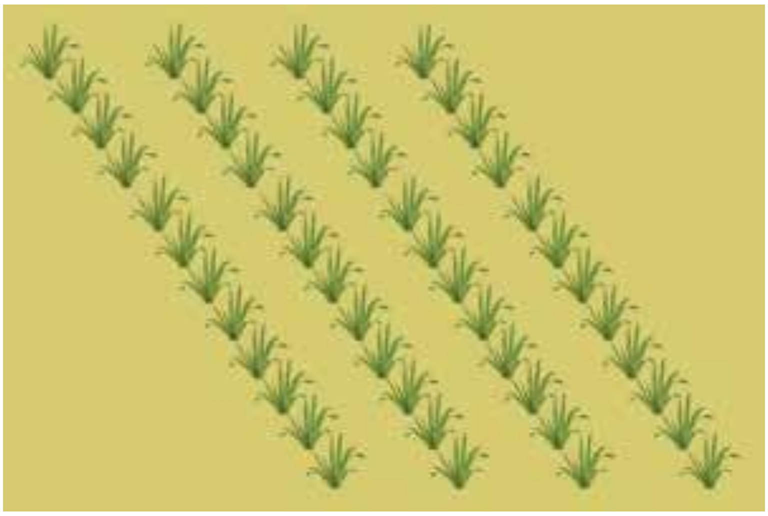


Figure 6.19 Diagonal Grass Planting
(Source: Godinho *et al*., 2023)

6. Rainwater Reservoir

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

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

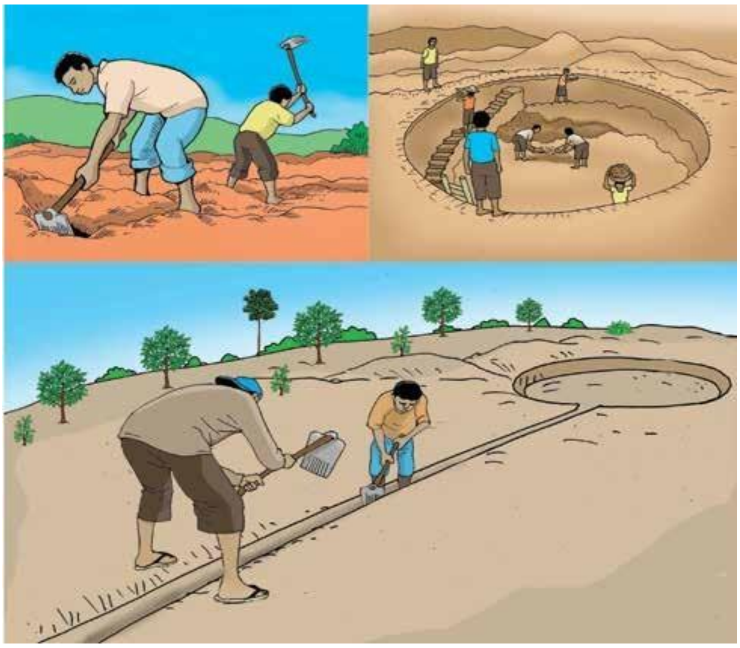


Figure 6.20 Rainwater Reservoir Construction
(Source: Godinho *et al*., 2023)

7. Drainage Channel Construction

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

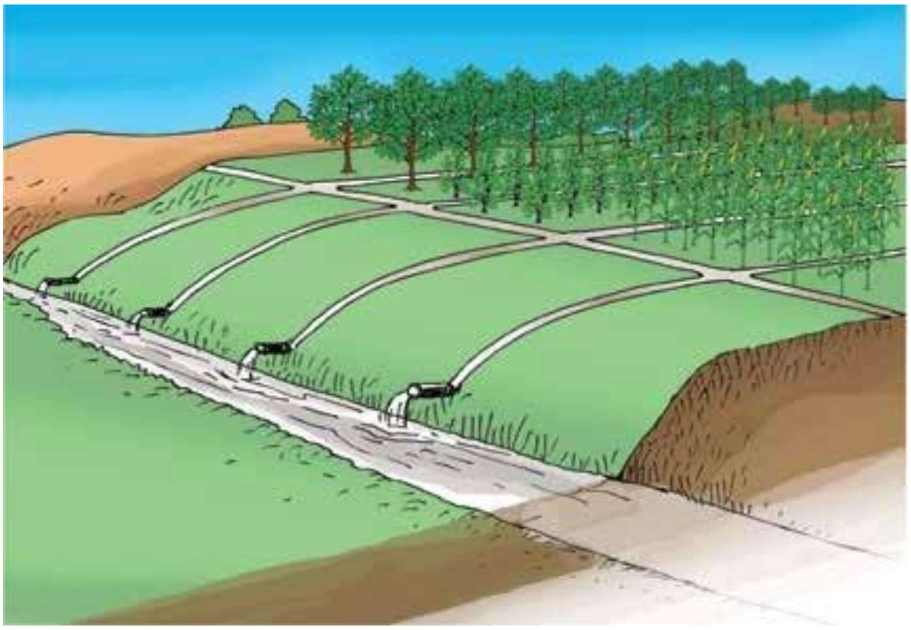


Figure 6.21 Drainage Channel
(Source: Godinho *et al.*, 2023)

8. Wattle Fence / Live Check Dam

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

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

Figure 6.22 Wattle Fence

9. Vegetative Measures

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

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

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

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

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

Figure 6.23 Reservoir Application

VII. AGRICULTURAL LAND SUITABILITY EVALUATION

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

7.1 AGRICULTURAL LAND SUITABILITY

The evaluation of land suitability based on current conditions uses data from field surveys. This assessment reflects the land's capacity in its existing state without any additional interventions. Current land suitability or natural land suitability has not considered potential improvements and management efforts that can be made to address the limitations or constraints present in each land unit/map unit. To determine the current suitability class, an assessment is first made on the quality of the land based on the most limiting factor or the poorest land characteristic. The suitability class is then determined based on the poorest or most limiting land quality.

Potential land suitability refers to land suitability after improvements have been made. For example, land that is marginally suitable (S3) for nutrients can become moderately suitable (S2) or even highly suitable (S1) after fertilization improvements. The evaluation of potential land suitability is done by implementing improvements on the quality of land factors that are limiting, so that land suitability is expected to increase. With technology, lands that naturally have a low suitability class (current suitability) can be improved and upgraded to a higher suitability class (potential suitability).

In land-use planning, the main focus is on potential land suitability because this evaluation provides an overview of the land's maximum potential for various uses after improvements. Therefore, potential land suitability helps in planning land use effectively and sustainably, and determining the necessary improvement steps to achieve optimal results. Efforts to improve current land characteristics into potential ones, based on management levels, are presented in Table 7.1.

Table 7.1 Types of Efforts to Improve Actual Land to Potential Suitability Based on Management Level

No	Land Quality/Charachteristic	Improvement Efforts	Management Level
1	**Radiation regime** (sunlight duration)	No improvement possible	-
2	**Temperature Regime** Average annual Temperature Average coldest monthly Temperature Average hottes monthly Temperature	 No improvement possible No improvement possible No improvement possible	 - - -
3	**Humidity regime** Relative humidity	 No improvement possible	 -
4	**Water availability** Dry month Rainfall	 Irrigation system Drainage	 Medium, High Medium, High
5	**Root Medium** Drainage Texture Effective depth	 Improvement of drainage system, such as masking drainage channels. Addition of organic material No improvement possible. Generally cannot be improved expect in soft and thin bedrock layers, which can be broken during land preparation	
6	**Nutrient retention:** Cation Exchange Capacity pH	 Lime application or addition of organic material	 Medium, High
7	**Nutrient availability:** Total Nitrogen Available Phosphorus Available Potassium	 Urea and ZA fertilization SP36 and TSP fertilization KCl fertilization	 Medium, High
8	**Diversity:** Salinity	 Addition of organic materials	 Medium, High
9	**Erosion Hazard**	Erosion control measures, terracing, contour planting, cover crop planting	Medium, High
10	**Flood hazard** Frequency Period	 Construction of water barriers and drainage channels to improve water management	 High
11	**Toxicity:** Aluminuin saturation Pyrite layer	 Liming Water management system regulation, groundwater level must be above the sulfide layer	 Medium, High Medium, High
12	Ease of cutivation	Soil moisture management to ease land prepaation	Medium, High
13	Terrain/potential mechanisms	No improvement possible	-

Descriptions:

- Moderate management level: Management can be carried out at the farmer level with moderate agricultural capital/techniques.
- High management level: Management can only be carried out with relatively large capital, typically done by the government or large or medium-sized companies.

Table 7.2 Assumptions for the Improvement of Actual Land Quality to Potential Based on Management Level

No	Land Quality and Characteristics	Management Level		Improvement Type
		Medium	High	
1	**Radiation regime**	-	-	-
2	**Temperature Regime**	-	-	-
3	**Humidity regime**	-	-	-
4	**Water availability**			
	Dry month	+	++	Crop combination
	Rainfall	+	++	Irrigation
5	**Root Medium**			
	Drainage	+	++	Drainage channels*)
	Texture	-	+	Addition of organic material
	Effective depth	-	+	Making planting holes and adding organic materials
				-
	Peat, maturity	-	-	-
	Peat, thickness	-	-	
6	**Nutrient retention:**			
	Cation Exchange Capacity	-	+	Addition of organic material
	Base saturation	-	+	
	pH	+	+	
	Organic Carbon	+	++	
7	**Nutrient availability:**			
	Total Nitrogen	+	++	Urea fertilization
	Available Phosphorus	+	++	SP36 and TSP fertilization
	Available Potassium	+	++	KCL fertilization
8	**Flood hazard**			
	Period	+	++	-
	Frequency	+	++	-
9	**Diversity**			Irrigation and additional
	Salinity	+	++	oforganic material
10	**Toxicity**			
	Aluminuin saturation	+	++	lime
	Pyrite layer	-	+	regulating groundwater level
11	**Ease of cutivation**	-	+	Mechanization
12	**Terrain/potential mechanisms**	-	+	Terracing
13	**Erosion Hazard**	+	++	Soil conservation efforts

Description:

- No Improvement possible

\+ Improvement can be made, resulting in an increase of one suitability class (S3 to S2)

++ A two class increase in suitability (S3 to S1)

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

7.2 LAND SUITABILITY CLASSIFICATION STRUCTURE

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

Table 7.3 Land Suitability Classification System (FAO, 1976)

Order	:	Indicates whether a land is suitable or not for a spesific use.
Class	:	Indicates the degree of suitability of a land.
Sub-classes	:	Indicates the type of limitation or the kind of improvement that must be carried out within each class.
Unit	:	Indicates the differences in the magnitude of limiting factors that affect the management of sub-classes.

Order and class are typically used in land reconnaissance mapping, sub-classes in semi-detailed land mapping, and units in detailed land mapping. Order is also used in coarse-scale (exploratory) land mapping.

Suitability Order

Suitability order describes the general suitability of land, indicating whether a land is suitable or not for a specific land use that has been considered. At the orderr level, land is categorized into suitable (S) and not suitable (N) land.

Suitable Order (S)

Land classified in this orderr can be used for long-term purposes for a particular use without or with minimal risk of degradation, and the benefits from land management will be satisfactory after considering the inputs.

Not Suitable Order (N)

Land classified in this orderr has significant difficulties or constraints, either physical (e.g., very steep slopes, rocky terrain) or economic (e.g., inputs do not balance with output, preventing the land from being used for the intended purpose).

Suitability Class

Suitability class indicates the level of land suitability within the orderr. At the class level, lands classified as suitable (S) are divided into highly suitable (S1), moderately suitable (S2), and marginally suitable (S3) lands. On the other hand, lands classified as not suitable (N) are not further subdivided.

Highly Suitable Class (S1)

Land with no significant limiting factors or only minor limiting factors that do not notably reduce productivity, allowing for sustainable land use.

Moderately Suitable Class (S2)

Land with some moderate limitations, which require a higher level of management. These limitations reduce productivity or profits and increase the necessary inputs.

Marginally Suitable Class (S3)

Land with significant limitations that require careful management. These limitations can reduce productivity and profits, requiring additional inputs to achieve the expected output.

Not Suitable Class (N1)

Land with severe limiting factors that are difficult to overcome, preventing sustainable use in the long term.

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

Suitability Sub-class

This reflects the type and intensity of the limiting factors that hinder land use or the types of improvements needed. Each class can consist of one or more sub-classes depending on the types of limitations present. The limitations are represented by small letters placed after the class symbol. For example, class S2 with a limitation of effective depth (s) can become sub-class S2s. A sub-class can have one, two, or at most three limitation symbols, with the most dominant limitation written first. For example, in the sub-class S2ts, the dominant limitation is topographic condition (t), while the effective depth limitation (s) is secondary.

Suitability Unit

Suitability at the unit level is a more detailed subdivision of sub-classes based on the intensity of the limiting factors affecting the land. All units within a sub-class have similar suitability levels and share the same type of limitations at the sub-class level.

Table 7.4 Land Suitability Classification Structure (FAO, 1976)

No	Order	Class	Sub-Classes	Unit
		S1	-	
			S2s	S2r-1
1.	S	S2	S2e	S2e-2
			S2se	Dsb..
		S3	Dsb.	
		N1	N1s	-
2.	N		N1e	-
		N2	Dsb.	

The differences between one unit and another typically lie in their production capacity or additional management aspects required, and they are often a more detailed distinction based on the limiting factors. Detailed knowledge of these limitations facilitates interpretation and planning in farm management. At the unit level, labeling is done by adding Arabic numerals separated by hyphens after the sub-class symbol. For example, S2e-1, S2e-2, and so on. The number of units within a sub-class is not limited. The symbol at the unit level is formed by adding Arabic numerals separated by a hyphen from the sub-class symbol. For instance, S2e-1, S3e-2, and so on. The number of units within a sub-class is unlimited.

7.3 LAND SUITABILITY EVALUATION RESULT

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

Geospatial data are used to map topography, land use distribution, and rainfall patterns in each District, while field observations provide direct information on land biophysical conditions such as slope gradients, vegetation cover, and drainage quality. Laboratory soil sample analysis complements this process by providing data on macronutrient content (N, P, K), organic matter, Cation Exchange Capacity (CEC), pH, and soil texture.

Next, the data obtained are analyzed based on the growth requirements of each plant species under current conditions, as well as potential suitability after various land improvement efforts such as fertilization, addition of organic matter, or application of soil conservation techniques. This process results in comprehensive information to determine priority commodities for development, identify limiting factors, and design relevant technical solutions. This scientific approach forms the foundation for the land suitability evaluation in Ermera District. The results of this analysis provide strategic guidance for maximizing land productivity while maintaining the sustainability of natural resources in each area.

Ermera District, known as a coffee production hub in Timor-Leste, has great potential for the development of both agricultural and forestry sectors. The area features various topographies, ranging from lowland to high mountain regions, with an average annual rainfall of 1,500 to 2,000 mm and Temperaturees ranging from 18°C to 27°C. Several key commodities that can be developed include irrigated rice, upland rice, maize, mung beans, arabica coffee, robusta coffee, and horticultural crops such as chili, tomatoes, and pineapples. However, agricultural development in Ermera District faces constraints such as slope gradient, shallow effective soil depth, erosion risk, and low nutrient availability.

The necessary improvement strategies include implementing contour-based planting patterns, constructing terraces and bunds, adding organic matter, and adjusting planting schedules. For areas with slope gradients greater than 35%, it is recommended to develop forestry crops or agroforestry systems that integrate fruit horticulture with perennial crops. The following section outlines the land suitability evaluation for each Sub-District in Ermera District.

A. Land Suitability Evaluation for Atsabe Sub-District

Atsabe Sub-District has high potential for developing food crops such as rice paddy, upland rice, maize, wheat, and mung beans, horticultural vegetables such as potatoes, carrots, shallots, and chili, and fruit crops such as rambutan, mango, and watermelon. Industrial crops such as rubber, coconut, cacao, and cloves, as well as medicinal and spice plants like ginger, vetiver, lemongrass, and vanilla, can also be developed.

Despite its potential, agricultural development in Atsabe faces several biophysical and chemical land constraints. These constraints include Temperaturee, rainfall, the length of the dry season, steep slopes, erosion, surface rock outcrops, shallow effective soil depth, drainage issues, flood risk potential, and chemical soil factors such as texture, cation exchange capacity

(CEC), base saturation (BS), and nutrient levels of nitrogen (N), phosphorus (P), and potassium (K). Many of these constraints can still be addressed through various technical interventions, such as optimizing irrigation systems, planting slope-stabilizing vegetation, constructing terraces, land clearing, digging planting holes, developing water recharge areas, adding organic matter, and applying appropriate fertilization. The land suitability evaluation matrix is presented in **Table 7.5.**

However, commodities like cotton, kapok, and quinine are generally not recommended for development due to permanent Temperaturee limitations. In addition to the mentioned commodities, **Table 11.1** presents alternative plant species that are considered suitable for agricultural development in Atsabe Sub-District.

B. Land Suitability Evaluation for Ermera Sub-District

Ermera Sub-District has significant potential for integrated farming systems that include various types of crops and optimal land use. This area is suitable for cultivating food crops such as maize, cassava, and peanuts, supporting local food security and potentially enabling both subsistence and commercial development. For horticultural vegetables, the agro-climatic conditions allow the development of snow peas, cucumbers, and cabbage, particularly in the cool highland areas. In the fruit horticulture sector, Ermera has the potential to produce high-value commodities such as bananas, papayas, oranges, and avocados, which can be marketed locally or regionally. Furthermore, spice and medicinal plants such as cinnamon, nutmeg, and pepper can be developed as raw materials for the food and traditional medicine industries, and support export orientations. Additionally, robusta coffee is suitable for lowland areas, while arabica coffee is best grown in highland regions. However, coffee development faces challenges such as erosion and shallow soil depth, which can be overcome with the construction of terraces and proper planting holes.

Although Ermera has promising biophysical potential for agricultural commodities, its utilization faces several limiting factors. These include climate characteristics (Temperature, rainfall intensity, and the length of the dry season), land morphological conditions (steep slopes, erosion levels, surface rock outcrops, and shallow effective soil depth), and soil characteristics (suboptimal drainage and flood risk). Additionally, chemical soil constraints such as texture, cation exchange capacity (CEC), base saturation (BS), and nutrient deficiencies in nitrogen (N), phosphorus (P), and potassium (K) affect land suitability for various agricultural commodities. In addition to the mentioned commodities, **Table 11.1** presents alternative plant species that are considered suitable for agricultural development in Ermera Sub-District.

C. Land Suitability Evaluation for Hatolia Sub-District

Hatolia Sub-District has potential for developing both food and industrial crops. Food crops such as irrigated rice, upland rice, and maize are considered moderately suitable. Horticultural vegetables such as chili, bell peppers, mustard, green beans, and broccoli, as well as fruit crops like papaya, soursop, and longan, are also suitable. Additionally, arabica coffee is moderately suitable for elevations above 1,000 m asl.

Agricultural commodity development in this area still faces several constraints, both from biophysical and soil chemical conditions. Biophysical constraints include relatively low Temperatures, uneven rainfall patterns and intensity, long dry seasons, steep slopes, significant erosion, surface rock outcrops, and shallow effective soil depth.

From a chemical soil perspective, limiting factors include soil texture, cation exchange capacity (CEC), base saturation (BS), and low levels of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K). Most of these constraints can still be addressed through appropriate technical interventions, including improving irrigation efficiency, stabilizing slopes through vegetation and terrace construction, land clearing and cultivation, selective planting hole digging, developing water recharge areas, and applying organic matter and fertilizers according to specific soil needs. However, Temperature remains a permanent limiting factor that cannot be technically modified. Therefore, adaptation strategies are required, including selecting agricultural commodities that are adapted to the specific environmental conditions of Hatolia Sub-District.

In addition to the mentioned commodities, **Table 11.1** presents alternative plant species that are considered suitable for agricultural development in Hatolia Sub-District.

D. Land Suitability Evaluation for Letefoho Sub-District

Letefoho Sub-District is one of the primary arabica coffee producing regions in Ermera District. This crop is moderately suitable (S2) for areas above 1,200 m asl. The main constraints, such as erosion risks and shallow soil depth, can be overcome through terrace construction and proper planting hole management.

Food crops that can be developed include irrigated rice, upland rice, maize, sorghum, and cassava. Horticultural crops such as potatoes and chili are moderately suitable (S2) in Ducurai and Catrai-Craic Villages. Other suitable horticultural vegetables include snow peas, cucumbers, cabbage, eggplant, bitter melon, and vegetable tomatoes. Medicinal and spice plants such as cinnamon, pepper, nutmeg, jatropha, ginger, and turmeric can also be developed. Industrial crops like cacao, sugarcane, and melinjo are suitable for development.

Despite having bio-physical potential to support agricultural development, resource utilization in Letefoho faces several constraints, both biophysical and chemical. Key biophysical factors include suboptimal Temperature, uneven rainfall intensity, long dry periods, steep slopes, high erosion levels, surface rock outcrops, and shallow effective soil depth.

Chemical soil constraints also contribute to the limitations of land productivity, including unfavorable soil texture for root systems, low cation exchange capacity (CEC), limited base saturation (BS), and nutrient deficiencies in nitrogen (N), phosphorus (P), and potassium (K).

Most of these constraints can be addressed through technical interventions using land conservation approaches. These efforts include optimizing irrigation systems, planting erosion-controlling vegetation, constructing terraces, intensive soil cultivation, efficient planting hole creation, developing water recharge zones, increasing organic matter content, and applying fertilizer tailored to specific soil needs. However, Temperature remains a permanent limiting factor that requires adaptive strategies, including the selection of agricultural commodities suitable for Letefoho's specific environmental conditions.

In addition to the mentioned commodities, **Table 11.1** presents alternative plant species that are suitable for agricultural development in Letefoho Sub-District.

E. Land Suitability Evaluation for Railaco Sub-District

Railaco Sub-District has potential for developing food crops such as irrigated rice, upland rice, sorghum, maize, cassava, sweet potato, and taro. Horticultural vegetables like carrots, mustard, cabbage, and broccoli can also be developed. Fruit crops like rambutan, mango, and guava are suitable for development. Industrial crops such as rubber, coconut, and oil palm, as well as medicinal plants like jatropha, ginger, and turmeric, are also suitable.

Railaco has significant biophysical potential to support agricultural development. However, its full utilization faces various constraints due to biophysical and soil chemical characteristics. The main biophysical constraints include suboptimal Temperatures, irregular rainfall distribution, long dry periods, steep slopes, high erosion levels, surface rock outcrops, shallow effective soil depth, and inadequate drainage systems with seasonal flood risks.

Soil chemical constraints, such as unfavorable soil texture for root systems, low cation exchange capacity (CEC), limited base saturation (BS), and deficiencies in essential nutrients like nitrogen (N), phosphorus (P), and potassium (K), further limit land productivity.

Most of these constraints can be mitigated through technical interventions and integrated land conservation efforts. Strategies include improving irrigation systems, rehabilitating land by planting erosion-controlling vegetation, constructing terraces, intensive soil cultivation, creating structured planting holes, developing water recharge zones, increasing organic matter content, and applying tailored fertilization.

In addition to the mentioned commodities, **Table 11.1** presents alternative plant species that are suitable for agricultural development in Railaco Sub-District.

Table 7.5 Land Suitability Evaluation Matrix in Ermera District

Commodities	Sub-District	Limiting Factors	Potential Land Suitability
FOOD COMMODITIES			
Irrigated Rice	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope, Erosion **S3:** Effective Depth, Surface Rock, Rock Outcrop **S2:** Temperature, Drainage, Texture, Coarse Fragment, N-total, Available Phosphorus, Available Pottasium	**S2:** Temperature, Texture, Coarse Fragment, Effective Depth, Slope, Erosion **S3:** Surface Rock, Rock Outcrop
Dry Land Food Commodities			
Upland Rice	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope, Erosion, Surface Rock, Rock Outcrop **S3:** Drainage, Texture, Effective Depth, N-total, Available Phosphorus, Available Pottasium **S2:** Temperature, Coarse Fragment	**S2:** Temperature, Texture, Coarse Fragment, Effective Depth, Slope, Erosion **N:** Surface Rock, Rock Outcrop
Peanut	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope **S3:** N-Total, Available Phosphorus, Available Pottasium **S2:** Temperature, Rainfall, Coarse Fragment, Effective Depth, Erosion	**S2:** Temperature, Coarse Fragment, Effective Depth, Slope, Erosion
Sorghum	• Atsabe • Ermera • Hatolia • Letefoho Railaco	**N:** Rainfall, Slope, Erosion **S2:** Temperature, Surface Rock **S3:** Effective Depth, N-total, Rock Outcrop	**S2:** Temperature, Effective Depth, Slope, Erosion, Surface Rock **S3:** Rock Outcrop
Corn	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope, Erosion, Batuan Permukaan, Rock Outcrop **S3:** Drainage, Rainfall, Texture, Effective Depth, N-total, Available Phosphorus, Available Pottasium **S2:** Temperature, Coarse Fragment	**S2:** Temperature, Texture, Coarse Fragment, Effective Depth, Slope, Erosion **N:** Surface Rock, Rock Outcrop

Cassava	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Effective Depth, Slope, Erosion **S2:** Surface Rock **S3:** Available Pottasium, Rock Outcrop	**S2:** Slope, Erosion, Surface Rock **S3:** Effective Depth, Rock Outcrop
Soybean Mung bean Cowpea	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope, Erosion **S2:** Temperature, Coarse Fragment, Surface Rock, Rock Outcrop **S3:** Rainfall, Drainage, Texture, Effective Depth, N-total, Available Phosphorus, Available Pottasium	**S2:** Temperature, Coarse Fragment, Effective Depth, Erosion, Surface Rock, Rock Outcrop
Taro	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope, Erosion **S2:** Temperature, Rainfall, Texture, Coarse Fragment **S3:** Effective Depth, Surface Rock, Rock Outcrop, N-total, Available Phosphorus, Available Pottasium	**S2:** Temperature, Texture, Coarse Fragment, Effective Depth, Slope, Erosion **S3:** Surface Rock, Rock Outcrop
Wheat	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Temperature, Flood **S3:** Rock Outcrop **S2:** Rainfall, Drainage, Lereng, Surface Rock	**N:** Temperature **S3:** Rock Outcrop **S2:** Surface Rock, Flood
Sweet Potato	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Dry Month, Flood **S3:** Rock Outcrop **S2:** Effective Depth, Lereng, Surface Rock	**S3:** Dry Month, Rock Outcrop **S2:** Effective Depth, Surface Rock, Flood
VEGETABLE HORTICULTURA COMMODITIES			
Potatoes Carrot	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope **S2:** Effective Depth, N-total **S3:** Temperature, Erosion, Available Pottasium	**S2:** Effective Depth, Erosion **S3:** Temperature, Slope
Garlic	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Effective Depth **S3:** Coarse Fragment, N-total, Available Pottasium, Surface Rock, Rock Outcrop **N:** Rainfall, Slope, Erosion	**S2:** Temperature, Rainfall, Coarse Fragment, Effective Depth, Erosion **S3:** Slope, Surface Rock, Rock Outcrop
Shallot	• Atsabe • Ermera • Hatolia	**N:** Rainfall, Slope, Erosion **S2:** Texture	**S2:** Rainfall, Texture, Coarse Fragment, Effective Depth, Erosion

	• Letefoho • Railaco	**S3:** Temperature, Coarse Fragment, Effective Depth, N-total, Available Pottasium	**S3**: Temperature, Slope
Chilli	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope, Erosion, Surface Rock, Rock Outcrop **S2:** Coarse Fragment, Effective Depth **S3:** Rainfall, Drainage, Texture, N-total, Available Phosphorus, Available Pottasium	**S2:** Texture, Coarse Fragment, Effective Depth, Erosion **S3:** Slope, Rock Outcrop dan Surface Rock.
Bell Pepper	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Coarse Fragment, Effective Depth **S3:** Rainfall, Drainage, N-total, Available Pottasium **N:** Slope, Erosion	**S2:** Coarse Fragment, Effective Depth, Erosion **S3:** Slope
Caisim	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Effective Depth **S3:** Available Pottasium, Erosion **N:** Rainfall, Slope	**S2:** Temperature, Rainfall, Effective Depth, Slope, Erosion
Green Beans Broccoli	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Coarse Fragment **S3:** Rainfall, Drainage, Texture, Effective Depth, N-total, Available Pottasium **N:** Slope, Erosion, Surface Rock, Rock Outcrop	**S2:** Temperature, Texture, Coarse Fragment, Effective Depth, Erosion **S3:** Slope, Rock Outcrop dan Surface Rock
Snow Pea	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope, Erosion **S2:** Rainfall, Coarse Fragment, Effective Depth **S3:** Temperature, Drainage, N-total, Available Pottasium	**S2:** Coarse Fragment, Effective Depth, Erosion **S3:** Temperature, Slope
Cucumber	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope, Erosion **S2:** Temperature, Coarse Fragment, Effective Depth **S3:** Rainfall, Drainage, N-total, Available Pottasium	**S2:** Temperature, Coarse Fragment, Effective Depth, Erosion **S3:** Slope
Cabbage	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Flood **S3:** Rainfall, Drainage, Lereng, Rock Outcrop	**S2:** Lereng, Rock Outcrop, Temperature, Surface Rock, Texture

		S2: Temperature, Erosi, Surface Rock, Texture, N-total, Available Phosphorus, Available Pottasium, CEC, BS	
Eggplant Bitter melon Tomato Vegetable Long Beans	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Texture, Coarse Fragment **S3:** Drainage, N-total, Available Pottasium **N:** Effective Depth, Slope, Erosion, Surface Rock, Rock Outcrop	**S2:** Temperature, Texture, Coarse Fragment, Erosion **S3:** Effective Depth, Slope, Rock Outcrop, Surface Rock.
FRUIT HORTICULTURA COMMODITIES			
Rambutan Mango	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Effective Depth, Erosion **S3:** Available Pottasium, Slope	**S2:** Temperature, Effective Depth, Slope, Erosion
Guava Jackfruit	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Rainfall, Coarse Fragment **S3:** Temperature, N-total, Available Pottasium, Surface Rock, Rock Outcrop **N:** Effective Depth, Slope, Erosion,	**S2:** Coarse Fragment, Slope, Erosion, Rock Outcrop **S3:** Temperature, Effective Depth, Surface Rock
Water Melon Melon	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Coarse Fragment **S3:** Rainfall, Drainage, Effective Depth, N-total, Available Pottasium **N:** Slope, Erosion	**S2:** Lereng, Flood, Rock Outcrop, Surface Rock
Banana	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Rainfall, Coarse Fragment, Erosion **S3:** Dry Month, Drainage, Effective Depth, N-total, Available Pottasium, Slope	**S2:** Temperature, Dry Month, Coarse Fragment, Effective Depth, Slope, Erosion
Papaya	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope **S2:** Temperature, Rainfall, Coarse Fragment, Erosion, Surface Rock, Rock Outcrop **S3:** Drainage, Effective Depth, N-total, Available Pottasium	**S2:** Temperature, Coarse Fragment, Effective Depth, Slope, Erosion Surface Rock, Rock Outcrop
Orange	• Atsabe • Ermera • Hatolia • Letefoho	**S2:** Coarse Fragment, Erosion	**S2:** Rock Outcrop, Surface Rock, Effective Depth

	• Railaco	**S3:** Dry Month, Drainage, Effective Depth, N-total, Available Pottasium **N:** Slope	
Avocado	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Dry Month **S3:** Rock Outcrop, N-total, Available Phosphorus **S2:** Rainfall, Erosi, Effective Depth, Lereng, Surface Rock, K-tersedia	**S2:** Dry Month, Texture, Coarse Fragment, Effective Depth, Slope, Erosion
Soursop	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Effective Depth, Slope, Erosion **S2:** Temperature, Rainfall, Coarse Fragment, Surface Rock, Rock Outcrop **S3:** Drainage, Texture, N-total, Available Phosphorus, Available Pottasium	**S2:** Temperature, Texture, Coarse Fragment, Erosion, Surface Rock, Rock Outcrop **S3:** Effective Depth, Slope
Breadfruit	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Effective Depth, Slope, Erosion **S2:** Temperature, Rainfall, Surface Rock, Rock Outcrop **S3:** Draianse, Texture, Coarse Fragment, N-total, Available Phosphorus, Available Pottasium	**S2:** Temperature, Texture, Coarse Fragment, Erosion, Surface Rock, Rock Outcrop **S3:** Effective Depth, Slope
Snakefruit	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Rainfall, Erosion **S3:** Effective Depth, Available Pottasium, Slope	**S2:** Effective Depth, Slope, Erosion
Longan	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S3:** Rock Outcrop, N-total, Available Phosphorus **S2:** Temperature, Rainfall, Erosi, Lereng, Effective Depth, Surface Rock, K-tersedia	**S2:** Temperature, Rock Outcrop, Surface Rock, Effective Depth
Durian	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Erosion **S3:** Effective Depth, Available Pottasium, Slope	**S2:** Temperature, Effective Depth, Slope, Erosion
Custrad Apple	• Atsabe • Ermera • Hatolia • Letefoho	**S2:** Rainfall, Erosion **S3:** Effective Depth, Available Pottasium, Slope	**S2:** Effective Depth, Slope, Erosion

	• Railaco		
Pineapple	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Effective Depth, Erosion **S3:** Rainfall, K_2O, Slope	**S2:** Effective Depth, Slope, Erosion
Strawberry	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope, Erosion, Surface Rock, Rock Outcrop **S2:** Temperature, Rainfall, Coarse Fragment, Effective Depth **S3:** Drainage, Texture, N-total, Available Phosphorus, Available Pottasium	**S2:** Temperature, Texture, Coarse Fragment, Effective Depth, Erosion **S3:** Slope
Grapes	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope **S2:** Temperature, Dry Month, Texture, Coarse Fragment, Erosion **S3:** Drainage, Effective Depth, N-total, Available Pottasium	**S2:** Temperature, Dry Month, Texture, Coarse Fragment, Effective Depth, Slope, Erosion
Passion Fruit	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Dry Month, Effective Depth, Slope, Erosion, Surface Rock, Rock Outcrop **S2:** Rainfall, Texture, Coarse Fragment **S3:** Temperature, Drainage, N-total, Available Phosphorus, Available Pottasium	**S2:** Texture, Coarse Fragment, Slope, Erosion **S3:** Temperature, Dry Month, Effective Depth, Surface Rock, Rock Outcrop
ORNAMENTAL FLOWER HORTICULTURAL COMMODITIES			
Rose **Aster**	• Atsabe • Hatolia • Railaco	**S2:** Rainfall, N-total, Available Pottasium Surface Rock, Rock Outcrop **S3:** Effective Depth, Available Phosphorus **N:** Coarse Fragment, Slope, Erosion	**S2:** Effective Depth, Slope, Erosion, Surface Rock, Rock Outcrop **S3:** Coarse Fragment
Sunflower	• Atsabe • Hatolia • Railaco	**N:** Coarse Fragment, Slope, Erosion **S3:** Rainfall, Effective Depth, Available Phosphorus **S2:** CEC, SOC, Surface Rock, Rock Outcrop	**S2:** Coarse Fragment, Slope, Erosion, Rainfall, Effective Depth, Surface Rock, Rock Outcrop

SPICE AND MEDICINAL PLANT COMMODITIES			
Ginger	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope **S2:** Rainfall, Dry Month, BS, N-total **S3:** Temperature, Effective Depth, Available Pottasium, Erosion	**S2:** Dry Month, Effective Depth, Slope, Erosion **S3:** Temperature
Vetiver Root	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope, Erosion **S2:** Temperature, BS, N-total **S3:** Dry Month, Coarse Fragment, Effective Depth, N-total, Available Phosphorus, Available Pottasium, Slope, Surface Rock, Rock Outcrop	**S2:** Temperature, Coarse Fragment, Effective Depth, Slope, Erosion **S3:** Dry Month, Surface Rock, Rock Outcrop
Lemongrass	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Rainfall, Coarse Fragment, Effective Depth, BS, N-total **S3:** pH, Available Pottasium Slope, Erosion **N:** Rainfall, Dry Month	**N:** Dry Month **S2:** Temperature, Coarse Fragment, Effective Depth, Slope, Erosion
Vanilla	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope, Erosion **S3:** Rainfall, Coarse Fragment, Effective Depth, N-total, Available Phosphorus, Available Pottasium, Surface Rock, Rock Outcrop	**S2:** Coarse Fragment, Effective Depth, Slope, Erosion **S3:** Surface Rock, Rock Outcrop
Cinnamon	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Dry Month **S2:** Temperature, Rainfall, Coarse Fragment, Effective Depth, BS, N-total **S3:** pH, Available Pottasium, Slope, Erosion	**S2:** Temperature, Coarse Fragment, Effective Depth, Slope, Erosion **N:** Dry Month
Nutmeg	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, BS, N-total, Erosion **S3:** Effective Depth, Available Pottasium, Slope **N:** Dry Month	**S2:** Temperature, Effective Depth, Slope, Erosion **S3:** Dry Month
Pepper	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Effective Depth, BS, N-total, Erosion **S3:** Dry Month, Available Pottasium, Slope	**S2:** Temperature, Dry Month, Slope, Erosion

Jatropha	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Rainfall, Slope **S2:** Temperature, Coarse Fragment, Effective Depth, BS, N-total **S3:** pH, Available Pottasium, Erosion	**S2:** Temperature, Rainfall, Coarse Fragment, Effective Depth, Slope, Erosion
Aromatic Ginger	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope **S2:** Rainfall, BS, N-total **S3:** Effective Depth, Available Pottasium, Erosion	**S2:** Effective Depth, Slope, Erosion
Tumeric	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Rainfall, Texture, Coarse Fragment, CEC, BS **S3:** Drainage, Effective Depth, N-total, Available Pottasium, Rock Outcrop **N:** Slope, Erosion, Surface Rock	**S2:** Temperature, Texture, Coarse Fragment, Effective Depth, Slope, Erosion **S3:** Rock Outcrop, Surface Rock
Galangal	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Rainfall, BS, N-total **S3:** Effective Depth, Available Pottasium, Erosion **N:** Slope	**S2:** Temperature, Lereng, Effective Depth, Surface Rock Rock Outcrop, Flood
Cardamom	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Slope **S2:** Rainfall, BS, N-total **S3:** Effective Depth, Available Pottasium, Erosion	**S2:** Effective Depth, Slope, Erosion **S3:** Dry Month
INDUSTRIAL COMMODITIES			
Rubber	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Dry Month **S2:** Rainfall, Texture, Erosion **S3:** Temperature, Effective Depth, BS, Available Pottasium, Slope	**S2:** Texture, Effective Depth, Slope, Erosion **S3:** Temperature, Dry Month
Coconut	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Dry Month, Effective Depth, Slope, Erosion, Surface Rock, Rock Outcrop **S2:** Temperature, Rainfall **S3:** Drainage, Coarse Fragment N-total, Available Pottasium	**S2:** Temperature, Coarse Fragment, Slope, Erosion **S3:** Dry Month, Effective Depth **N:** Surface Rock, Rock Outcrop

Oil Palm	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**N:** Dry Month, Effective Depth, Slope, Erosion, Surface Rock, Rock Outcrop **S2:** Temperature **S3:** Drainage, Coarse Fragment N-total, Available Phosphorus, Available Pottasium	**S2:** Temperature, Coarse Fragment, Slope, Erosion **S3:** Dry Month, Effective Depth, Surface Rock, Rock Outcrop
Arabica Coffee	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Dry Month, Erosion **S3:** Temperature, Rainfall, Effective Depth, Available Pottasium, Slope	**S2:** Dry Month, Effective Depth, Slope, Erosion **S3:** Temperature
Robusta Coffe	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Dry Month, Texture, Erosion **S3:** Effective Depth, Available Pottasium, Slope	**S2:** Dry Month, Texture, Effective Depth, Slope, Erosion
Cacao Clove	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Texture, Erosion **S3:** Effective Depth, Available Pottasium, Slope **N:** Dry Month	**S2:** Temperature, Texture, Effective Depth, Slope, Erosion **S3:** Dry Month
Tea	• Atsabe • Ermera • Hatolia • Letefoho • Railaco	**S2:** Temperature, Rainfall, Texture, Erosion **S3:** Effective Depth, N-total, Available Pottasium, Slope **N:** Dry Month	**S2:** Temperature, Texture, Effective Depth, Slope, Erosion **S3:** Dry Month
Tobacco	• Atsabe • Ermera • Hatolia • Railaco	**N:** Slope, Erosion **S2:** Coarse Fragment, Effective Depth **S3:** Rainfall, N-total, Available Pottasium	**S2:** Coarse Fragment, Effective Depth, Slope, Erosion
Sugarcane	• Ermera • Railaco	**S2:** Temperature, N-total **S3:** Rainfall, Effective Depth, Available Pottasium, Erosion **N:** Slope	**S2:** Temperature, Effective Depth, Slope, Erosion
Melinjo	• Atsabe • Ermera • Hatolia • Railaco	**N:** Dry Month, Effective Depth, Surface Rock, Rock Outcrop **S2:** Temperature, Texture, Coarse Fragment	**S2:** Temperature, Texture, Coarse Fragment, Slope, Erosion **S3:** Dry Month, Effective Depth

		S3: Drainage, N-total, P_2O_5, Available Pottasium, Slope, Erosion	
Cotton	• Ermera • Railaco	**N:** Slope **S2:** Temperature, Coarse Fragment, Effective Depth **S3:** Rainfall, BS, Available Pottasium, Erosion	**S2:** Temperature, Coarse Fragment, Effective Depth, Slope, Erosion
Kapok	• Ermera • Hatolia • Railaco	**S3:** Rainfall, Effective Depth, K2O, Slope, Erosion **S2:** Temperature, Coarse Fragment	**S2:** Temperature, Coarse Fragment, Effective Depth, Slope, Erosion
Quinine	• Ermera • Hatolia • Railaco	**S2:** Temperature, Rainfall, Texture, Erosion **S3:** Effective Depth, Available Pottasium, Slope	**S2:** Temperature, Effective Depth, Slope, Erosion
GRAZING AREA AND LIVESTOCK FEED			
Grazing	• Ermera	**N:** Slope, Erosion **S3:** Temperature, Dry Month	

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

VIII. FOREST POTENTIAL

8.1 LAND SUITABILITY ASSESSMENT RESULTS

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

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

Subsequently, the data obtained are analyzed based on the growth requirements of each plant species under actual conditions, as well as potential suitability after the implementation of various land improvement measures, such as fertilization, addition of organic matter, or the application of soil conservation techniques. This process yields comprehensive information to determine priority commodities for development, identify limiting factors, and design relevant technical solutions.

This scientific approach forms the basis of land suitability evaluation in Ermera District. The results of this analysis provide strategic guiandce for maximizing land productivity while maintaining the sustainability of natural resources in each area.

In Table 8.1, the results of the land suitability evaluation show that several crop commodities are placed in the same column, indicating that these crops have similar growth requirements and limiting factors. Crops placed in different columns have distinct growth requirements and limiting factors and therefore require management approaches tailored to the needs of each commodity.

A. Land Suitability Evaluation for Hatolia Sub-District

Forestry commodity development in Hatolia Sub-District shows promising potential, particularly for species such as Agathis, Albizia, Eucalyptus, Melaleuca, and Pine, which are classified as moderately suitable (S2), and Sandalwood, which is classified as marginally suitable (S3) under the local biophysical conditions. Although the land faces constraints such as limited soil depth, rock outcrops, and surface rock, management can still be carried out through appropriate forestry technical measures.

High-value timber species such as Teak and Mahogany also have development potential. By contrast, Altingia is not recommended for development because of permanent temperaturee limitations that cannot be resolved through technical interventions. Nevertheless, in general the area retains considerable opportunities for forestry development, especially if suitable species are selected and appropriate land conservation techniques are applied. **Table 8.1** provides a list of alternative species with development potential, while **Table 11.1** presents recommendations for forestry development in Hatolia Sub-District as part of a strategy for diversification and optimal land use.

B. Land Suitability Evaluation for Railaco Sub-District

Forestry development in Railaco Sub-District also has good prospects, with species such as Agathis, Albizia, Eucalyptus, Melaleuca, and Pine classified as moderately suitable (S2), and Sandalwood as marginally suitable (S3) under the local biophysical conditions. Although the land faces constraints such as limited soil depth, rock outcrops, surface rock, and soil texture, management can still be carried out through forestry technical approaches.

High-value timber species such as Teak and Mahogany also have potential for development, whereas Altingia is not recommended because of permanent temperaturee limitations that cannot be addressed technically. Nevertheless, overall, the area still has good opportunities for forestry development, particularly if appropriate species are selected and suitable land conservation techniques are implemented. **Table 8.1** provides a list of alternative species with development potential, while **Table 11.1** presents recommendations for forestry development in Railaco Sub-District as part of a strategy for diversification and optimal land use.

The areas of Atsabe, Ermera, and Letefoho Sub-Districts have significant ecological constraints for forestry commodity development. One of the main limiting factors is the relatively constant temperature regime, which lies outside the optimal range for forest vegetation growth. The low and stable temperatures throughout the year do not provide adequate support for plant physiological processes such as photosynthesis and biomass formation, resulting in low productivity.

One of the main limiting factors is the relatively constant temperature regime, which lies outside the optimal range for forest vegetation growth. The low and stable temperatures throughout the year do not provide adequate support for plant physiological processes such as photosynthesis and biomass formation, resulting in low productivity.

The absence of temperature fluctuations needed to stimulate plant life cycles also limits the successful adaptation of commonly cultivated forestry species. Although land in these areas is relatively extensive and topographically suitable for cultivation activities, the unfavorable microclimatic characteristics reduce the effectiveness of forestry sector development.

Table 8.1 Land Suitability Evaluation Matrix in Ermera District

Commodity	Sub-District	Limiting Factor	Potential Land Suitability
Teak	• Hatolia • Railaco	**N:** Effective Depth, Slope, Erosion **S3:** Rainfall, Coarse Fragment, N total, Available Pottasium **S2:** Temperature, Surface Rock, Rock Outcrop	**S2:** Temperature, Rock Outcrop, Surface Rock, Slope, Coarse Fragment
Mahogany	• Hatolia • Railaco	**N:** Effective Depth, Slope, Erosion **S3:** N-total, Available Pottasium, Dry Month, Drainage **S2:** Temperature, Surface Rock, Rock Outcrop and Texture	**S2:** Temperature, Effective Depth, Surface Rock, Rock Outcrop, Texture, Slope, Erosion
Agathis	• Hatolia • Railaco	**N:** Effective Depth, Erosion, and Slope **S3:** N-total, Available Pottasium, Dry Month	**S2:** Temperature, Surface Rock, Rock Outcrop, Erosion, and Slope.

		S2: Temperature, Surface Rock, Rock Outcrop	
Altingia	• Railaco • Hatolia	**N:** Temperature, Effective Depth, Slope, Erosion **S3:** Dry Month, N-total, Available Pottasium, Rock Outcrop **S2:** Rainfall, Surface Rock	**N:** Temperature **S2:** Dry Month, Effective Depth, Slope, Rock Outcrop, Surface Rock
Albizia	• Railaco • Hatolia	**N:** Effective Depth, Slope, Erosion **S3**: N-total, Available Pottasium **S2:** Surface Rock, Rock Outcrop, and Dry Month	**S2:** Surface Rock, Rock Outcrop, Dry Month, Erosion **S3:** Effective Depth
Acacia	• Railaco • Hatolia	**N:** Slope, Erosion **S3:** Effective Depth, N-total, Available Pottasium **S2:** Dry Month, Texture, Temperature, Surface Rock, Rock Outcrop	**S2:** Slope, Erosion, Effective Depth, Dry Month, Texture, Temperature, Surface Rock, Rock Outcrop
Leucaena	• Railaco • Hatolia	**S3:** Slope, Erosion, Effective Depth, N-total, N-total, Available Pottasium **S2**: Dry Month, Surface Rock, Rock Outcrop, Rainfall, CEC, BS	**S2:** Slope, Effective Depth, Dry Month, Surface Rock, Rock Outcrop
Eucalyptus	• Railaco • Hatolia	**S3:** Dry Month, Effective Depth, N-total, Available Pottasium, Slope, Erosion **S2:** Texture, Surface Rock, Rock Outcrop	**S2:** Dry Month, Effective Depth, Slope, Erosion, Texture, Surface Rock, Rock Outcrop.
Melaleuca	• Railaco • Hatolia	**N:** Effective Depth, Slope, Erosion **S3:** Drainage, N-total, Available Pottasium **S2:** Rainfall, Dry Month, Surface Rock, Rock Outcrop	**S2:** Slope, Erosion, Dry Month, batuan and Rock Outcrop **S3:** Effective Depth
Pine	• Railaco • Hatolia	**N:** Rainfall, Slope, Erosion **S3:** Effective Depth, N-total, Available Pottasium **S2:** Dry Month, Texture, Surface Rock, Rock Outcrop	**S2:** Effective Depth, Texture, Slope, Erosion, Rock Outcrop, Surface Rock, Dry Month

Sandalwood	• Railaco • Hatolia	**N:** Rock Outcrop **S3:** Lereng, Surface Rock, N-total, Available Phosphorus, Available Pottasium **S2:** Coarse Fragment, Lereng, C-organik	**S3:** Rock Outcrop **S2:** Surface Rock, Coarse Fragment

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

8.2 LAND IMPROVEMENT MEASURES

Agricultural productivity and sustainability in Ermera District depend heavily on properly and integratively addressing land limiting factors. Although the land faces constraints such as limited soil depth, rock outcrops, and surface rock, management can still be implemented through forestry technical approaches. Improvement efforts include the application of intensive silvicultural techniques, such as making deep planting holes filled with organic matter to improve soil structure and expand the rooting zone, as well as clearing surface rock and breaking rocks to support root growth.

In addition to physical constraints, soil chemical properties also show significant limitations. Soil organic carbon content is low, which weakens soil structure and reduces microbial activity. Key nutrients such as nitrogen, phosphorus, and potassium are also at levels that are insufficient to support vegetative growth. Therefore, improving soil fertility through the addition of organic matter and balanced fertilization is a strategic measure to increase production capacity and support the cultivation of forestry commodities that are adapted to marginal conditions.

Although many of the constraints are permanent, land management can still be carried out through adaptive approaches based on local biophysical characteristics. Strategies that can be implemented include erosion control, selection of planting sites at appropriate elevations, planting under shade stands to reduce thermal stress, and the use of improved varieties that are more tolerant of extreme temperatures. This integrated approach enables sustainable optimization of land functions, supports vegetation rehabilitation, and strengthens ecological functions of the area, such as runoff control, increased water infiltration, and biodiversity conservation. Thus, marginal land in Ermera District still has strategic value for the development of conservation- and adaptation-based forestry.

8.3 FORESTRY PLANT DEVELOPMENT ZONING

Ermera District has development potential distributed across several main land categories, namely irrigated rice fields covering 0.04 km² (0.01 %), rainfed rice fields 72.89 km² (9.49 %), grazing areas 2.18 km² (0.28 %), dryland agriculture or mixed gardens 197.35 km² (25.69 %), agroforestry 431.94 km² (56.22 %), and protected and conservation forest covering 63.91 km² (8.32 %).

A. Agroforestry

Agroforestry zoning in Ermera District is the most extensive, covering 431.94 km² (56.22 %) of the total area, located at elevations of 500 to 1,000 m asl with slope gradients of 25 to 45 %. The main distribution is in Hatolia Sub-District (16.39 %), which has the largest potential, followed by Atsabe (12.63 %), Letefoho (12.51 %), and Railaco (9.62 %). The agroforestry systems in this area combine agricultural crops such as coffee, cacao, and peanuts and tobacco (30 to 40 %) with forestry species such as Teak, Albizia, Mahogany, and other conservation trees (60 to 70 %). In addition to supporting food security, this system provides ecological benefits such as carbon sequestration, soil conservation, and reduced erosion risk. Agroforestry also allows integration with small-scale livestock production to diversify the incomes of local communities.

One of the flagship commodities in Ermera District is coffee, with Letefoho Sub-District as one of the main producing areas. This region is widely known for producing high-quality organic Arabica coffee grown in highland areas with ideal agroclimatic conditions, including cool temperaturees, fertile soils, and adequate rainfall. Arabica coffee from Letefoho has a complex flavor profile, with bright acidity, floral aroma, and notes of red fruits at light roast levels. At medium to dark roast levels, its flavor becomes more intense, with chocolate nuances and a full body. The most commonly used processing method is the natural process, in which coffee cherries are dried with the skin intact before the beans are separated, resulting in a bold and layered flavor profile. In addition to its superior quality, Letefoho coffee is grown sustainably by local farming communities without the use of synthetic chemicals, thereby providing economic value while also supporting environmental conservation and community empowerment.

Figure 8.1 Application of Agroforesty System and Coffe Development in Covalima District (Documentation Researcher, 2024)

B. Protected Forests

Protected forests and conservation areas cover 63.91 km² (8.32%) of the total area of Ermera District. Located at elevations above 1,000 m asl with slopes greater than 45%, these areas are situated within agro-climatic Zone C, which experiences a wet season lasting 6 to 7 months. The distribution of this zoning is most extensive in Hatolia Sub-District (3.13%), followed by Atsabe (2.89%), Railaco (1.01%), Ermera (0.72%), and Letefoho (0.57%). The main focus of management in this area is soil and water conservation, biodiversity preservation, and the mitigation of land degradation and erosion. Reforestation and ecosystem restoration programs are prioritized to maintain environmental stability and water resources. This zonal-based approach provides an integrated framework for scientific and sustainable land management in Timor-Leste, supporting national food security, environmental protection, and community well-being.

Protected forests play a vital role in maintaining ecosystem balance, especially in mountainous regions that are vulnerable to erosion, land degradation, and climate change. In Timor-Leste, protected areas not only serve as habitats for biodiversity but also act as water catchment areas, carbon sinks, and living spaces that hold high social and cultural value. According to available data, Ermera District has three protected forest areas, one of which is the AP Monte Tatamailau, the largest protected area, covering around 4,144.60 ha as shown in **Figure 8.2.** This area is significantly larger than the AP Monte Talobu/Laumeta, which spans 1,693.85 ha, and the Lagoa Tasitolu Protected Area, which covers only about 0.39 ha.

The presence of forests in Monte Tatamailau serves a highly strategic ecological function, such as being a habitat for endemic flora and fauna, a water catchment area that supplies the local population's needs, and a carbon sink that aids in mitigating climate change. Additionally, this forest is crucial in protecting soil from erosion and landslides, and it holds significant social and cultural value as Monte Tatamailau (Ramelau) is considered a sacred mountain and a symbol of national identity for the people of Timor-Leste.

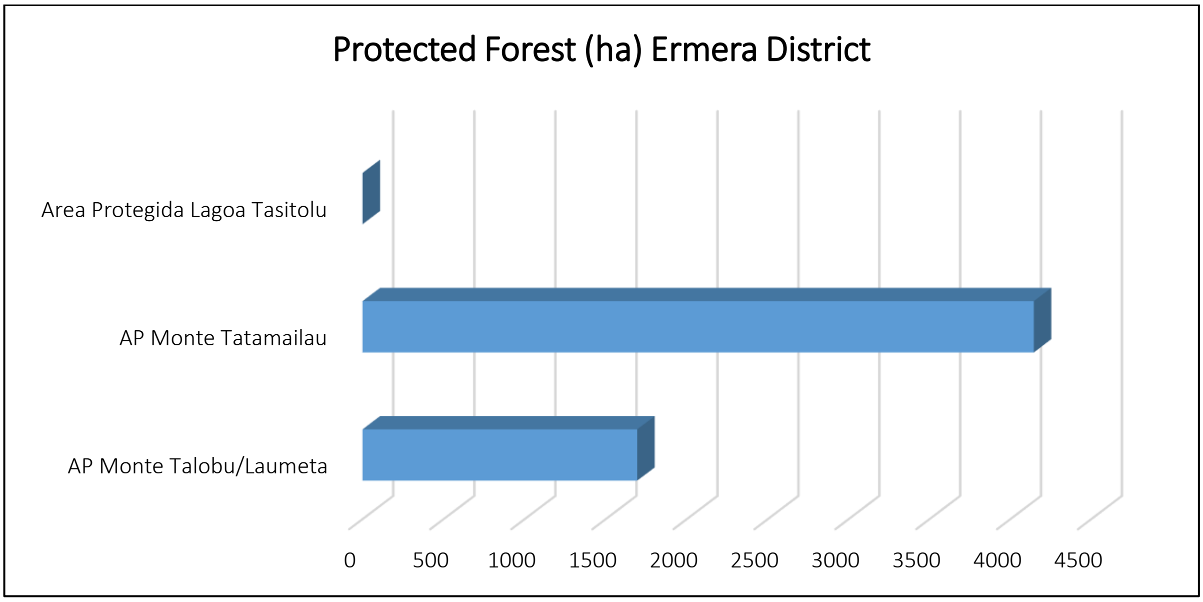


Figure 8.2 Protected Forest Area in Ermera District

8.4 POTENTIAL FOR SANDALWOOD DEVELOPMENT

The land suitability evaluation results show that the potential for sandalwood development in Ermera District falls under the S3 (marginally suitable) class. This means that land is still suitable for sandalwood cultivation; however, there are biophysical constraints that require technical intervention. Recommended actions include selecting appropriate planting locations, maintaining host trees to support growth, and applying adaptive silvicultural techniques. With proper management based on conservation principles, these limitations will not hinder sandalwood from becoming a regional flagship commodity.

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 security. This program aims to document the number, distribution, and condition of sandalwood trees in various regions, including Aileu, as a basis for data-driven development planning. With government policy support, high economic value, and a broad market potential, the development of sandalwood in Ermera holds significant prospects. If managed sustainably, sandalwood can not only become a source of income for local communities but also serve as a symbol of cultural identity and the success of local natural resource conservation efforts.

IX. LIVESTOCK POTENTIAL

9.1 INTRODUCTION

Timor-Leste is a country whose territory consists largely of mountains and highlands. Administratively, the territory of Timor-Leste is divided into 14 Districts, namely Ainaro District, Aileu District, Autoridade Administrativa Ataúro, Bobonaro District, Baucau District, Covalima District, Dili District, Ermera District, Lautém District, Liquiçá District, Manufahi District, Manatuto District, Região Administrativa Especial Oe-Cusse Ambeno (RAEOA), and Viqueque District. The country has two seasons, namely a dry season that extends from June to November and a rainy season that occurs from December to May. The topography, which is dominated by hilly areas, together with its proximity to the Australian continent, causes Timor-Leste to be influenced by dry easterly monsoon winds. As a result, parts of the territory tend to experience drought. In addition, low rainfall also limits vegetation growth in many areas of the country.

The hilly topography and low rainfall not only affect vegetation growth and agricultural activities but also constrain the availability of forage for the livestock sector. Development of the livestock sector is highly dependent on the potential of land resources, the appropriateness of land use, and the methods of land management. These factors are crucial for the provision of forage feed for livestock, which generally consists of grasses and legumes.

Forage feed can originate from natural sources or from cultivated sources, including grazing lands (Priyanto, 2016). Optimal use of livestock land is strongly influenced by anthropogenic factors and the biophysical conditions of the land. Therefore, the adoption of technological and institutional innovations is needed to ensure that land resources can be used effectively and optimally (Suryana and Rahman, 2006).

In general, the livestock sector in Timor-Leste faces various constraints. One of the main causes is that livestock management systems remain traditional and extensive, so production has not yet reached its optimal potential. Low levels of awareness, knowledge, and technological capacity among farmers also hinder development, particularly in meeting forage feed requirements in terms of both type and quality. Livestock are generally kept as household savings that can be sold at any time to meet emergency needs. In addition, some communities still use livestock as draft power for land cultivation under traditional management systems.

The success of livestock production depends on three main factors, namely breeding stock, feed, and management (Aman *et al*., 2019). These three factors form an integrated system: if one of them is neglected or receives insufficient attention, then even very good handling of the other factors will not yield optimal output. Livestock productivity, particularly that of ruminants, is highly dependent on effective feed management in terms of quantity, quality, and its continuous availability (Rokhayati and Evadewi, 2023). According to Winarni and Sukaesih (2015), feed plays an important role in supporting livestock development because it directly affects animal production, productivity, and health. The quality of forage feed itself is influenced by the forage variety, genotype, maturity at harvest, season, and the management practices applied (Adesogan *et al*., 2015).

One of the initial steps that can be taken to develop the livestock sector in Timor-Leste is to optimize land use for the sustainable provision of forage feed. To achieve this, land characteristics must be matched with the types of forage feed to be cultivated. Therefore, land suitability evaluation is an essential approach for assessing the potential and carrying capacity of land resources (Harahap *et al*., 2019). This evaluation not only assesses land potential but also determines its level of suitability for various types of use under specified management levels (Nugroho *et al*., 2014). Land suitability evaluation requires environmental data and soil quality data for a given area. The evaluation is conducted by identifying various land characteristics, such as topography, climate, soil conditions and soil quality, and other physical environmental properties (Iswan *et al*., 2019). Through this evaluation process, information is obtained on biophysical land resources, including climate and soil, so that land suitability classes can be determined and limiting factors that need to be improved can be identified (Jawang *et al*., 2018).

9.2 RESEARCH METHOD

The research was conducted using a survey method and descriptive analysis in a purposively selected study area, namely the KTS Center *(Karau Timor Susubeen)* and the recommended livestock land. The types of data collected comprised quantitative and qualitative data derived from primary and secondary sources. Primary data included interview data on livestock production and socio-economic conditions, as well as observations of land biophysical conditions and soil characteristics for forage feed land suitability. The biophysical and soil properties were further analyzed according to standard laboratory procedures. The secondary data used were obtained from the 2019 Timor-Leste Agricultural Census.

The interview data obtained were analyzed using simple tabulation based on the Miles and Herberman analytical model, which includes data reduction, data display, conclusion drawing, and verification. The land biophysical data and soil characteristics were analyzed and presented using a Geographic Information System (GIS) approach with GIS software, involving several procedures 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 carried out through interview techniques using parameters such as livestock species, livestock population, land area, husbandry/housing system, feed and nutrition management system, water sources, mating/breeding system, animal health system/management, livestock products, marketing, infrastructure, farmer characteristics, and customary practices/traditions.

2. Land Suitability for Forage Feed

The research procedures for land suitability for forage feed have been described in **Chapter III (Methods).**

9.3 GENERAL OVERVIEW

The livestock sector plays an important role in supporting the livelihoods of many households in Ermera District. The distribution of households engaged in livestock farming differs substantially among Sub-Districts. Atsabe Sub-District has the largest number of households involved in the livestock sector, reaching 93 households (29.90 %). Conversely, Letefoho Sub-District has the fewest households engaged in the livestock sector, namely 25 households (8.04 %).

The livestock sector plays an important role in supporting the livelihoods of many households in Ermera District. The distribution of the number of households engaged in livestock farming shows considerable variation across

Sub-Districts. Atsabe Sub-District has the largest number of households engaged in the livestock sector, with 93 households (29.90 %). By contrast, Letefoho Sub-District has the fewest households engaged in the livestock sector, namely 25 households (8.04 %).

Nevertheless, their contribution remains important in meeting local needs and maintaining the livestock-keeping traditions that have long been part of the local community's way of life. Given these differences, each Sub-District has its own contribution to the sustainability of the livestock sector in Ermera District. The number of agricultural households engaged in the livestock sector is presented in **Figure 9.1.**

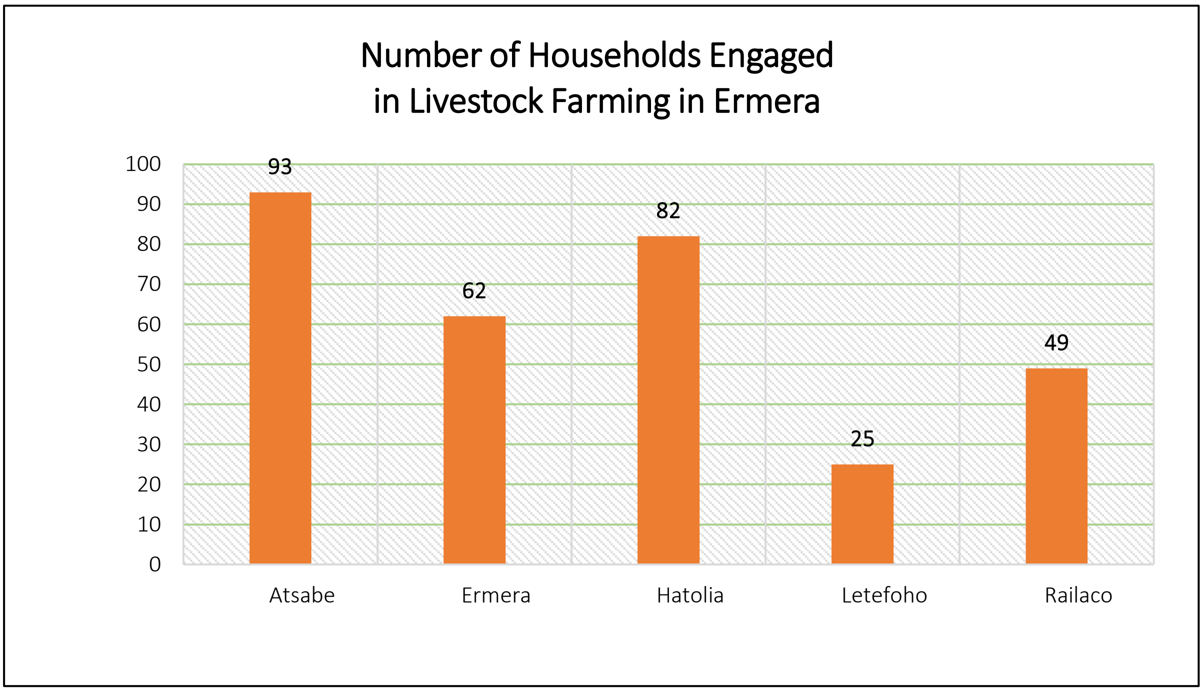


Figure 9.1 Number of Households Engaged in Livestock Activities
(Source: Timor-Leste Agriculture Census, 2019)

Figure 9.2 and **Figure 9.3** show that cattle are the predominant type of large livestock raised in Ermera District. Hatolia Sub-District has the largest number of households raising cattle, reaching 2,692 households (36%) with a total cattle population of 8,333 head. By contrast, Railaco Sub-District has the fewest cattle-raising households, with 623 households (8%) and a total of 1,550 head.

For horses as large livestock, Letefoho Sub-District has the highest number of households keeping horses, namely 336 households (39%) with a population of 521 head. Conversely, Railaco Sub-District has the lowest number of horsekeeping households, with a total of 47 households (5%) and a population of 63 head.

For buffalo as large livestock, Hatolia Sub-District shows dominance in buffalo husbandry, with 513 households (55 %) and a population of 1,956 head. Conversely, Railaco Sub-District has the lowest number of buffalo-raising households, with 28 households (3%) and a total of 65 head. Dairy cattle in Ermera District are kept by all households, although their numbers remain very limited. Atsabe Sub-District records the highest number of households keeping dairy cattle, namely 7 households (44%).

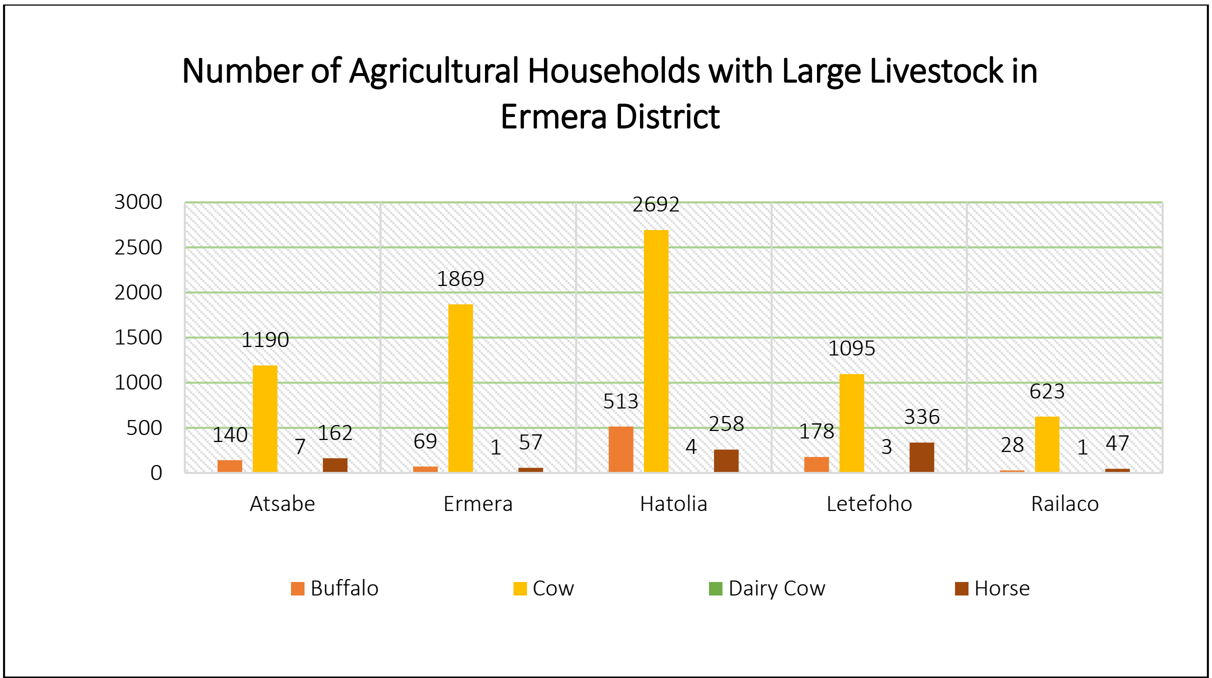


Figure 9.2 Number of Households with Large Livestock
(Source: Timor-Leste Agriculture Census, 2019)

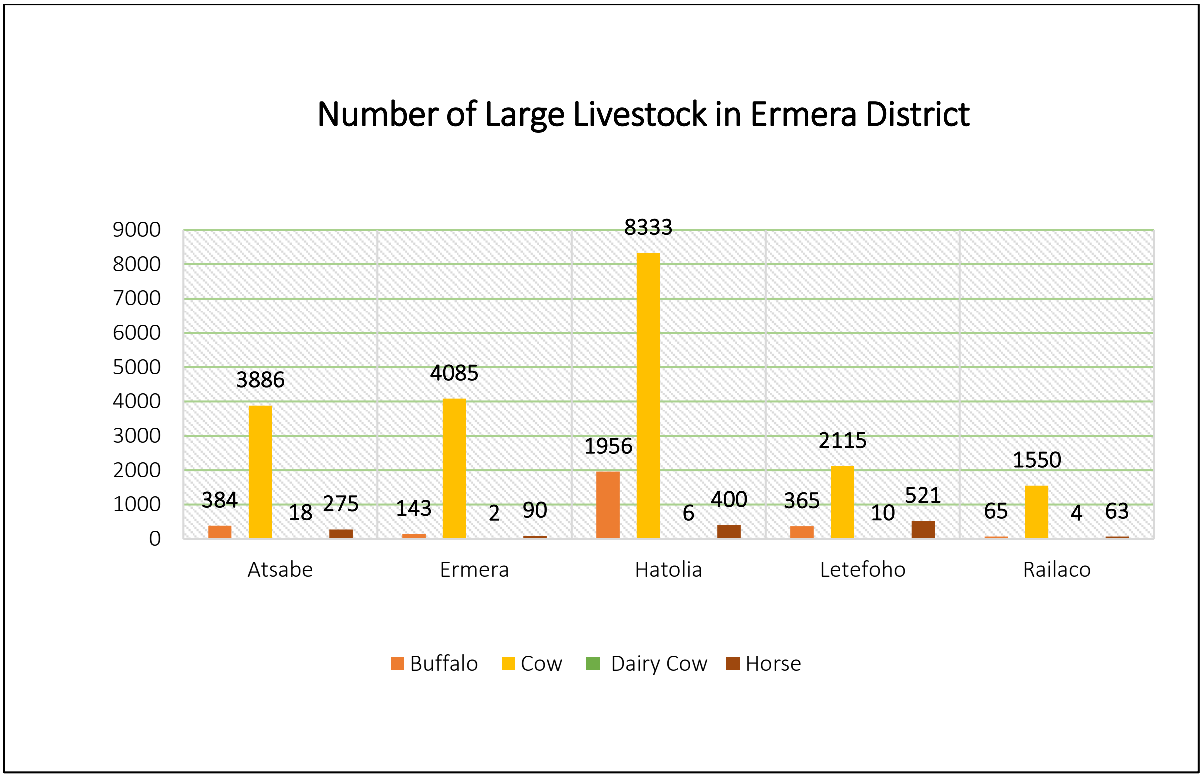


Figure 9.3 Number of Large Livestock
(Source: Timor-Leste Agriculture Census, 2019)

Ermera District has pigs as the predominant type of small livestock raised. Hatolia Sub-District has the largest number of pig-keeping households, namely 3,936 households (32%) with a total of 12,289 head, while Railaco Sub-District has the lowest number, with 944 households (8%) and 3,206 head **(Figures 9.4 and 9.5).**

The number of households keeping goats shows a variable distribution. Hatolia Sub-District has the highest number of goat-keeping households, reaching 1,826 households (44%) with a population of 5,066 head, whereas Railaco Sub-District has the fewest goat-keeping households, namely 359 households (9%) with a total of 981 head.

Sheep are raised by some households in Ermera District, although in limited numbers. Ermera Sub-District records the highest number of sheep-keeping households, namely 65 households (35 %), while the lowest number is recorded in Railaco Sub-District, with only 6 households (3%).

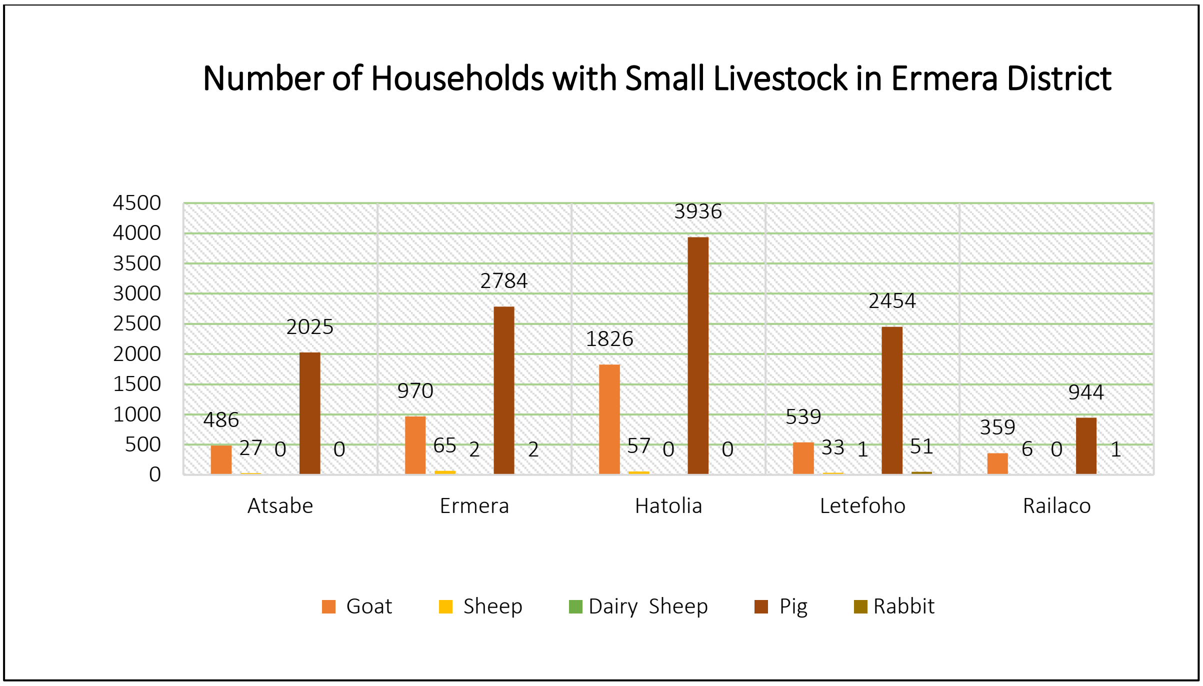


Figure 9.4 Number of Households with Small Livestock
(Source: Timor-Leste Agriculture Census, 2019)

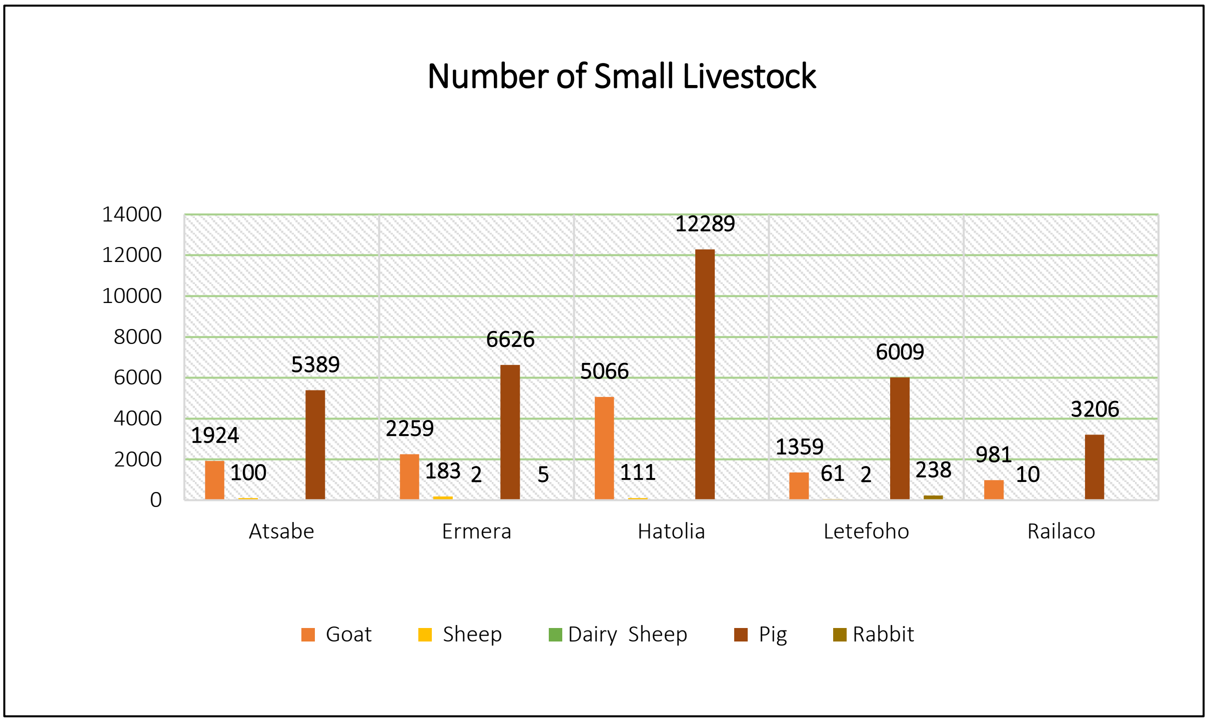


Figure 9.5 Number of Small Livestock
(Spurce: Timor-Leste Agriculture Census, 2019)

The number of households keeping poultry in Ermera District shows significant differences among Sub-Districts, with chickens being the most widely raised poultry species **(Figure 9.6).** Hatolia Sub-District has the largest number of chicken-keeping households, namely 4,413 households (34%), with a total of

43,938 birds. Meanwhile, Railaco Sub-District has the fewest chicken-keeping households, with 1,037 households (8 %) and a total of 10,887 birds. These data are presented in **Figures 9.6 and 9.7.**

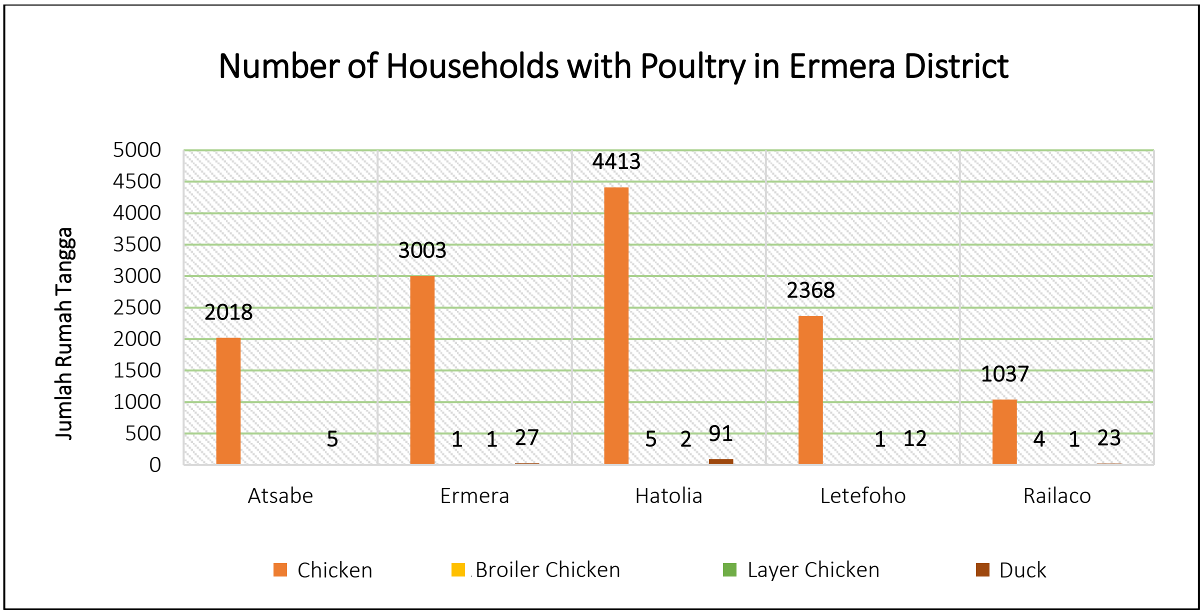


Figure 9.6 Number of Households with Poultry
(Source: Timor-Leste Agriculture Census, 2019)

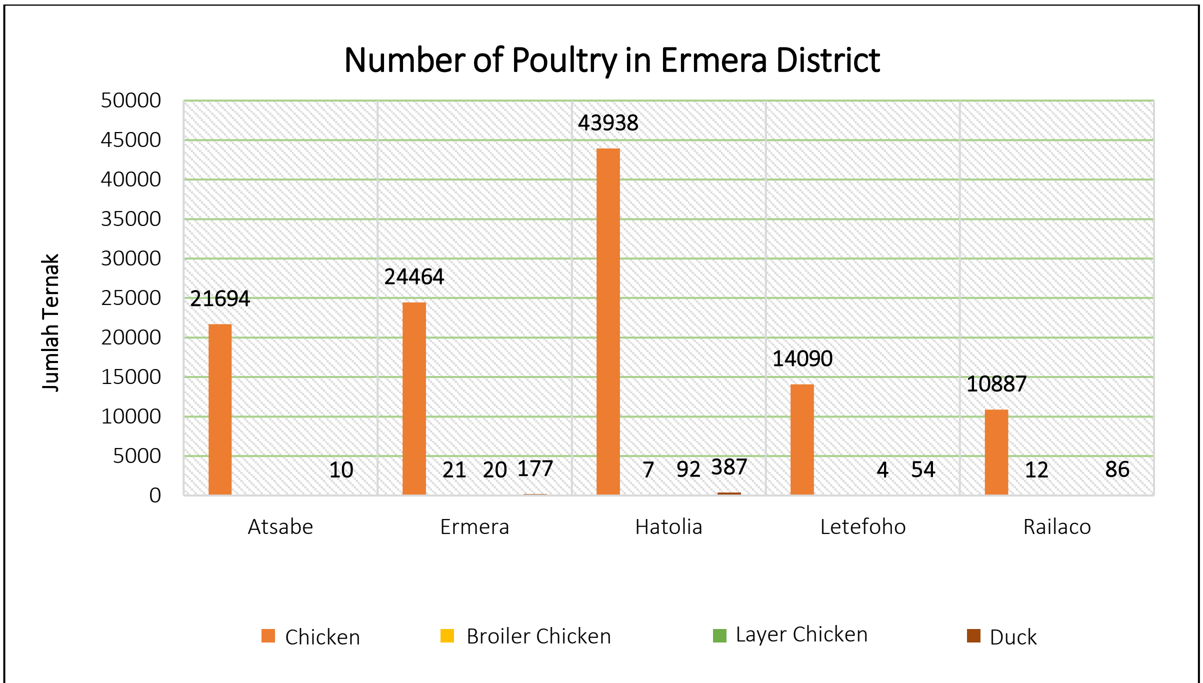


Figure 9.7 Number of Poultry
(Source: Timor-Leste Agriculture Census, 2019)

The potential of grazing lands is one of the key assets that can serve as a primary source of feed for livestock, especially for animals such as cattle, goats, and sheep that require high-quality grasses to support growth and production in a sustainable livestock sector. Ermera District has two types of grazing lands, namely temporary and permanent grazing lands.

Atsabe Sub-District has the largest grazing area in the District, both permanent and temporary. The area of permanent grazing land reaches 133.66 ha (68.60 %), while the area of temporary grazing land is recorded at 69.35 ha (60.07 %). The presence of these lands indicates substantial potential to support sustainable livestock activities, particularly in providing natural feed sources for livestock. Based on these data, Atsabe Sub-District has a significant advantage in terms of grazing land area, making it the Sub-District with the largest grassland dominance compared with other Sub-Districts. Ermera Sub-District has the smallest grazing area in the District, both for temporary and permanent grazing lands. The area of temporary grazing land is only 1.69 ha (1.46 %), while permanent grazing land covers 3.60 ha (1.85 %). Despite their limited extent, these lands still have the potential to support efficient livestock activities, particularly through optimized land use and the application of sustainable management practices. The area of grazing land is presented in **Figure 9.8.**

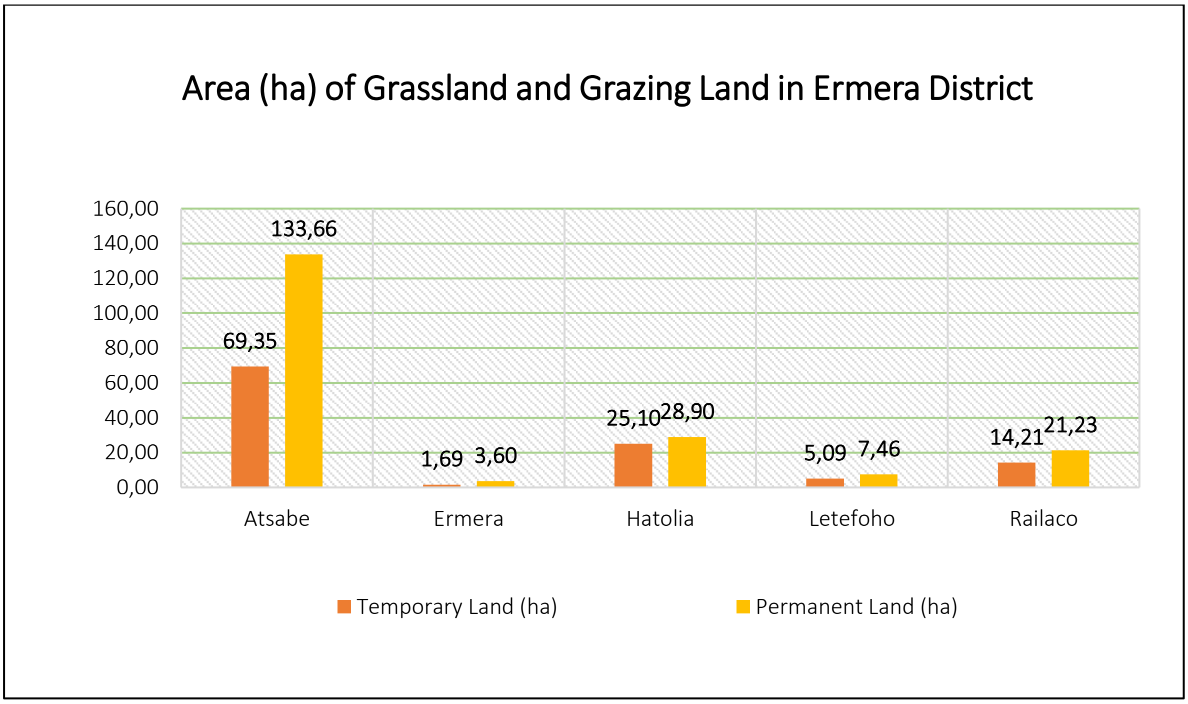


Figure 9.8 Grazing Land Area
(Source: Timor-Leste Agriculture Census, 2019)

9.4 DISCUSSION

A. Evaluation of Land Suitability for Forage Feed

The land suitability analysis for forage feed in Ermera District is a method used to evaluate the degree of suitability for the growth of various forage feed species and grasses on grazing lands in a given area. This analysis aims to facilitate the development of livestock feed resources and to ensure their optimal availability. According to Djaenudin *et al*. (2003), land suitability is defined as the degree of fitness of a given type of land for a specific kind of use. Land suitability can be assessed under current conditions (actual land suitability) or after improvement (potential land suitability). Land suitability evaluation in Timor-Leste was conducted using a matching method between land characteristics and land quality data and land suitability criteria based on the growth requirements of the evaluated plant species. Several forage feed commodities that were mapped in relation to land resource potential include Elephantgrass (*Pennisetum purpureum*), legumes, and pasture grasses.

The land suitability evaluation results for Atsabe, Ermera, Hatolia, Letefoho, and Railaco Sub-Districts indicate the potential for developing forage feed, including Elephantgrass, Setaria, legumes, and grazing lands, as described in **Table 7.5** in Chapter VII of this book. Based on this table, the actual land suitability classes for grazing range from S2 (moderately suitable) to N (not suitable), with limiting factors including rainfall, drainage, Total Nitrogen, Available Phosphorus, Available Potassium, pH, slope, erosion, and surface rock. Nevertheless, these constraints can still be addressed through technical interventions such as adjusting cropping patterns, constructing and improving drainage, adding NPK fertilizers, increasing organic matter, planting terrace-stabilizing species, constructing terraces, developing irrigation systems such as sprinkler irrigation, and land clearing. In addition, there is a limiting factor in the form of rock outcrops, which are permanent and cannot be improved. To improve livestock development sites, particularly for the development of forage feed (Hijauan Pakan Ternak, HPT) in Timor-Leste, several important steps are required to enhance both the quantity and quality of forage, namely:

1. Planting legume forage species

Planting legume forage species should be prioritized, given that legumes generally have higher nutrient content than grasses. However, because legumes have certain limitations in their use, the proportion of legumes relative to grasses needs to be carefully considered. As a guideline, Susetyo (1980) recommends that the ideal composition of grazing lands consists of 60% grasses and 40% legumes. Furthermore, according to Skerman (1977), legume species also play a role in controlling erosion, even more effectively than forest in some cases, because they have strong and deep root systems.

2. **Increasing the diversity of forage species, both legumes and grasses**

Increasing the diversity of forage species, both legumes and grasses, is an important aspect of feed development. The greater the diversity of forage species consumed by livestock, particularly ruminants, the higher the likelihood that their nutritional requirements will be met comprehensively. Several legume species with high nutritional content that have potential for development include indigofera, kaliandra, turi, and stylo. A widely found local legume species is Lamtoro Taramba. Feeding lamtoro to pregnant livestock needs to be done with caution. Although it has high nutritional content, lamtoro leaves contain anti-nutritional compounds such as mimosine and hydrocyanic acid, which are toxic if consumed in excessive amounts. This can be mitigated by providing lamtoro in moderate quantities, mixing it with other feeds, and ensuring that lamtoro is offered after wilting (air-dried), so that the levels of anti-nutritional compounds can be reduced.

B. Livestock Potential and Ecological Suitability

Ermera District has a total area of 76,762.92 ha, with 51,913.36 ha allocated for livestock sector development. This potential needs to be utilized optimally through human resource empowerment and effective use of the available land. One important factor in determining the potential of an area for livestock development is environmental or ecological suitability. Areas that do not meet ecological environmental suitability indicators are categorized as having low potential for livestock development. Therefore, the development of livestock enterprises in Ermera District must take ecological suitability aspects into account.

After field measurements were obtained for each parameter, including geophysical parameters such as rainfall and temperature, and soil chemical parameters such as soil organic carbon (SOC), Total Potassium, Available Potassium, cation exchange capacity (CEC), base saturation, and others, these data were analyzed using a Geographic Information System (GIS) application to determine the level of ecological suitability for five livestock types, namely sheep, beef cattle, dairy cattle, pigs, and buffalo. The physical ecological livestock land suitability map is shown in **Figure 9.9.**

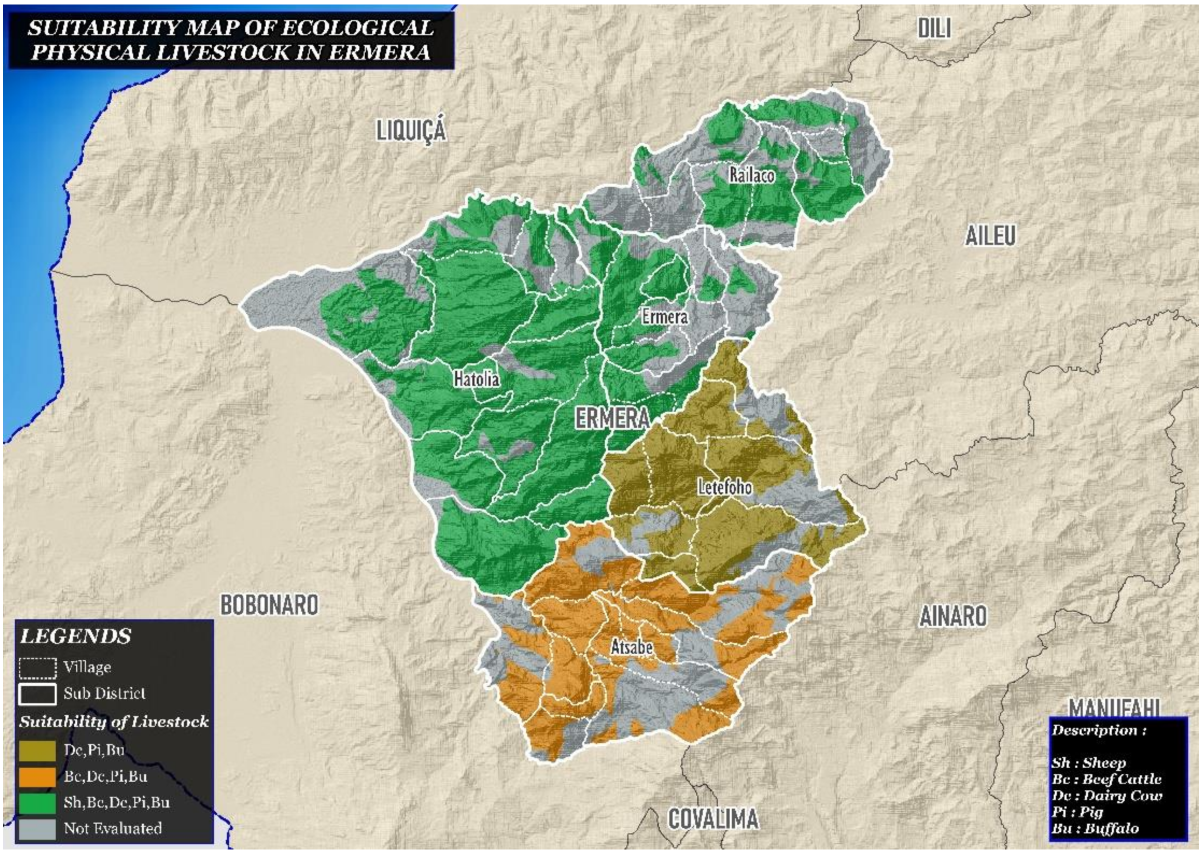


Figure 9.9 Ecological Physical Suitability Map for Livestock in Ermera District

The land available for livestock development in Ermera District consists of areas designated as mixed gardens and grazing lands. These lands are categorized as available because they are assumed to be capable of producing forage feed in the form of grasses and legumes, as well as crop residues from food crops. Land uses categorized as unavailable for livestock development include areas designated as forest and rice fields. From a technical perspective, this factor can be mitigated by providing housing with good air circulation and ventilation systems. However, for dairy cattle, temperature is an absolute requirement that must be met for successful husbandry.

Table 9.1 Area Available for Livestock development in Ermera District

Sub-District	Livestock Development Suitability Results					Area (ha)
	Sheep	Beef Cattle	Dairy Cattle	Pig	Bufallo	
Atsabe	N	S	S	S	S	10.766,6
Ermera	S	S	S	S	S	5.166,85
Hatolia	S	S	S	S	S	21.520,58
Letefoho	N	N	S	S	S	9.706,76
Railaco	S	S	S	S	S	4.488,56

Based on the results of the data analysis presented in **Table 9.1**, the ecological land suitability for the development of large livestock, including sheep, beef cattle, dairy cattle, pigs, and buffalo, shows a varied spatial distribution across the study area. Hatolia Sub-District is the most dominant area for large livestock development in Ermera District, followed by Atsabe Sub-District, while Railaco Sub-District has the smallest area for livestock development. Ermera, Hatolia, and Railaco Sub-Districts are suitable for the development of sheep, beef cattle, dairy cattle, pigs, and buffalo. Livestock development in Atsabe Sub-District is suitable for beef cattle, dairy cattle, pigs, and buffalo but not suitable for sheep due to limiting temperature conditions. Livestock development in Letefoho Sub-District is suitable for dairy cattle, pigs, and buffalo, but not suitable for sheep and beef cattle, which are constrained by temperature. The ecological land suitability for poultry in the study area shows a very high and uniform suitability level, with coverage reaching 100%. This reflects the biological characteristics of poultry, which have a broad adaptive capacity to various environmental conditions, allowing poultry to be raised on almost all available land types.

To support livestock sector development programs, it is necessary to identify and map areas that function primarily as locations for livestock husbandry and forage feed cultivation. Ermera District has an average environmental temperature of about 20.87 °C and annual rainfall of 2,334.41 mm /year providing ecologically conducive conditions to support livestock production optimally. These conditions also favor the sustainable availability of forage feed throughout the year.

Environmental temperature plays a central role in determining thermal comfort and livestock productivity. Environmental temperatures that are too low can cause cold stress in livestock, triggering an increase in body heat production and basal metabolic rate. If such conditions persist without adequate feed support, the animals' metabolic energy will decline, thereby reducing their tolerance to extreme temperatures. This situation disrupts livestock growth, decreases productivity, and significantly increases the risk of disease incidence.

Conversely, excessively high environmental temperatures cause livestock to reduce feed intake and instead increase water consumption. This reduction in nutrient intake directly leads to a decline in production performance. Therefore, optimal environmental management, particularly appropriate regulation of temperature and humidity, is a key prerequisite in sustainable livestock production systems. These efforts aim to create conditions that support the physiological balance of livestock so that productivity can be maintained at a maximal level.

C. Socio-Economic Aspects of Community Livestock Production

For communities in Ermera District, livestock play a very important and multifunctional role that goes far beyond serving merely as a food source. Livestock are an integral component of subsistence farming systems and the broader cultural life that has developed over time. It is still common to find people using livestock such as cattle, buffalo, and horses as draft power for ploughing rice fields and croplands. The use of animal traction enables farmers to cultivate larger areas and significantly increase agricultural productivity. In addition, in some communities, livestock have specific social, economic, or ritual meanings. For example, in certain cultures, livestock are used as bridewealth or offerings in customary ceremonies. Furthermore, the number of animals owned by a household often serves as an indicator of wealth and social status in the community.

One of the endemic livestock breeds in Timor-Leste is the Timor buffalo *(Karau Timor).* Timor buffalo hold an important position and role in the social life of Timor-Leste communities, particularly as offerings in funeral, birth, and marriage ceremonies. Timor buffalo are also used in traditional transactions such as land sales and purchases, their manure is used as fertilizer, and in the past communities commonly consumed buffalo milk to meet their animal protein needs. Consequently, Timor buffalo command a high market price.

Buffalo milk has long been consumed by communities and is one of the preferred types of milk besides cow and goat milk. Buffalo milk is thicker and has a more distinct aroma than cow milk. In the past, people commonly consumed

Timor buffalo milk directly without further processing. Thus, Timor buffalo milk forms part of cultural identity.

Livestock production is generally still carried out under traditional free-grazing systems, more commonly referred to as extensive systems. According to Williamson and Payne (1993), in extensive systems livestock are kept in a free-ranging manner and graze on natural forage. In this system, animals are released with a composition of males and several females within one population. A key characteristic of extensive systems is that housing is not provided and no supplementary feed is given (Jamili, M. A. 2022). Extensive systems have advantages such as low labor requirements, short working hours, and the ability of livestock to seek feed in grazing lands and on fallow agricultural land. However, the disadvantages for the animals include difficulties in controlling nutritional intake and higher susceptibility to disease and mortality. Free-ranging livestock that are poorly supervised can also trigger social problems, such as livestock theft and damage to farmers' gardens caused by roaming animals.

Livestock production patterns still rely on local knowledge that has been passed down from generation to generation. The absence of large-scale livestock industries means that production has not yet reached its full potential, with many aspects still needing improvement. The distribution of livestock within communities is relatively low because of limited capital and weak breeding practices. This is because efforts to increase herd size require substantial financial investment and long periods of time. As a result, livestock are not used as the main source of income, which contributes to low livestock production in the area (Serey *et al*., 2014).

Interview results indicated that communities received cattle and buffalo support in 2014 from MAPPF. However, over time, due to weak monitoring and limited community education, this assistance did not develop as initially intended. Households used the animals to meet household needs or as bridewealth (Dowry or *belis*). As a consequence, attention to the sustainability of breeding stock was neglected, which has the potential to hinder long-term development.

Other constraints in livestock production are highly complex, spanning from upstream to downstream, and also include limitations in facilities and infrastructure that need to be developed. In terms of animal breeding, communities still rely on natural mating systems without using artificial insemination (IB) technology, making it difficult to establish sustainable breeding programs. In terms of knowledge, communities are generally unfamiliar with good livestock management practices. They have not yet been educated about appropriate feed to support livestock productivity. In addition, from a marketing perspective, farmers are only able to sell live animals, which makes it difficult to increase the selling price of livestock products. Although road access from Dili as the capital city to other districts has opened up, many road infrastructures remain inadequate. This situation constrains communities in marketing their livestock products to wider markets.

Given the many constraints encountered from pre-production to post-production, these issues need to receive attention so that the key problems can be identified as a basis for designing a livestock development master plan. Recommendations for improvement can begin with community education on breeding, along with the introduction of IB technology. In addition, education is needed on the importance of livestock management within communities. This aims to motivate people to adopt a more economic orientation in livestock keeping rather than viewing livestock solely as household savings. The government should not only provide education but also inject capital through credit schemes to facilitate community livestock enterprises. Product marketability can be enhanced by educating farmers and opening livestock marketing channels that are not limited to live animal sales.

X. FRESHWATER FISHERIES POTENTIAL

10.1 INTRODUCTION

Timor-Leste has substantial potential in the fisheries sector, including in Ermera District, which offers diverse biophysical conditions. This study specifically focuses on freshwater aquaculture in lowland and coastal areas, as this subsector is considered capable of supporting food security while providing sustainable economic opportunities for local communities. This potential is important within the framework of regional development that emphasizes the prudent and sustainable use of natural resources.

The success of freshwater aquaculture depends heavily on appropriate site selection. Each fish species has different tolerances to environmental factors; therefore, land suitability analysis represents a critical initial stage. The main factors that must be considered include topography and hydrology, soil conditions, water quality, and climate. This study is expected to provide a strong scientific basis for aquaculture planning, enabling production activities to operate efficiently and competitively.

The research method used an evaluation matrix that assigned weights to each factor according to its level of importance. This approach aimed to generate data-driven recommendations to support systematic and sustainable planning of freshwater aquaculture in Ermera District. Through the use of the evaluation matrix, both local government and communities have a clear reference for determining locations that are suitable for aquaculture development.

In addition to technical aspects, this study also considered local policies, community participation, and customary practices in water resource management. The integration of biophysical analysis with sociocultural aspects is important to ensure that the resulting recommendations can be implemented effectively and accepted by the community. Through this holistic approach, freshwater aquaculture in the lowland and coastal areas of Ermera District is expected to enhance food security, strengthen the local economy, and support sustainable development objectives in Timor-Leste.

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.**

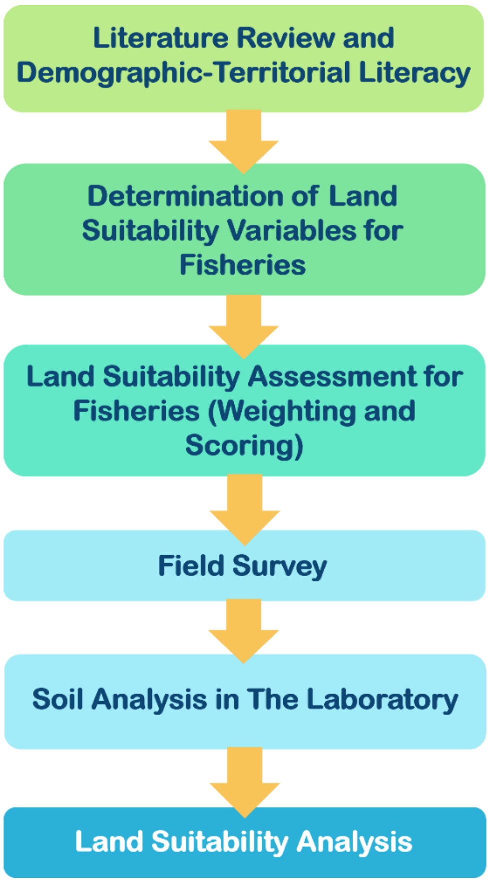


Figure 10.1 Flowchart of the research process for land suitability in the aquaculture sector

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	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 - Dry months	 mm/tahun -	 Remote Sensing/ Climatology Remote Sensing/ Climatology	 Ex Situ / Digital 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 Ermera District

No.	Schedule	Sub-District	Village	Allocation (Ownership)
1	18 May 2025	Ermera	Talimoro	Non-Business (Goverment)
2	18 May 2025	Ermera	Talimoro	Non-Business (Goverment)

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	Affects water infiltration and retention as well as sediment transport.	High clay → ideal habitat for mollusks, but poor for demersal fish

	enhances the soil's ability to store nutrients but can hinder aeration.		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

In terms of the number of fishing households in Ermera District, Ermera Sub-District has the highest number, with 19 households (33.93%). In contrast, Railaco Sub-District has the fewest fishing households, with only 2 households (3.57%). This could indicate limited local involvement in fishing activities.

This distribution reflects differences in potential and challenges in managing the fisheries sector across each Sub-District. Ermera Sub-District, with its dominant number of fishing households, has significant opportunities for further development through improved fishing technology, fisher training, and market access. Meanwhile, Railaco Sub-District, with its initial potential, can be strengthened through empowerment programs and infrastructure support to encourage community participation in the fisheries sector. Through a strategic approach, the fisheries potential in both Sub-Districts can be maximized to support the local economy sustainably. A graph showing the number of fishing households is presented in **Figure 10.2** and **Figure 10.3.**

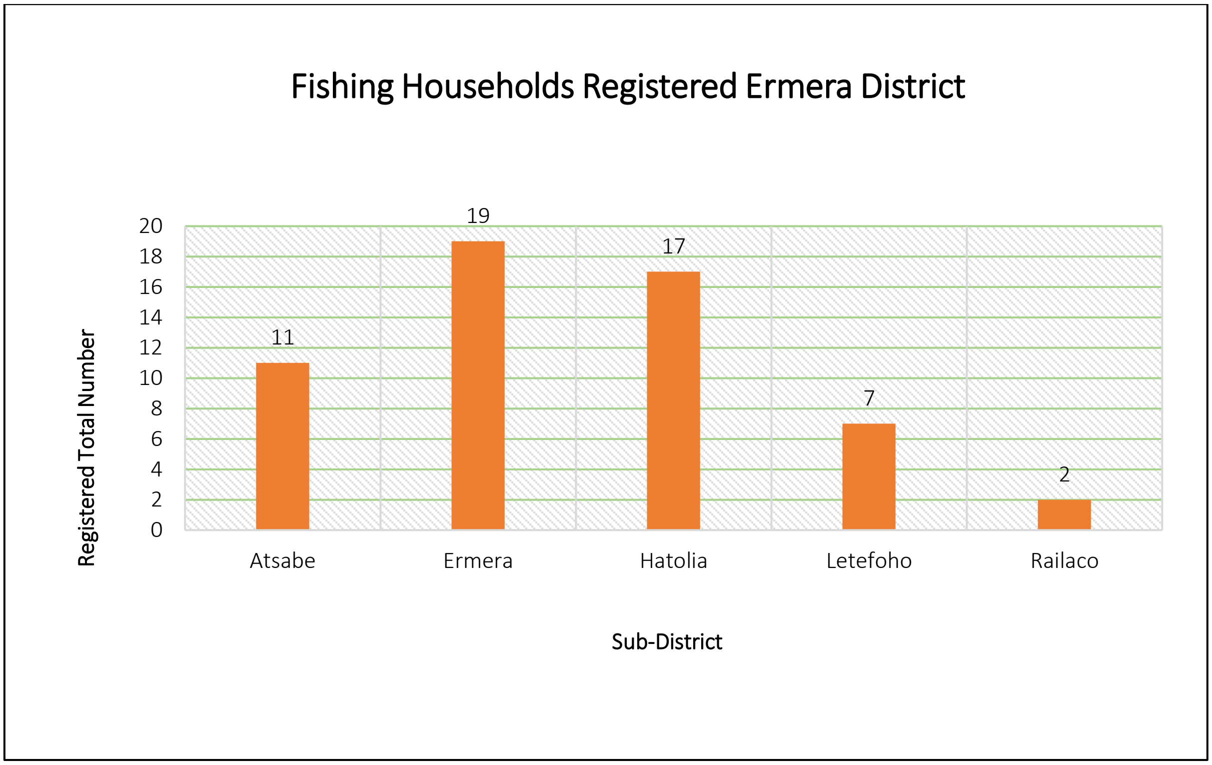


Figure 10.2 Fishing Households in Ermera District
(Source: Timor-Leste Agriculture Census, 2019)

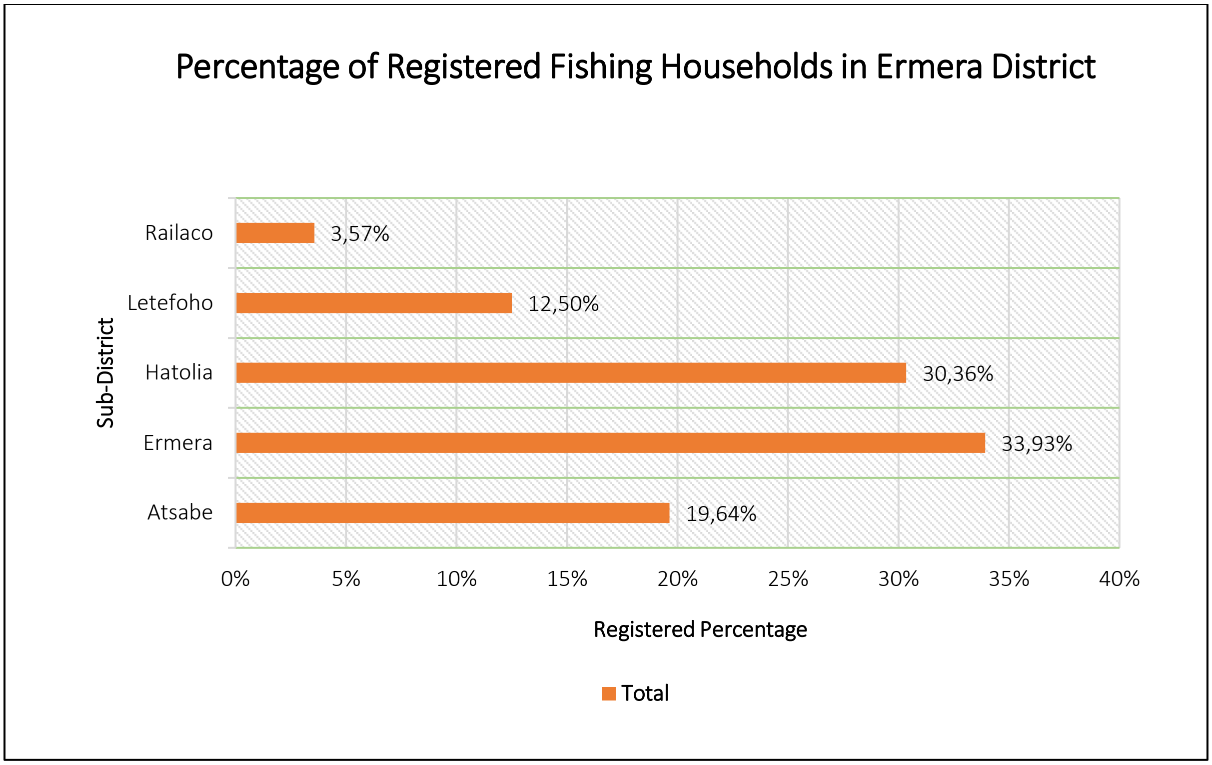


Figure 10.3 Percentage of Fishing Households in Ermera District
(Source: Timor-Leste Agriculture Census, 2019)

2. Households Involved in Fishing Activities

Households involved in fishing activities are categorized into three activities: for consumption and social obligations, for consumption and occasional sales, and for direct sales.

Hatolia Sub-District has the highest number of households involved in fishing for consumption and occasional sales, with a total of 5 households (41.67%). In contrast, Ermera Sub-District has the fewest households in this category, with only 3 households (25.00%), reflecting significant differences in the scale of fishing activities between these areas. Meanwhile, Ermera and Hatolia Sub-Districts have the highest number of households engaged in fishing for consumption and social obligations, with 18 households (36.00%). Railaco Sub-District has 3 households (6.00%). Ermera, Hatolia, and Letefoho Sub-Districts each have one household involved in fishing for direct sales.

This shows that most households use fish catch for personal consumption or social obligations, with only a few households directly selling their catch as a source of income. However, the low direct sales also present an opportunity for further development. With better management, such as increased production, technical training, and wider market access, sales activities can support the local economy and provide economic benefits to households in Ermera. The number of households involved in fishing activities is shown in **Figure 10.4** and **Figure 10.5.**

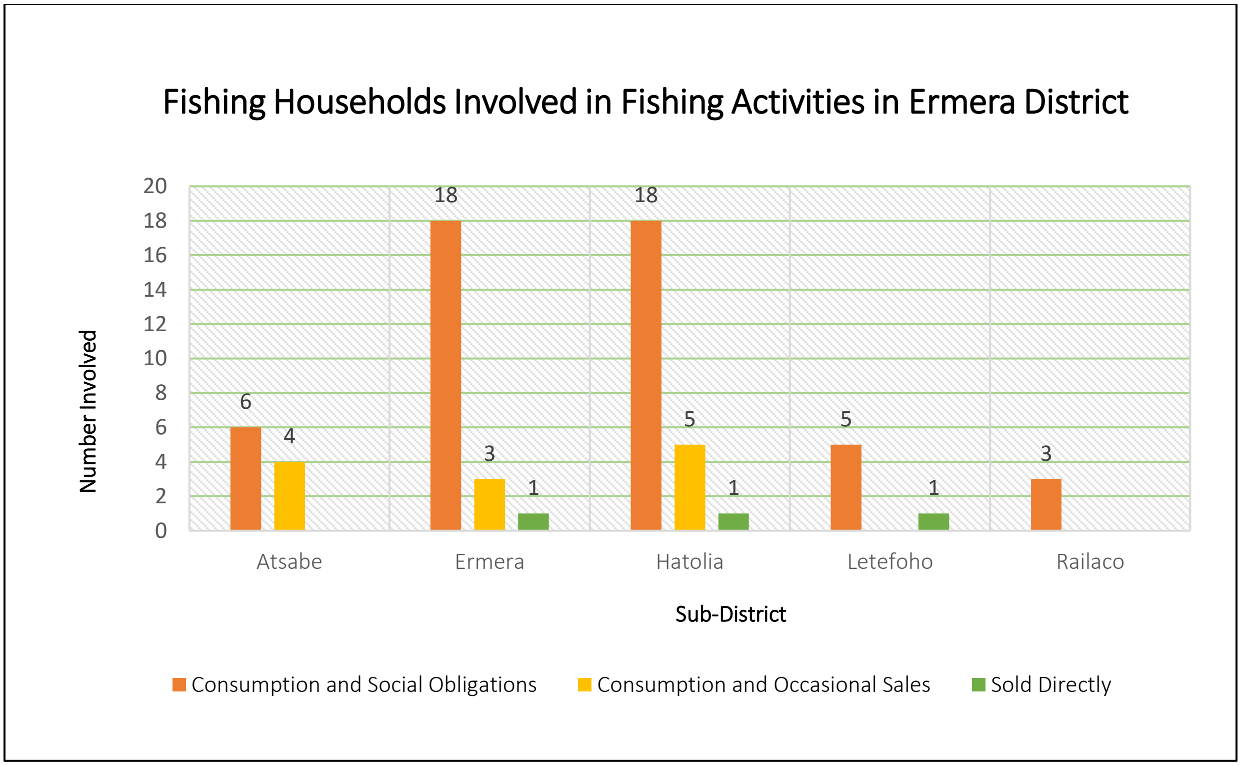


Figure 10.4 Number of Households Involved in Fishing Activities
(Source: Timor-Leste Agriculture Census, *2019*)

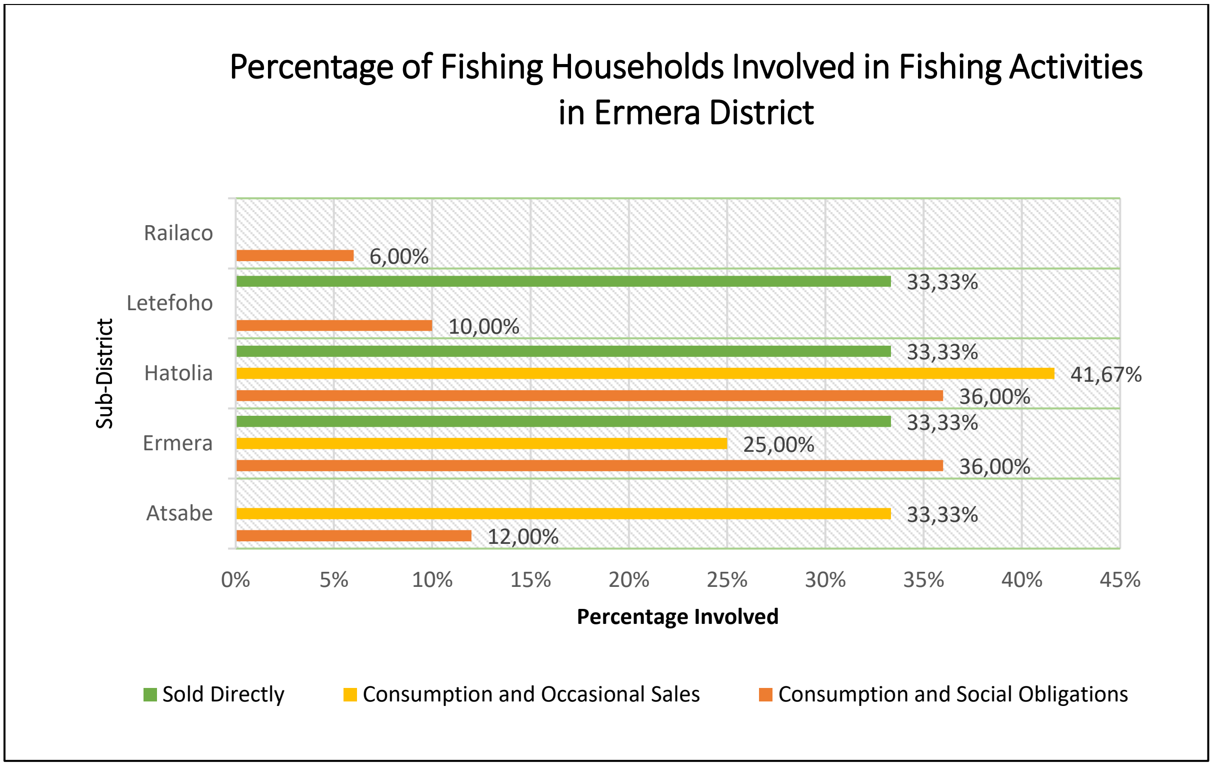


Figure 10.5 Number of Households Involved in Fishing Activities
(Source: Timor-Leste Agriculture Census, 2019)

B. Aquaculture

Aquaculture in Ermera District has significant potential for development. Aquaculture production in Ermera has shown an increasing trend in recent years, although it has experienced fluctuations. This reflects efforts to improve efficiency and sustainability in managing the sector. According to data from da Fonseca *et al*. 2022, the per capita consumption of aquaculture fish in Ermera District was 0.35 kg per person per year in 2019. In the following year, consumption significantly dropped to 0.21 kg per person per year, and this figure has remained constant through the estimated year of 2023. The decline after 2019 was due to changes in production levels. The stabilization of consumption in subsequent years indicates the potential to further optimize the aquaculture sector to meet the nutritional needs of the community

1. Proportion of Land for Aquaculture

The distribution of aquaculture land in Ermera District shows significant differences across Sub-Districts. Ermera Sub-District dominates with the largest aquaculture land area, reaching 177.18 ha or 55.86%. In contrast, Railaco Sub-

District has only about 5.16 ha of aquaculture land or 1.63%, which indicates limited potential or relatively smaller aquaculture development compared to Ermera Sub-District. The proportion of land used for aquaculture is shown in **Figure 10.6** and **Figure 10.7**.

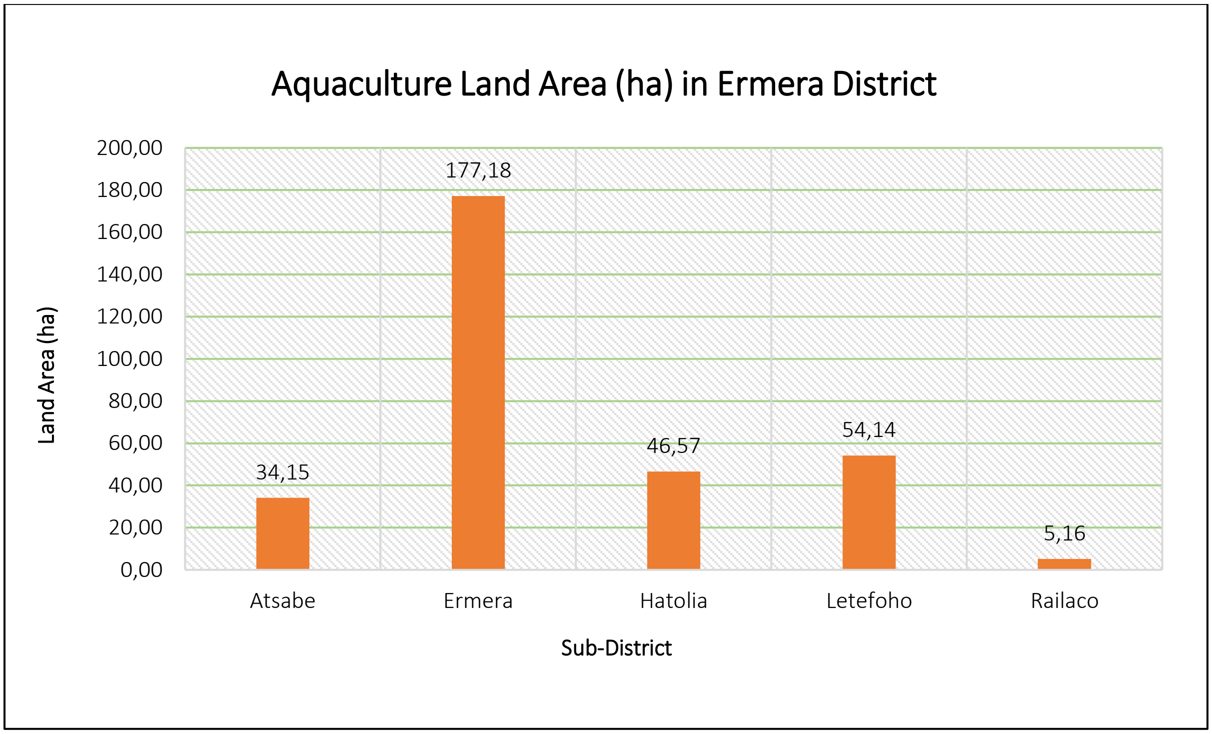


Figure 10.6 Aquaculture Land Area in Ermera District
(Source: Timor-Leste Agriculture Census, 2019)

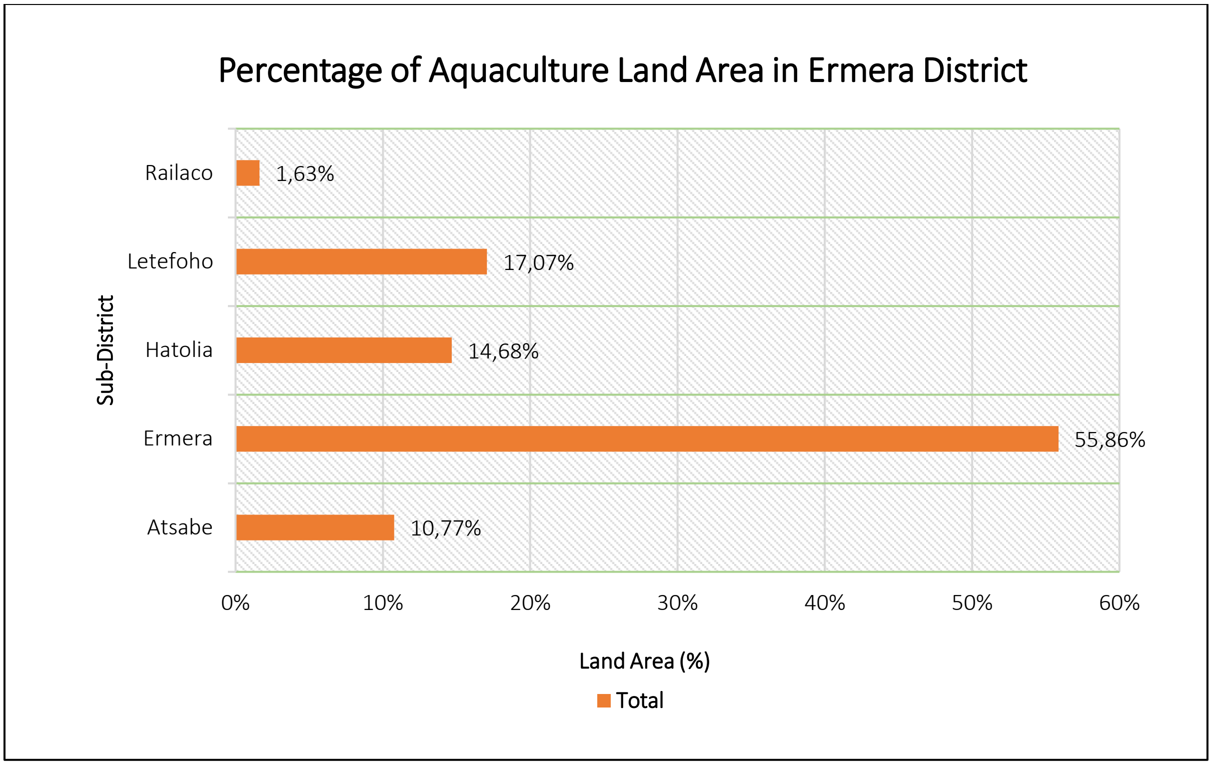


Figure 10.7 Percentage of Aquaculture Land in Ermera District
(Source: Timor-Leste Agriculture Census, 2019)

2. Aquaculture Households

Households involved in aquaculture play an important role in driving the growth of the fisheries sector at the local level, while also supporting food security and the local economy. Each household reflects the sustainability of aquaculture practices and their adaptation to water resource-based economic opportunities.

The number of households engaged in aquaculture in Ermera District shows significant variation across Sub-Districts. Hatolia Sub-District has the highest number of households in aquaculture, with 344 households (43.54%), while Railaco Sub-District has only 37 households (4.68%) involved in aquaculture.

A strategic approach is needed to increase community participation in Sub-Districts with low involvement in aquaculture. Through strengthening local capacity and optimizing the aquaculture potential in each Sub-District, Ermera District can increase the contribution of this sector to local economic growth. The number of households involved in aquaculture in Ermera District is shown in **Figure 10.8** and **Figure 10.9**.

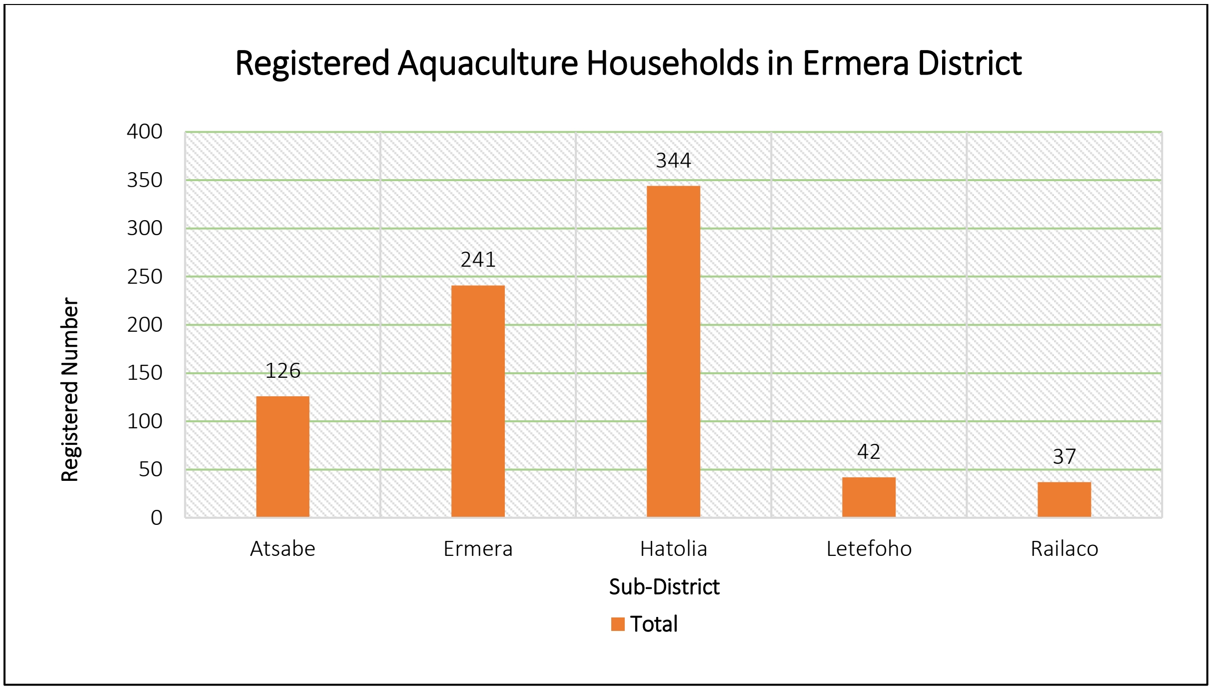


Figure 10.8 Aquaculture Households in Ermera District
(Source: Timor-Leste Agriculture Census, 2019)

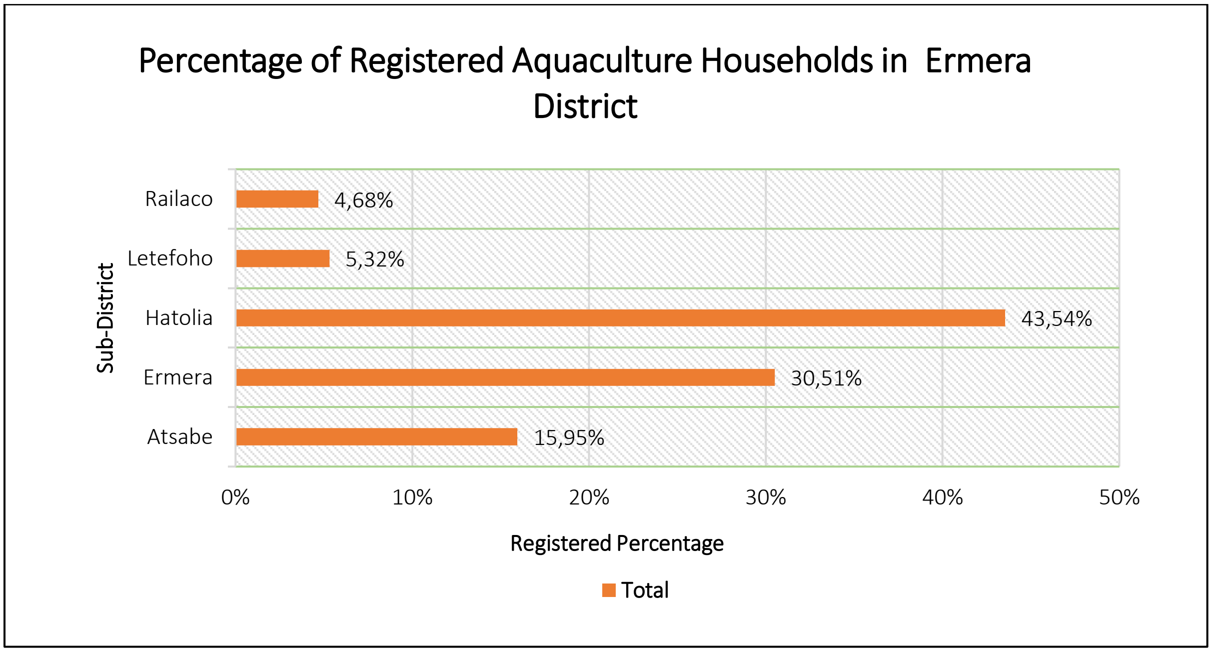


Figure 10.9 Percentage of Aquaculture Households in Ermera District
(Source: Timor-Leste Agriculture Census, 2019)

3. Aquaculture Systems

Aquaculture systems in Ermera District show varying distribution patterns across each Sub-District, with pond-based systems being the dominant system throughout the region. Hatolia Sub-District has the highest number of ponds, with 262 units or about 42%. Additionally, rice-fish systems have been implemented in several Sub-Districts, such as Atsabe, Ermera, and Railaco, although on a limited scale. Among these three Sub-Districts, Railaco records the highest number of rice-fish units, with 5 units or about 71% of the total.

Meanwhile, brackish-water pond aquaculture has been developed in several Sub-Districts, including Ermera, Hatolia, and Letefoho, albeit on a limited scale. Of the three Sub-Districts, Hatolia has the highest number of brackish-water pond units, with 13 units or about 57% of the total. Furthermore, aquaculture for breeding has been developed in two Sub-Districts: Ermera and Hatolia. Hatolia records the highest number of breeding units, with 5 units (83%), indicating diversity in aquaculture methods, although still on a limited scale. A graph of aquaculture systems used in Ermera District is presented in **Figure 10.10** and **Figure 10.11**.

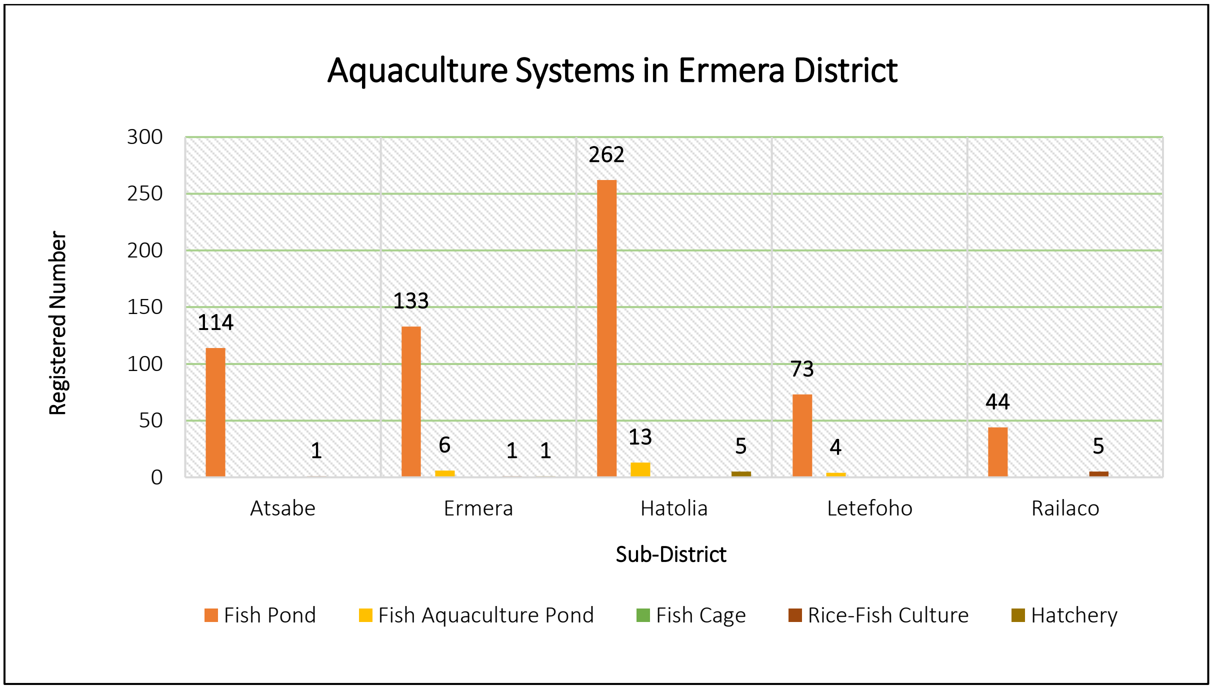


Figure 10.10 Aquaculture Systems in Ermera District
(Source: Timor-Leste Agriculture Census, 2019)

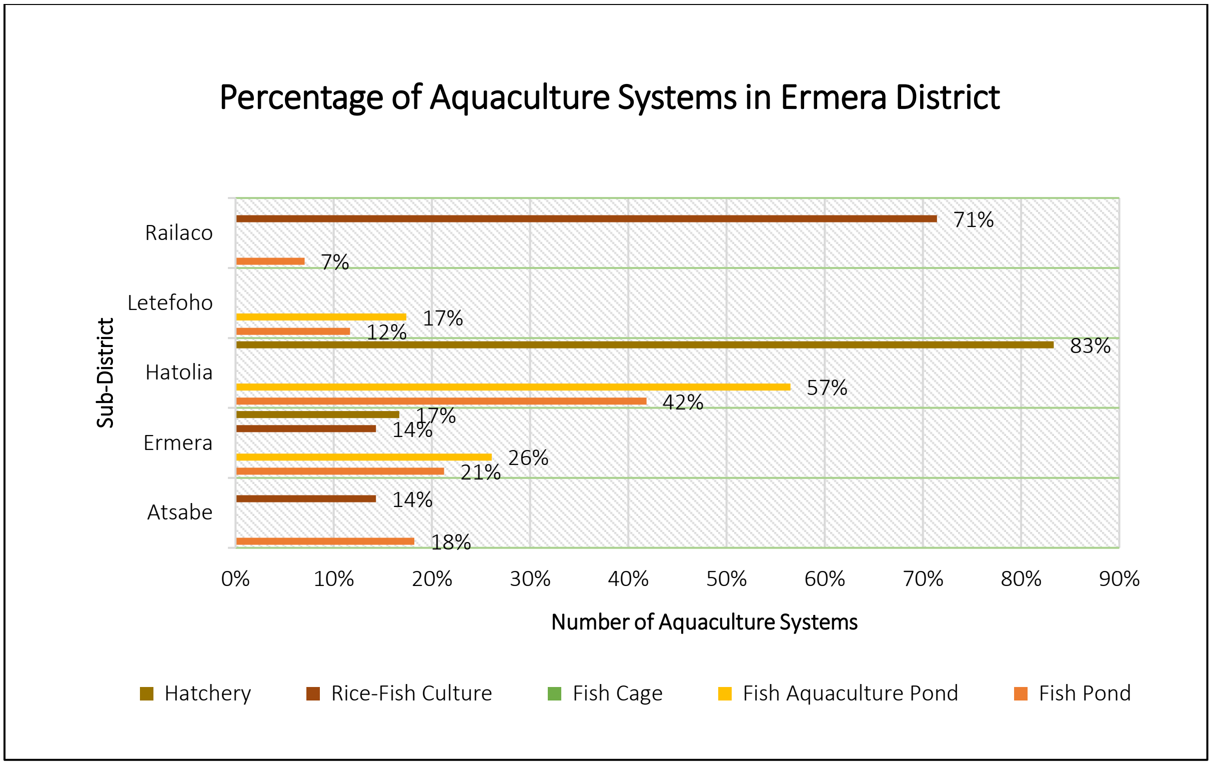


Figure 10.11 Percentage of Aquaculture Systems in Ermera District
(Source: Timor-Leste Agriculture Census, 2019)

C. Field Observation Results

Aquaculture activities in Ermera District demonstrate the utilization of abundant mountain water resources, particularly springs, as the main source for fish breeding and growth. There is a combination of government-managed breeding centers and semi-intensive community-managed aquaculture activities on a relatively large scale. However, technical and management challenges still affect productivity and efficiency.

In Talimoro Village, Ermera Sub-District, there is a government-owned breeding center that functions as a production center for tilapia fry. All pond facilities at this center are made of concrete and receive water from three permanent springs that are channeled through a reservoir system. This center focuses on the maintenance of tilapia broodstock, which is used as fry stock for nearby farmers. With the availability of stable and relatively clean water sources, this location has great potential to be developed into a regional breeding center and a technical training hub for the community.

Figure 10.12 Breeding Facilities and Water Source at Talimoro Breeding Center
(Source: Research Documentation, 2025)

On the other hand, fish farming activities are conducted by community groups in Tocoluli Village, Railaco Sub-District. The ponds used consist of a combination of semi-permanent ponds and conventional earthen ponds. The total number of ponds at this site is very large, with 500 units measuring 10 × 11 meters and 400 units measuring 10 × 10 meters. The main water source comes from groundwater.

Fish maintenance is done over a six-month cycle, with a feed requirement of one sack per day. The feed costs about 60 USD per sack, which is the largest operational cost. The reported survival rate during the maintenance period is 50%. Despite this, the farmers report that the farming activities still generate profit.

One of the technical challenges observed at this location is fish mortality that occurs when the water quality is too clear. This phenomenon suggests a possible imbalance in the chemical parameters of the water or disruptions in plankton stability, which serves as natural feed and requires further study. Additionally, the high feed cost and limited access to technical training are other challenges in maintaining the efficiency of aquaculture activities.

Figure 10.13 Breeding Facilities and Water Source at Talimoro Breeding Center
(Source: Research Documentation, 2025)

Overall, Ermera District has water resources that support the development of the aquaculture sector, particularly in the hilly regions with abundant spring water. However, enhancing the technical capacity of farmers, improving feed efficiency, and introducing simple technologies for water quality management are necessary to boost productivity and sustainability in the sector. Strengthening the role of breeding centers is also crucial to create a more integrated and self-sufficient aquaculture system.

10.4 COMPREHENSIVE LAND SUITABILITY ANALYSIS FOR AQUACULTURE

A. Aquaculture Land Suitability in Ermera District

Land suitability refers to the degree of appropriateness of an area for a specific purpose, in this case, for aquaculture activities. This evaluation aims to assess whether the land possesses physical, chemical, and climatic characteristics that can support the optimal and sustainable growth of aquatic commodities. Land suitability evaluation can be conducted based on two conditions: current condition (as it is) and potential condition (after improvements).

In the current land suitability, the evaluation is based on field survey data, reflecting the land's capacity in its natural state without any interventions. This evaluation does not consider corrective actions or management measures that can be applied to address existing constraints. The process begins with an analysis of land quality based on limiting factors, followed by scoring and generating an evaluation score. The result provides an honest depiction of the limitations and challenges that need to be faced.

In contrast, potential land suitability reflects the land's condition after improvements have been made to overcome limiting factors. For example, land that is only marginally suitable (S3) in the current condition can be improved to moderately suitable (S2) or even highly suitable (S1) through interventions such as topographic modification or water quality management. This evaluation is conducted by identifying limiting factors and determining feasible improvement steps, allowing the land's suitability to be increased.

Technological advancements allow land with low suitability in its current condition to be upgraded to higher potential suitability. However, not all factors can be improved technically, or they may require very intensive management. Therefore, in land-use planning for aquaculture, the primary focus is on potential suitability, as it provides a picture of the land's maximum capacity after improvements. This evaluation helps in designing more effective, sustainable land-use strategies that achieve optimal productivity.

B. Results of Aquaculture Land Suitability Evaluation in Ermera District

Land suitability analysis is a critical step in formulating sustainable land resource management strategies to support aquaculture development. The evaluation is carried out using an integrated approach that combines geospatial data, field observations, and physical and chemical analyses of both soil and water in laboratories. This approach enables the accurate identification of the land's potential and bio-physical limitations for supporting the development of various aquaculture commodities.

The obtained data is analyzed based on the growth requirements of each aquatic commodity, both in the current condition and potential condition after land improvements such as topographic modifications, water quality management, or the application of adaptive cultivation techniques. This process results in comprehensive information that can be used to prioritize commodity development, identify limiting factors, and design appropriate technical solutions. This scientific approach serves as the foundation for land suitability evaluation in Ermera District.

The results provide strategic guidance for maximizing land productivity while ensuring the sustainability of aquatic resources in each area. All field and laboratory data, which form the basis for land suitability evaluation, are presented in relevant supporting documents as references. The land distribution map for aquaculture is shown in **Figure 10.14**.

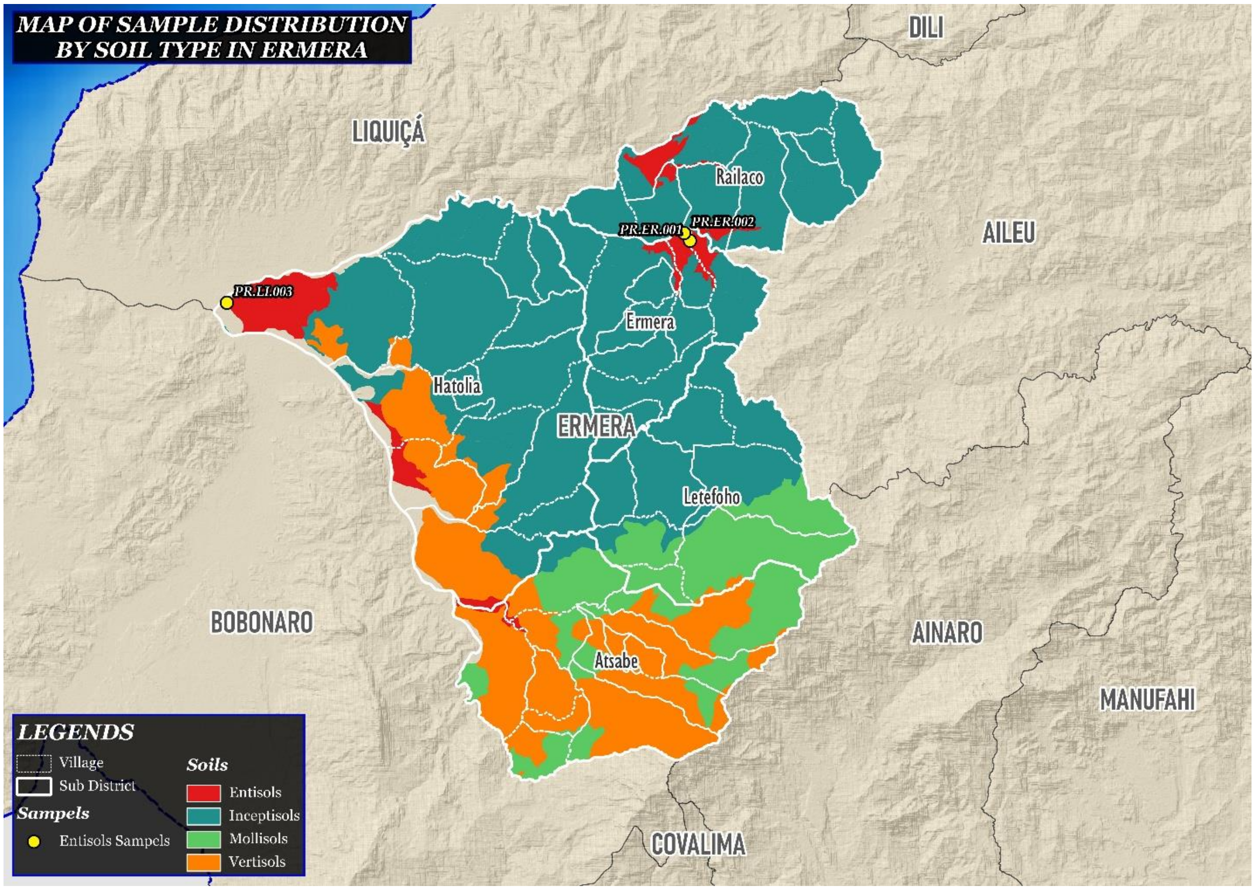


Figure 10. 14 Map of Soil Distribution on Aquaculture Land in Ermera District

a. Land Suitability Evaluation in Ermera Sub-District

Ermera Sub-District, located in the mountainous region, has potential for aquaculture development, particularly freshwater fish farming. The results of the land suitability evaluation show several bio-physical limiting factors, especially topography and climate. Freshwater commodities such as gourami, catfish, carp, and tilapia are generally constrained by slope gradient and the length of dry months. Both of these factors are often rated as "Not Suitable" (N) in the current condition.

Slope gradient is a primary constraint because it affects the technical feasibility and cost of pond construction. The steep topography in Ermera Sub-

District complicates the construction of conventional ponds and increases the risk of erosion. The recommended management approach to address this is the use of terraced pond systems, as detailed in **Table 10.10.** This method allows the construction of ponds following the land's contour and uses gravity for water distribution, thus improving the land suitability value to S3 (marginally suitable). Meanwhile, the long dry months are a permanent constraint due to limited water supply. As an alternative, rainwater harvesting through reservoirs could help reduce dependence on rainfall.

Other factors such as unstable pH, low temperatures, and limited rainfall play a secondary role as limiting factors. However, these constraints can be relatively addressed, such as by replacing water, using zeolite to stabilize pH, or implementing shallow ponds with dark-colored bottoms to increase water temperature.

For brackish-water commodities like milkfish, mangrove crab, and vannamei shrimp, low salinity is the main challenge. Technically, low salinity can be addressed by mixing seawater, but this approach is unrealistic in Ermera Sub-District due to its distance from the coast. This presents a significant technical and economic barrier, making brackish-water aquaculture unfeasible in the region.

Based on these conditions, aquaculture development in Ermera Sub-District should focus on freshwater commodities, particularly carp, catfish, and tilapia. These species are more adaptable to the local conditions and have the potential to yield optimal results with affordable technical interventions.

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

Commodity	Current Land Suitability Limiting Factors	Current Final Evaluation	Potential Land Suitability Limiting Factors	Potential Final Evaluation
Gourami (*Ospronemus gouramy*)	N: Slope gradient, dry months S3: pH S2: Low temperature, rainfall	3.09	N: Dry months S3: Slope gradient S2: Rainfall	3.4
Catfish (*Clarias batrachus*)	N: Slope gradient, dry months S2: pH, rainfall	3.21	N: Dry months S3: Slope gradient S2: Rainfall	3.4
Carp (*Cyprinus carpio*)	N: Slope gradient, dry months S2: pH, rainfall	3.19	N: Dry months S3: Slope gradient S2: Rainfall	3.4
Tilapia (*Oreochromis niloticus*)	N: Slope gradient, dry months S2: pH, rainfall, Low temperature	3.16	N: Dry months S3: Slope gradient S2: Rainfall	3.4
Milkfish (*Chanos chanos*)	N: Slope gradient, dry months S3: Low salinity S2: Low temperature, pH, rainfall	2.96	N: Dry months S3: Slope gradient S2: Rainfall	3.4
Mangrove crab (*Scylla serrata*)	N: Low salinity, slope gradient, dry months S3: pH S2: Low temperature, rainfall	2.79	N: Dry months S3: Slope gradient S2: Rainfall	3.4
Vannamei (*Litopenaeus vannamei*)	N: Slope gradient, dry months S3: Low salinity S2: Low temperature, pH, rainfall	3.22	N: Dry months S3: Slope gradient S2: Rainfall	3.4

C. Aquaculture Land Improvement Efforts

The results of the current land suitability evaluation in Ermera District show that most areas face significant limiting factors, making them either unsuitable or only marginally suitable for aquaculture development. To improve land suitability, corrective efforts must be made on the limiting factors, as far as technical aspects allow. Land improvement efforts in aquaculture include various technical interventions aimed at improving the bio-physical conditions of the land and water quality to meet the optimal requirements of the cultivated commodities. These improvements may involve habitat modifications (e.g., improving pond conditions physically), water quality manipulation, or providing supporting infrastructure.

According to **Table 10.10**, there are various types of improvement efforts categorized into three levels of management difficulty: low, medium, and high. These levels serve as the basis for assessing the effectiveness of improving current land suitability 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. ZONING FOR AGRICULTURE COMMODITY DEVELOPMENT

11.1 ZONING FOR AGRICULTURE DEVELOPMENT

Ermera District has significant land resource potential to support the development of agriculture, forestry, and livestock sectors. To maximize this potential, a comprehensive scientific land suitability evaluation was conducted, including field observations, laboratory testing of soil samples, and matching plant growth requirements with agro-climatic maps of the area. The results of this evaluation led to the development of a systematic, scientifically-based zoning map to identify the potential for developing various strategic commodities, such as rice, corn, horticulture, industrial crops, and forestry areas. This zoning is expected to support efficient and sustainable land resource management, contributing to national food security while improving community welfare.

Ermera's District land development potential is divided into several main categories: irrigated rice fields covering 0.04 km^2 (0.01%), rainfed rice fields 72.89 km^2 (9.49%), grazing areas 2.18 km^2 (0.28%), dryland farming or mixed gardens 197.35 km^2 (25.69%), agroforestry 431.94 km^2 (56.22%), and protected and conservation forests 63.91 km^2 (8.32%). The spatial distribution data is presented in **Figure 11.1**, and further details are shown in **Figure 11.2.** This zoning reflects the diversity of land use potential to sustainably support agriculture, forestry, and livestock sectors, contributing to food security, environmental protection, and community welfare. With structured and sustainable management efforts, Ermera District can become a resilient food production center, not only to meet local needs but also to support national food security comprehensively. The vast potential in this area can be optimized through collaboration between the government, policymakers, and the local community, ensuring benefits for all parties.

A. Irrigated Rice Fields

The irrigated rice field zone covers only 0.04 km^2, or 0.01% of the total area of District Ermera, located in low-elevation areas (0–100 meters above sea level) with a slope gradient of 0–8%. This area has a very small potential for developing irrigated rice fields or is difficult to develop because almost the entire area is situated above 100 meters above sea level, surrounded by other land areas. Irrigated rice fields are only found in Hatolia Sub-District, the area closest to the sea and the river course that runs through this region. The low potential for developing irrigated rice fields in this area is also related to the short rainy season, lasting only 5 to 6 months.

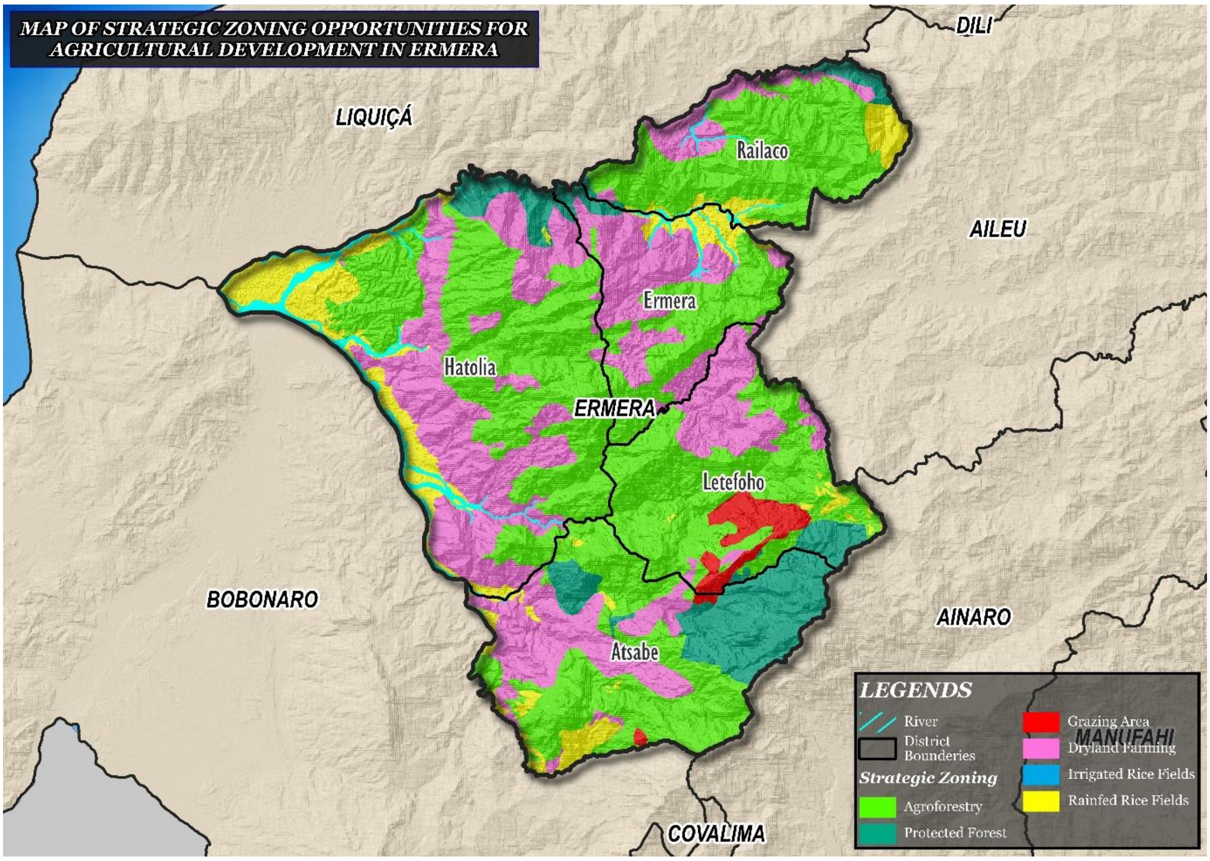
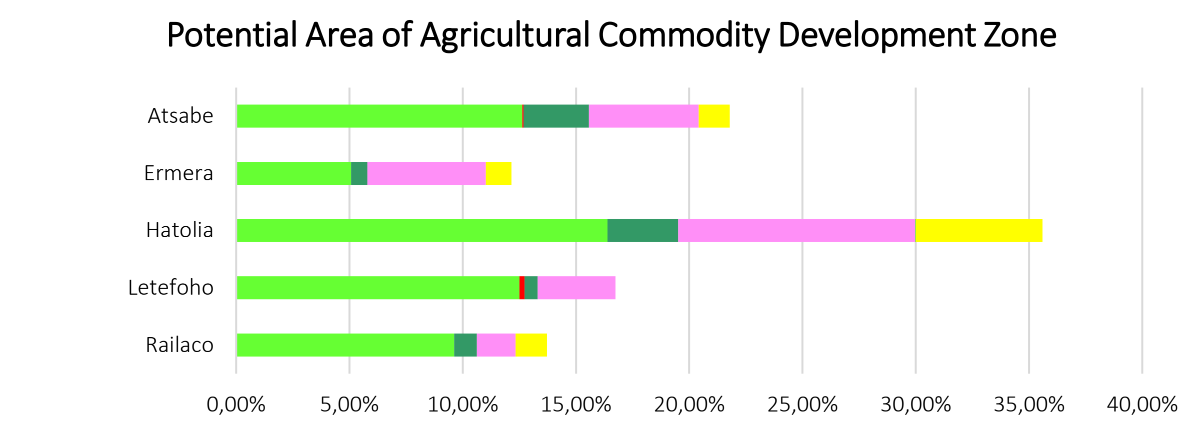


Figure 11.1 Map of Agricultural and Forestry Commodity Development Potential in Ermera District

B. Rainfed Rice Fields

Rainfed rice fields cover an area of 72.89 km² (9.49%) of the total area of District Ermera, dominated by agro-climatic zones A, B, and C, with a monomodal rainfall pattern and a wet season lasting 4 to 6 months per year. Located at an elevation of 100 to 500 meters above sea level, this area is suitable for the development of rainfed rice fields. The main locations include Sub-District Atsabe (1.36%), Ermera (1.14%), Hatolia (5.62%), which has the largest potential for development, and Railaco (1.38%). The productivity of rainfed rice fields is highly dependent on seasonal rainfall. Recommended strategies include the construction of reservoirs, the use of drought-resistant rice varieties, and water management practices to increase crop yields.



	Railaco	Letefoho	Hatolia	Ermera	Atsabe
Agroforestry	9,62%	12,51%	16,39%	5,07%	12,63%
Grazing Area	0,00%	0,23%	0,00%	0,00%	0,05%
Protected Forest	1,01%	0,57%	3,13%	0,72%	2,89%
Dryland Farming	1,71%	3,44%	10,46%	5,23%	4,85%
Irrigated Rice Fields	0,00%	0,00%	0,01%	0,00%	0,00%
Rainfed Rice Fields	1,38%	0,00%	5,62%	1,14%	1,36%

Figure 11.2 Area of Agricultural and Forestry Commodity Development per Sub-District

C. Dryland Farming (Mixed Gardens and Upland Farming)

Dryland farming or mixed gardens is the second-largest sector, covering an area of 197.35 km² (25.69%) of the total area of Ermera District. This zoning is located at elevations of 100 to 500 meters above sea level with slope gradients of 8 to 25%. The main distribution areas include Hatolia Sub-District (10.46%), which has the highest potential for developing dryland farming, followed by Ermera Sub-District (5.23%), Atsabe (4.85%), Letefoho (3.44%), and Railaco (1.71%). This area supports a wide range of commodities, such as corn, cassava, peanuts (food crops); vegetables, fruits, and flowers (horticulture); and coffee, cacao, and spices (industrial crops). The mixed cropping system in this zone can enhance land productivity and farmer income. To prevent erosion on moderate slopes, soil conservation approaches such as strip cropping and crop rotation are recommended.

D. Grazing Area

The grazing area covers 2.18 km² (0.28%) of the total area of Ermera District, dominated by grasslands and savannahs. The main distribution areas include Letefoho Sub-District (0.23%), which has the largest potential, followed by Atsabe (0.05%). This area supports the grazing of livestock such as goats and cattle, with area management including the implementation of a rotational grazing system to prevent land degradation and improve forage productivity. Integration with agroforestry is also recommended to enhance both ecological and economic benefits. The forestry sector is discussed in Chapter 8 of this report.

Table 11.1 Land Use Recommendations (Recommendations) for Food Crops, Industrial Crops, Horticulture, Spice and Medicinal Plants, and Forestry in Ermera District

NO	DISTRICT	SUB-DISTRICT	FOOD CROPS	DRYLAND AGRICULTURE (PLANTATIONS & HORTICULTURE)	FORESTRY	GRAZING AREA
1	Ermera	Atsabe	DRY LAND CROPS **S2:** Wheat, Mung Bean **S3:** Upland rice , Corn, Sorghum, Cassava , Sweet Potato	INDUSTRY **S3:** Arabica Coffee, Robusta Coffee, Tobacco FRUITS **S2:** Papaya , Apple, Mango, Rambutan, Guava, Star fruit, Durian, Duku, Jackfruit, Soursop, Custard Apple, Breadfruit, Snake Fruit, Sapodilla, Longan, Mangosteen, Pineapple, Carica, Persimmon , Kepayang, Banana, Orange, Avocado, Grape **S3:** Watermelon, Cantaloupe, Melon, Strawberry, Passion Fruit VEGETABLES **S2:** *Lettuce*, Petsai, Caisim, Spinach **S3:** Eggplant, Bit, Vegetable Tomato, Carrot, Garlic, Red Chili, Bell Pepper, Cabbage, Green Beans, Red Bean, Long Bean, Snow Pea, Bitter Melon, Kailan, Shallot FLOWERS **S3:** Rose, Ylang-Ylang, Aster, Gladiol, Tuberose, *Hairgrass*, Sunflower SPICES & MEDICINE **S2:** Vanilla, Aromatic Ginger, Turmeric, Galangal **S3:** Candlenut, Lemongrass, Vetiver Root, Cardamom, Jatropha	**S3:** *Eucalyptus grandis*	

2	Ermera	Ermera	DRY LAND CROPS **S2:** Corn, Mung Bean, Cowpea, Chickpea, Cassava, Hui **S3:** Sorghum, Soy Bean, Peanut, Sweet Potato, Taro, Iles-Iles	INDUSTRY **S2:** Robusta Coffee, Tobacco, Sugarcane, Cotton, Quinine **S3:** Coconut, Arabica Coffee, Kapok FRUITS **S2:** Papaya , Apple, Mango, Rambutan, Guava, Starfruit, Durian, Duku, Jackfruit, Soursop, Custard Apple, Breadfruit, Snake Fruit, Sapodilla, Longan, Mangosteen, Pineapple, Persimmon , Kepayang, Banana, Orange, Avocado, Grape **S3:** Watermelon, Cantaloupe, Melon, Strawberry, Carica, Passion Fruit VEGETABLES **S2:** *Lettuce*, Spinach, Caisim, Petsai **S3:** Eggplant, Bit, Vegetable Tomato, Red Chili, Bell Pepper, Cabbage, Green Beans, Long Bean, Snow Pea, Cucumber, Bitter Melon, Shallot FLOWERS **S2:** Rose, Tuberose, Hairgrass, Gladiol, Aster, Sunflower **S3:** Ylang-Ylang SPICES & MEDICINE **S1:** Vanilla **S2:** Candlenut, Aromatic Ginger, Turmeric, Galangal, Jatropha **S3:** Pepper, Lemongrass, Vetiver Root, Cardamom		

3	Ermera	Hatolia	WETLAND FOOD **S2**: Irrigated Rice DRY LAND CROPS **S2:** Upland rice , Corn **S3:** Sorghum, Peanut, Cowpea, Cassava , Taro	INDUSTRY **S2:** Arabica Coffee, Robusta Coffee **S3:** Coconut, Tobacco, Sugarcane FRUITS **S2:** Papaya , Mango, Rambutan, Guava, Starfruit, Durian, Watermelon, Cantaloupe, Melon, Duku, Jackfruit, Soursop, Custard Apple, Breadfruit, Snake Fruit, Sapodilla, Longan, Mangosteen, Pineapple, Strawberry, Persimmon , Kepayang, Banana, Orange, Avocado, Passion Fruit, Grape **S3:** Apple, Carica VEGETABLE **S2:** Petsai, Caisim, Spinach, Cucumber **S3:** *Lettuce*, Eggplant, Bit, Vegetable Tomato, Red Chili, Bell Pepper, Green Beans, Long Bean, FLOWERS **S2:** Sunflower **S3:** Rose, Ylang-Ylang, Tuberose, *Hairgrass*, Gladiol, Aster SPICES & MEDICINE **S3:** Vanilla, Aromatic Ginger, Turmeric, Galangal, Jatropha	**S2:** Albizia, Melaleuca **S3:** Teak, Mahogany, Agathis, Acacia, Leucaena, *Eucalyptus*	

4	Ermera	Letefoho	DRY LAND CROPS **S3:** Corn, Wheat, Mung Bean, Chickpea	INDUSTRY **S2:** Arabica Coffee **S3:** Tobacco, Quinine FRUITS **S2:** Apple, Mango, Pineapple **S3:** Papaya , Guava, Starfruit, Watermelon, Cantaloupe, Melon, Jackfruit, Soursop, Custard Apple, Breadfruit, Snake Fruit, Sapodilla, Longan, Mangosteen, Strawberry, Carica, Persimmon , Kepayang, Banana, Orange, Avocado, Passion Fruit, Grape VEGETABLES **S2:** Petsai, Caisim, Spinach **S3:** Lobak, *Lettuce*, Eggplant, Bit, Vegetable Tomato, Carrot, Garlic, Red Chili, Bell Pepper, Cabbage, Green Beans, Long Bean, Bitter Melon, Broccoli, Petai, Potatoes, Kailan, Shallot FLOWERS **S2:** Rose **S3:** Ylang-Ylang, Tuberose, *Hairgrass*, Gladiol, Aster, Sunflower SPICES & MEDICINE **S3:** Vanilla, Lemongrass, Vetiver Root, Aromatic Ginger, Turmeric, Galangal, Jatropha		**S3:** Grazing

5	Ermera	Railaco	DRY LAND CROPS **S2:** Corn, Wheat, Soy Bean, Peanut, Mung Bean, Cowpea, Chickpea, Iles-Iles, Hui **S3:** Sorghum, Cassav, Sweet Potato, Taro	INDUSTRY **S2:** Robusta Coffee, Tobacco, Sugarcane **S3:** Coconut, Cotton, Kapok, Quinine FRUITS **S2:** Papaya, Mango, Starfruit, Durian, Duku, Jackfruit, Soursop, Custard Apple, Breadfruit, Snake Fruit, Sapodilla, Longan, Mangosteen, Pineapple, Persimmon, Kepayang, Banana, Orange, Avocado, Grape **S3:** Apple, Rambutan, Guava, Watermelon, Cantaloupe, Melon, Strawberry, Carica, Passion Fruit VEGETABLES **S2:** *Lettuce*, Petsai, Caisim, Spinach, Petai **S3:** Eggplant, Bit, Vegetable Tomato, Red Chili, Bell Pepper, Cabbage, Green Beans, Long Bean, Cucumber, Bitter Melon, Broccoli, Asparagus, Kailan, Shallot FLOWERS **S2:** Rose, Ylang-Ylang, Tuberose, *Hairgrass*, Gladiol, Aster **S3:** Sunflower SPICES & MEDICINE **S2:** Candlenut, Vanilla, Aromatic Ginger, Turmeric, Galangal, Jatropha **S3:** Pepper, Lemongrass, Vetiver Root, Cardamom	**S3:** Teak, Mahogany, Agathis, Altingia, Albizia, Leucaena, *Eucalyptus*, Melaleuca	

Descriptions: S1: Highly Suitable, S2: Moderately Suitable, S3: Marginallly Suitable, N: Not Suitable

11.2 FOOD CROP POTENTIAL ZONES

Ermera District has substantial potential for the development of food crops that can support national food security and reduce dependence on imports. Agroclimatic zoning indicates that this District has extensive areas suitable for the development of dryland food crops, particularly upland rice (rainfed), as well as other food crop commodities such as corn, wheat, soybean, peanut, cassava, sweet potato, and taro **(Figure 11.3).** Each Sub-District has distinct characteristics and potential, allowing for site-specific management to maximize productivity and sustainability.

Food crops in this area are a priority in efforts to achieve food self-sufficiency. Given the extensive land potential, the development of upland rice (rainfed) is the main component of this strategy. Rainfed rice plays an important role, with development covering 72.89 km² in most of Ermera District. Hatolia Sub-District stands out with the largest area of rainfed rice fields, reaching 43.16 km², making it the center of seasonal rice production. The monomodal rainfall regime in this area enables rainfed rice to grow well, although long-term success requires drought-tolerant rice varieties and efficient water management strategies. Other Sub-Districts such as Atsabe, Ermera, and Railaco also make significant contributions to rainfed rice production, thereby supporting national food needs in a sustainable manner.




Figure 11.3 Food Crop Development Potential

The extensive dryland agriculture in Ermera District provides major opportunities for food crop diversification. With an area reaching 197.35 km², dryland agriculture forms the backbone of food security. Hatolia Sub-District ranks first, with 80.34 km² of dryland, enabling large-scale production of corn, sorghum, peanut, cowpea, cassava, taro, and horticultural crops. Dryland in Ermera Sub-District, with an area of 40.16 km², offers the second largest potential for commodities such as corn, mung beans, cowpea, chickpea, cassava, and hui, while Atsabe, Letefoho, and Railaco also have considerable potential for root and tuber crops such as cassava and sweet potato.

A. Production Estimates for Major Food Crops (Corn, Rice, and Root and Tuber Crops)

The potential of the agricultural sector in Ermera District is reflected in significant production data for several key commodities. According to the 2021 Crop and Food Security Assessment Mission (CFSAM), corn is one of the leading commodities, with a total cultivated area of 2,000 ha and production of 5,000 t, even in the absence of second-season production. In addition to corn, rice is also one of the main commodities, with a planted area of 660 ha and total production of 1,200 t, without a second cropping season. This production highlights the important role of corn and rice in supporting food security in the district.

Furthermore, Ermera District has substantial potential in the production of root and tuber crops, with total production reaching 3,000 t. When combined, total cereal-equivalent production, a standard unit for measuring harvests from different types of crops, reaches 7,160 t. These data reflect the high food production capacity in Ermera, which can be strengthened through improved land management and diversification of agricultural outputs.

With structured and sustainable management efforts, Ermera District can become a resilient food production center, not only to meet local needs but also to support national food security more broadly. The considerable potential of this area can be optimized through synergy between government, policymakers, and local communities so that the benefits are shared by all stakeholders.

B. Food Security

Food security in Ermera District is one of the key aspects that reflects the area's significant potential to meet local food needs. With its strengths in the agricultural sector, Ermera produces several main commodities such as corn, rice, and root and tuber crops, which serve as staple foods for the local population. Efforts continue to be made to ensure that this food production meets local needs while creating sustainable food stability.

Land resource management in Ermera District is carried out using a science-based approach that incorporates agroclimatic zoning to determine the commodities most suited to the land characteristics. This approach allows land to be used efficiently while supporting the sustainability of the agricultural sector in the area. In addition, this strategy opens opportunities for diversification of agricultural products, such as horticultural and industrial crops, which can increase the economic value of the district.

The success of the agricultural sector in Ermera District is closely linked to effective collaboration between government, policymakers, and local communities. With appropriate policies and integrated management, the area has strong potential to continue increasing its contribution to local and national food security. In addition to being a primary food producer, Ermera also has substantial opportunities to enhance community welfare through a sustainable agricultural sector.

XII. RECOMMENDATIONS

12.1 LAND MANAGEMENT RECOMMENDATIONS

The recommendations outlined in this report are based on the findings of a comprehensive study aimed at exploring the potential of Ermera District for the development of the agriculture, horticulture, plantation, forestry, and grazing sectors. Through a thorough land suitability evaluation, regional zoning has been identified as the foundation for designing land management strategies. These strategies are focused on achieving three main pillars: food security, economic sustainability, and environmental protection. Based on the analysis, the total area is divided into six main categories: agroforestry, which covers 56.22% of the total area; mixed plantations, which cover 25.69%; rainfed rice fields, covering 9.49%; irrigated rice fields, covering 0.01%; grazing areas, covering 0.28%; and protected forests, which cover 8.32% of the total area. This distribution reflects the region's diverse biophysical potential and underscores the importance of a tailored approach to managing each zone.

The food production zone plays a strategic role in supporting national food security. Areas identified as key food production centers, such as Hatolia Sub-District, are expected to become the main rice granary of Ermera District. With the optimization of irrigation networks, focused soil fertility management, and the adoption of sustainable agricultural technologies, this food zone can directly contribute to the achievement of SDGs related to the eradication of hunger and the improvement of rural livelihoods.

The agroforestry and protected forest zones, which together account for 64.54% of the total area, represent critical areas for economic diversification through the development of high-value commodities. Regions such as Sub-District Atsabe, Ermera, Hatolia, Letefoho, and Railaco have been identified as having significant potential for industrial crops such as robusta coffee, arabica coffee, and cacao, as well as horticultural crops like mango, rambutan, and spinach. The integrated agroforestry systems, coupled with horticultural crops, not only enhance land productivity but also play a key role in soil and water conservation, reducing erosion risks, and supporting climate change adaptation.

The forestry zone in Ermera District encompasses protected forest areas designed as ecosystem conservation zones, with a focus on biodiversity protection, water resource management, and climate change mitigation. These protected forest areas are recommended for comprehensive development across the entire district as a strategic effort to reduce greenhouse gas emissions, increase carbon stocks, and maintain ecosystem stability. Additionally, the potential for production forests planted with teak, mahogany, and albizia is proposed as part of efforts to add economic value and engage local communities in sustainable forest management.

This strategy directly supports the Sustainable Development Goals (SDGs), particularly in the areas of food security, climate change, and water resource preservation. By integrating scientific approaches and zoning-based management systems, these recommendations are expected not only to provide concrete solutions to the agrarian challenges faced by Timor-Leste but also to foster balanced sustainable development that harmonizes economic and ecological needs. In efforts to improve productivity and sustainability in the agricultural sector, addressing limiting factors remains a top priority. Conditions such as shallow effective soil depth, poor drainage, erosion threats, and the presence of surface rocks require targeted solutions to maximize land potential. Recommendations for improving these limiting factors have been prepared as the basis for implementing land suitability enhancement for agricultural and forestry commodity development, as further outlined in **Table 12.1.**

Table 12.1 Recommendations for Improvement Efforts on Each Limiting Factor

No	Land Quality/Characteristics	Type of Improvement Measure	Management Level
1.	**Temperature (tc)** - Average annual temperature	No improvement possible. Replacement with suitable commodities/varieties.	Not improveable
2.	**Water availability (wa)** - Rainfall/year - Rainfall during the growing period	Irrigation/construction of small reservoirs/drip irrigation. Planting Pattern/Planting Calendar Management	Moderate, high
3.	**Rooting medium (rc)**		
	- Drainage	Improvement of the drainage system, such as construction of drainage channels and ridges/raised beds.	Moderate, high
	- Texture	No direct improvement possible; constraints can be mitigated by adding organic matter.	High
	- Effective depth	Generally not improvable, except in soft and thin hardpan layers that can be broken up during land preparation.	Moderate, high
	- Coarse Fragments	Depends on the amount and distribution in the soil profile. If the amount is less than 35 %, it is referred to as an obstructing layer (root-impeding) and can be addressed by adding organic matter and applying minimum tillage. If the amount is more than 90 %, it is referred to as a restricting layer (root-restricting) and is difficult to improve.	High
4.	**Nutrient retention (nr)**		
	- Cation Exchange Capacity	Addition of organic matter.	Moderate, high
	- Base Saturation	Liming and addition of organic matter.	Moderate, high
	- pH	Liming when soil pH is low, whereas for high pH sulfur or ammonium sulfate (ZA) can be applied.	Moderate, high
	- C-organic	Addition of organic matter/organic fertilizer and returning crop residues to the soil.	Moderate, high

5.	Nutrient Availability (na) - Total-N - Available - P - Available - K	 N fertilization (urea and ammonium sulfate/ZA) P fertilization (SP-36 and TSP) K fertilization (KCl) Compound fertilizer (NPK)	 Low, Moderate, High Low, Moderate, High Low, Moderate, Highs
6.	Erosion Hazard (eh) - Slope (%) - Erosion Hazard	Erosion control, terracing, contour planting, planting of cover crops, application of mulch/crop residues, implementation of agroforestry.	Moderate, high
7.	Flood Hazard (fh) - Height - Duration	Construction of flood protection dikes, construction of drainage channels to accelerate water removal, construction of infiltration wells.	High
8.	Land Preparation (lp) - Surface Rock (%) - Rock Outcrops (%)	If the amount is small, rocks are removed; if the amount is high or very high, apply no-tillage (TOT), construct planting holes, and add organic matter.	Moderate, high
9.	Improvement of technical cultivation practices	Plot establishment, pruning, and maintenance/care.	Moderate, high

Descriptions:

- *Low management level: Management can be carried out by farmers with relatively low costs.*
- *Moderate management level: Management can be carried out by intermediate-level farmers and requires medium capital*
- *Intermediate-level agricultural techniques.*
- *High management level: Management can only be carried out with relatively large capital and is generally implemented by the government or large or medium-scale companies.*

12.2 GLOBAL RECOMMENDATIONS

These recommendations are designed to provide strategic guidance based on comprehensive data for policymakers in Ermera District. The main focus is on the management of conservation sectors and the sustainable utilization of weeds. The proposed approach aims not only to address complex ecological challenges but also to integrate management strategies that support food security, environmental sustainability, and the improvement of community welfare.

One of the significant challenges is the weed *Chromolaena odorata (C. odorata),* known for its invasive biological characteristics and exceptional regenerative ability. Conventional approaches, such as eradication, often prove ineffective, costly, and risk exacerbating existing ecosystem degradation. Conversely, a sustainable utilization approach offers an innovative solution by turning this threat into an opportunity that provides economic, social, and ecological benefits.

Through the synergy between soil conservation, agroforestry, and innovative weed management, this strategy offers a holistic solution to optimize available natural resources. This approach not only aims to enhance land productivity but also creates lasting positive impacts on the environment and society. With a new paradigm focused on utilizing *C. odorata*, these recommendations are expected to make a tangible contribution to sustainable development in Ermera District.

A. New Paradigm: Utilization of *Chromolaena odorata*

The eradication approach to the weed *Chromolaena odorata* (*C. odorata*) has faced numerous challenges that hinder its success. One major obstacle is the rapid regeneration ability of the remaining roots and stems, combined with the prolific seed production, making it difficult to eradicate this weed entirely. Additionally, the use of herbicides in eradication efforts poses risks to ecosystem health, worsening environmental quality overall. Destructive practices, such as slash-and-burn, which remain common, also have the potential to accelerate land degradation. Therefore, a shift in paradigm towards a more innovative and sustainable approach is needed to manage this weed in a way that provides benefits to both ecology and economy.

One recommended approach is the sustainable utilization of *C. odorata* to create significant economic value. The biomass of this weed can present a great opportunity, especially in marginal areas like Timor-Leste. Biomass from *C. odorata* can be processed into organic fertilizer or vermicompost, which has been shown to improve soil fertility in an environmentally friendly way. Furthermore, extracts from this plant have the potential to be used as raw materials for pharmaceutical and health products, due to their proven antimicrobial, anti-inflammatory, and anticancer properties. Additionally, *C. odorata* biomass can also be utilized for biochar production or plant-based fuel, helping to reduce dependency on fossil fuels while simultaneously creating new business opportunities for rural communities.

The success of this strategy's implementation heavily depends on the empowerment of local communities. Training and education are necessary to provide practical knowledge on how to process biomass into organic fertilizers, biochar, or herbal products. Furthermore, collaboration between government, academia, and the private sector is crucial in developing simple technologies based on multidisciplinary research to support the utilization of this weed. The fertilizer, pharmaceutical, and energy industries can be strategic partners in supporting the production and marketing of *C. odorata*-based products, thereby directly improving community welfare.

Policy and regulatory support are also key elements for the sustainability of this strategy. Inventory and mapping are needed to determine priority areas for effective weed management. Economic incentives can be provided to farmers and entrepreneurs involved in sustainable utilization, while socialization and education should be enhanced to raise public awareness of the potential benefits of this plant. Through an integrated strategy, the sustainable utilization of *C. odorata* can become an innovative solution that not only addresses ecological challenges but also supports economic development based on environmental balance in Ermera District.

B. Soil and Water Conservation

The soil and water conservation recommendations have been formulated to optimize the efficiency of implementation through a blend of technical, ecological, and economic aspects. The main strategy proposed is the implementation of agroforestry systems as a long-term solution that integrates conservation with agricultural production. This approach includes agro-silviculture, which combines food crops with timber trees, silvopastoral systems that integrate trees with pasture for livestock feed, and agro-silvopastoral systems that integrate crops, trees, and livestock on the same land. This strategy not only strengthens the sustainability of the agricultural sector but also improves land use efficiency.

In addition, simple technologies such as biopore holes and drainage channels are recommended to enhance water infiltration while reducing waterlogging in horticultural and rocky land areas. This system also plays a key role in increasing groundwater reserves, which are crucial in areas with erratic rainfall patterns. Given that Ermera District is dominated by steep slopes, erosion mitigation strategies such as terracing and the use of ground cover vegetation are particularly relevant. Terracing limits surface water flow, enhances infiltration, and allows for crop cultivation on sloping land. Meanwhile, ground cover vegetation such as legumes or deep-rooted grasses helps stabilize soil and reduce erosion risks.

Overall, this strategy is expected to have a significant impact on natural resource management, create a balance between land productivity and ecosystem conservation, and support food security and environmental sustainability in Ermera District.

C. Organic Matter Addition and fertilization

Much of the land in Ermera District faces the challenge of low organic matter content, which directly impacts soil fertility, water retention capacity, and the activity of microorganisms crucial to soil ecosystems. To address this constraint, several strategic measures have been designed to sustainably improve soil quality.

The first step is to utilize local organic waste, such as manure, compost, and biochar. These materials can help improve soil structure, support detoxification processes, and enhance biological activity that strengthens soil resilience. This strategy is particularly effective for improving the quality of land used in the development of key commodities such as upland rice, sorghum, chili, and tomatoes.

The second approach involves using organic litter as mulch applied to the soil surface. This technique helps retain soil moisture, improves water retention, and reduces the risk of erosion. This method is especially suitable for use on flat land or land prone to drought, including sloped areas vulnerable to soil loss.

The third step includes applying site-specific fertilizers to increase the nitrogen, phosphorus, and potassium content in the soil. Recommended macro-fertilizer doses include 200 kg NPK ha^{-1}, 175 kg Urea ha^{-1}, 40 kg SP-36 ha^{-1}, and 100 kg KCl ha^{-1}. This approach is tailored to the local soil fertility characteristics to support optimal growth, particularly in rice cultivation.

By implementing a combination of these strategies, it is expected that the challenge of low organic matter content in the soil can be effectively addressed. This will not only improve land productivity but also support the sustainability of the agricultural sector in Ermera District.

D. Drainage Management and Shallow Soil Depth

The rocky and sloping areas in District often face challenges of poor drainage and shallow soil depth, which can hinder land productivity and ecosystem health. To address these issues, several technical solutions have been formulated to improve land management efficiency while supporting environmental sustainability.

One key strategy is improving drainage channels using bundling or raised beds. This technology is designed to prevent waterlogging, support efficient water management, and improve soil aeration. This approach is ideal for horticultural land, as it can enhance water use efficiency and reduce excessive water loss.

Another approach is the creation of biopore holes, pits, or infiltration wells, which help improve water infiltration in rocky soils. These holes also serve as storage for organic materials such as plant residues or other organic fertilizers, which help improve drainage quality and increase water storage capacity during the dry season.

Additionally, another recommended solution is the creation of deep planting holes, especially for industrial crops such as coconut and timber trees. This technique allows plant root systems to penetrate shallow soil layers, providing stability and supporting optimal growth even on soils with limited effective depth.

The implementation of this combination of strategies is expected to provide practical and sustainable solutions to the challenges in rocky and sloped areas, while also optimizing land potential to support the sustainability of the agricultural sector.

E. Alternative Crop Development on Rocky Land

Rocky land requires an adaptive approach that maximizes the potential of crops in challenging conditions. One recommended strategy is the utilization of medicinal and spice plants, such as turmeric, ginger, galangal, and aromatic ginger, which thrive well in rocky environments. Planting these commodities under the canopy of forestry trees not only provides additional protection for the crops but also enhances land use efficiency, supporting ecosystem sustainability.

Another significant strategy is the use of ground cover plants, such as legumes and setaria grass. These plants are effective in reducing erosion risks, increasing organic matter content, and improving soil structure in vulnerable areas. This approach also helps maintain soil stability while supporting the continued ecological functions of the land.

Furthermore, deep-rooted industrial crops, such as coconut and timber trees, are ideal for rocky land. These plants have high tolerance for shallow soil depth and optimal growth in rocky soils, thus offering both economic and ecological value.

By implementing these adaptive strategies, the potential of rocky land can be maximized to support agricultural productivity while ensuring environmental sustainability.

F. Implementation Strategy

The implementation strategy designed based on regional zoning aims to optimize land management in Ermera District. The zoning, which includes irrigated rice fields (0.01%), rainfed rice fields (9.49%), dryland agriculture/mixed plantations (31.44%), agroforestry (32.26%), grazing areas (0.28%), and protected forests (8.32%), serves as the primary foundation for developing strategies focused on food security, economic sustainability, and environmental conservation. Based on this zoning approach, the following steps are relevant:

1. Optimization of Food Production Zone

The food production zone, which includes irrigated and rainfed rice fields, plays a strategic role in supporting national food security:

a) **Irrigation Network Enhancement**: Efforts to expand the irrigation network in areas such as Sub-Disrict Hatolia and Railaco, which have the potential to become key rice production centers in Ermera District. Micro-irrigation technology and the construction of water reservoirs are prioritized to support intensive cropping systems.

b) **Management of Rainfed Rice Fields:** The use of drought-resistant rice varieties in areas with monomodal rainfall patterns. Training for farmers on simple water management systems, such as rainwater harvesting technologies, is essential to improve yields in this zone.

c) **Crop Diversification**: In addition to rice, this zone can also be used to grow other food crops such as maize, soybeans, and cassava. This diversification aims to broaden food sources and enhance national food security.

2. Utilization of Agroforestry and Protected Forest Potential

The agroforestry and protected forest zones, covering 64.54% of the total area, offer strategic opportunities for economic diversification and ecosystem conservation. The recommended strategies include:

a) Agroforestry System Development:
   - Industrial Crops: Development of high-value commodities such as robusta coffee, arabica coffee, cacao, and coconut in areas like Ermera Sub-District.
   - Horticulture: Integration of fruit crops such as avocado and mango, as well as vegetables like tomatoes and chili, with forestry trees on sloping land to support soil conservation and diversify crops.

b) Protected Forest Management:
   - Protected forests are focused on biodiversity protection, climate change mitigation, and sustainable land resource management.
   - Production Forests: The development of teak, mahogany, and albizia trees as sources of economic value, carried out in collaboration with local communities to promote sustainable forest management.

c) Utilization of Weed Biomass: The weed *Chromolaena odorata* is proposed for use as organic fertilizer or bioenergy, which would reduce pressure on forest ecosystems and support more efficient resource use.

3. Infrastructure and Technology Development

a) Supporting Infrastructure Development:
   - Water Reservoirs and Rainwater Storage: Constructed in rainfed rice field and dryland areas to improve water availability during dry seasons.
   - Drainage Channels: To control water runoff in sloping areas, particularly in agroforestry zones, to reduce erosion and improve water management efficiency.

b) Use of GIS and Remote Sensing Technology:
   - GIS technology is employed to support more accurate spatial planning based on land suitability data.
   - Remote sensing is used to evaluate land cover changes and the effectiveness of conservation strategies.

4. Capacity Building for Communities

a) Training and Education:
   - Training programs for farmers to support better land management practices across all zones.
   - Education on integrating productive crops in agroforestry zones to expand income opportunities.

b) **Community Empowerment**: Formation of farmer groups based on zoning to encourage community participation in implementing conservation strategies efficiently.

c) **Empowerment of Women**: Special training for women in managing agroforestry products and weed biomass, supporting social inclusion and enhancing family income.

5. Weed Management Strategy: Utilization of *Chromolaena odorata*

a) Utilization of Biomass:
   - *C. odorata* biomass is processed into organic fertilizer to improve soil fertility and biochar as local bioenergy.

b) **Development of Herbal Products:** The potential of C. odorata as a traditional medicine is explored through collaboration between the government and the pharmaceutical sector.

c) **Multistakeholder Collaboration:** Partnerships between government, academia, and the private sector focus on research and development of weed management technologies.

6. Integrated Spatial Zoning

Spatial zoning approaches enable more effective land use:

a) **Protected Forest and Conservation Zones**: Areas with slopes >45% are prioritized for ecosystem preservation.

b) **Agroforestry Zones**: Areas with slopes 15–45% focus on timber and horticulture crops to support soil conservation and crop diversification.

c) **Intensive Agriculture Zones:** Flat land to slopes of 15% is utilized for the production of major food crops.

7. Policies and Incentives

a) Economic Incentives:
   - Subsidies or bonuses are provided to farmers implementing soil conservation technologies.

- Microcredit is available to support agroforestry businesses or weed utilization based on sustainable technologies.

b) **Zoning Regulations:** Land use rules are adjusted according to suitability zoning outcomes to ensure sustainable management.

8. Monitoring and Evaluation

a) **Data-Based Monitoring:** GIS technology is used to assess land changes and the effectiveness of conservation strategies.

b) **Participatory Evaluation**: Local communities, stakeholders, and the government are involved in the evaluation process to ensure the strategy remains relevant to community needs.

This strategy is designed to integrate scientific approaches, cutting-edge technology, and community participation. Based on regional zoning, it is expected to address conservation challenges, enhance food security, and promote sustainable economic development in Ermera District.

12.3 CONCLUSIONS AND RECOMMENDATIONS FOR THE LIVESTOCK SECTOR

Based on the results of the geospatial analysis, Ermera District has significant potential to be developed as a pilot project for the poultry industry. Its strategic location near the city of Dili provides high accessibility to key infrastructure, such as transportation networks and energy sources. Additionally, the availability of relatively large land areas and favorable topography facilitate the construction of modern production facilities, such as closed poultry houses and waste processing areas. The stable rainfall pattern and optimal temperatures in the region further support the health and productivity of poultry sustainably. With support from local government policies and a strong local market, an integrated poultry industry model can be implemented, covering the entire value chain from upstream to downstream. This pilot project is expected to optimize production efficiency, reduce logistical costs, and improve the welfare of farmers through the adoption of modern technologies. The implementation of this project will also serve as a catalyst for local economic development and ensure a stable supply of animal protein to the urban population.

12.4 CONCLUSIONS AND RECOMMENDATIONS FOR THE FRESHWATER FISHERIES SECTOR

Ermera District has significant water resource potential, particularly in the hilly areas rich in permanent springs. These resources have been utilized in both government-run and community-based fish breeding and growing activities. Ermera Sub-District, especially Talimoro Village, has an established fish breeding infrastructure based on concrete ponds, with water supplied from three permanent springs, serving as the center for tilapia fry production. Large-scale fish farming activities, as found in Tocoluli Village, involve over 800 pond units. However, the farming systems applied are still semi-permanent and face various technical challenges, such as low survival rates (50%), unstable water quality, and high feed costs.

Based on the actual and potential land suitability analysis in Ermera Sub-District, the species with the highest current suitability scores are catfish (3.21), carp (3.19), and tilapia (3.16). All freshwater fish species analyzed have the potential to reach maximum suitability values (3.4) if interventions are made on limiting factors, such as slope and rainfall.

1. Specific Location-Related Issues and Technical Recommendations

The challenges in Ermera District include steep slopes and the imbalance between temperature and rainfall, especially during the dry season. Additionally, production costs, particularly for feed, are high due to the lack of distribution support and subsidies. Farmers also face difficulties accessing technical training, while the seed center has not yet optimally functioned as a training and technology hub.

The seed center in Talimoro Village should be optimized as a fish farming training center, including water and fry quality testing, superior seed distribution, and strengthening institutional support by assigning permanent extension workers for technology transfer. In Tocoluli Village, productivity and cost efficiency can be improved through simple water quality management (temperature, clarity), probiotic use, local feed diversification, and technical assistance for farmers.

2. Pilot Project Site Selection

Talimoro Village is recommended as the pilot project site for tilapia and catfish fry breeding, given the stability of its water sources and the existing infrastructure with an intensified technology approach (e.g., probiotic application, simple sensor-based water quality management, and feed efficiency).

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

a) **Fish Feed Subsidy or Distribution Program**: A regional fish feed subsidy or distribution program is needed to address the high cost of feed, supported by outreach on organic agricultural waste-based feed nutrition.

b) **Permanent Aquaculture Extension Team:** The establishment of a permanent aquaculture extension team in Ermera District is essential for training and assisting farmer groups, particularly in promising Sub-Disrict such as Sub-District Ermera, Hatolia, and Letefoho.

c) **Improvement of Production Roads, Small Irrigation, and Market Access:** Improvements to production roads, small-scale irrigation systems, and market access are required to enhance the economic value of aquaculture. The government can assist in establishing cooperatives or joint ventures for fish farmers in Tocoluli Village and surrounding areas.

Integration of aquaculture into local food security programs should consider the currently low per capita consumption of farmed fish. The government can incorporate local aquaculture products into school food programs, nutrition assistance, and public food procurement to boost local fish consumption and support market stability.

REFERENCE

Abilio da Fonseca, Mário Marques Cabral, Walter Oliveira Soares (2023), Timor-Leste Country Synthesis Report. Report to the Arafura and Timor Seas Ecosystem Action Phase 2 (ATSEA-2) Project, Bali, Indonesia, 178pp.

Administrasaun Munisípiu Ermera. (2025). Dadus Munisípiu Ba Dezenvolvimentu Sustentável Iha Timor-Leste : Autoridade Munisipal Ermera. Portal Municipio. https://ermera.gov.tl/

Amam, A., & Harsita, P. A. (2019). Tiga pilar usaha ternak: Breeding, feeding, and management. Jurnal Sain Peternakan Indonesia, 14(4), 431-439.

Arriola, K. G., Queiroz, O. C. M., Romero, J. J., Casper, D., Muniz, E., Hamie, J., & Adesogan, A. T. (2015). Effect of microbial inoculants on the quality and aerobic stability of bermudagrass round-bale haylage. *Journal of dairy science*, *98*(1), 478-485.

ATSEA Program. Arafura and Timor Seas Ecosystem Action Program. Diakses pada 13 Maret 2025, dari https://atsea-program.com

Baryła, A., & Pierzgalski, E. (2008). Ridged Terraces – Functions, Construction And Use. *Journal of Environmental Engineering and Landscape Management*, *16*(2), Ia - If.

Bettencourt, E. M. V., Tilman, M., Narciso, V., Carvalho, M. L. d. S., & Henriques, P. D. d. S. (2015). The Livestock Roles in the Wellbeing of Rural Communities of Timor-Leste. Revista de Economia e Sociologia Rural, 53, 63-80.

Bose, A.N., Ghosh, S.N., Yang, C.T., & Mitra, A. (1991). Coastal Aquaculture Engineering. Chapman and Hall, Inc., New York, 365 pp.

Boyd, C.E. (1995). Bottom Soils, Sediment, and Pond Aq

Bray, W.A., Lawrence, A.L., & Leung-Trujillo, J.R. (1994). The effect of salinity on growth and survival of Penaeus vannamei, with observations on the interaction of IHHN virus and salinity. Aquaculture, 122: 133-146.

Browne, M., Goncalo, L., Ximenes, A., Lopes, M., & Erskine, W. (Year). *The place of ceremonial observances in sustainable livelihoods of crop producers in Timor-Leste*.

Brunet, J., Murphy, G. C., Terra, R., Figueiredo, J., & Serey, D. (2014, May). Do developers discuss design?. In *Proceedings of the 11th Working Conference on Mining Software Repositories* (pp. 340-343).

Carney, D. (1999). *Approaches to sustainable livelihoods*. DFID.

Chanratchakool, P., Turnbull, J.F., Funge-Smith, S., & Limsuwan, C. (1995). Health Management in Shrimp Ponds. Second edition. Aquatic Animal Health Research Institute, Department of Fisheries, Kasetsart University Campus, Bangkok, 111 pp.

Cogné, M., & Lescuyer, G. (2024). The role of agroforestry in farmers' strategies and its contribution to the well-being of rural people in Timor-Leste. *Forests, Trees and Livelihoods*. https://doi.org/10.1080/14728028.2023.2298986

Day, M. D., Brito, A. A., Da Costa Guterres, A., da Costa Alves, A. P., Paul, T., & Wilson, C. G. (2013). Biocontrol of *Chromolaena odorata* in Timor Leste. Proceedings of the Eighth International Workshop on Biological Control and Management of Chromolaena odorata and other Eupatorieae, Nairobi, Kenya, 1-2 November 2010

Deng, C., Zhang, G., Liu, Y., Nie, X., Li, Z., Liu, J., & Zhu, D. (2021). Advantages and disadvantages of terracing: A comprehensive review. *International Soil and Water Conservation Research*, *9*(13). https://doi.org/10.1016/j.iswcr.2021.03.002

DFID. (1999a). *Sustainable livelihoods guidance sheet*s. Department for International Development.

DFID. (1999b). *Sustainable livelihoods framework*. Department for International Development.

Do, F. H., La, N., Bergkvist, G., Dahlin, A. S., Mulia, R., Nguyen, V. T., & Öborn, I. (2023). Agroforestry with contour planting of grass contributes to terrace formation and conservation of soil and nutrients on sloping land. *Agriculture, Ecosystems & Environment*, *345*. https://doi.org/10.1016/j.agee.2022.108323

Fanzo, J., & Bonis-Profumo, G. (2019). *Timor-Leste Agriculture Sector Review*. The Ministry of Agriculture and Fisheries The Democratic Republic of Timor-Leste.

FAO, Food and Agriculture Organization. (2015). *The state of food insecurity in the world 2015*. Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/3/a-i4646e.pdf

FAO. (2021). *Special Report – 2021 FAO Crop and Food Supply Assesment Mission (CFSAM) to the Democratic Republic of Timor Leste. Food and Agriculture Organization of the United Nations.* Diakses pada halaman https://doi.org/10.4060/cb5245en

FAO. (2021). *Special Report – 2021 FAO Crop and Food Supply Assesment Mission (CFSAM) to the Democratic Republic of Timor Leste. Food and Agriculture Organization of the United Nations.* Diakses pada halaman https://doi.org/10.4060/cb5245en

Food and Agriculture Organization (FAO). (1976). A framework for land evaluation. In FAO Soil Bulletin 32. Soil Resources Management and Conservation Service and Water Development Division, FAO, Rome, 72 pp

Food and Agriculture Organization. Strategies for sustainable animal agriculture in developing countries. Retrieved April 13, 2025, from https://www.fao.org/4/T0582E/T0582E27.html

Fox JJ. (2003). Drawing from the past to prepare for the future: Responding to the challenges of food security in East Timor. In Da Costa H, Piggin C, Cruz CJ, Fox JJ. eds. Agriculture: new directions for a new nation East Timor (Timor-Leste). ACIAR Proceedings No. 11. Canberra, Australia: Australian Centre for International Agricultural Research. pp 105–114.

Ganguly, R. K., Al-Helal, M. A., & Chakraborty, S. K. (2022). Management of invasive weed Chromolaena odorata (Siam weed) through vermicomposting: An eco-approach utilizing organic biomass valorization. *Environmental Technology & Innovation*, *28*, 102952.

Godinho, M., Artati, Y., Bhatta, K. P., Maulana, A. M., Baral, H., & Finlayson, R. F. (Eds.). (2023). *Agroforestry manual for Timor-Leste*. Center for International Forestry Research (CIFOR) and Nairobi, Kenya: World Agroforestry (ICRAF).

Haidar, J. (2009*). Sustainable livelihoods: A conceptual framework for rural development*.

Hastari, I. F., Kurnia, R., & Kamal, M. M. (2017). Analisis Kesesuaian Budidaya KJA Ikan Kerapu Menggunakan SIG Di Perairan Ringgung Lampung. Jurnal Ilmu Dan Teknologi Kelautan Tropis, 9(1), 151–159.

Hossain, M.S., Chowdhury, S.R., Das, N.G., & Rahaman, M.M. (2007). Multi-criteria evaluation approach to GISbased land-suitability classification for tilapia farming in Bangladesh. Aquaculture International, 15(6): 425- 443.

Huang, B., Yuan, Z., Zheng, M., Liao, Y., Nguyen, K. L., Nguyen, T. H., Sombatpanit, S., & Li, D. Q. (2022). Soil and Water Conservation Techniques in Tropical and Subtropical Asia: A Review. *Sustainability*, *14*(9). https://doi.org/10.3390/su14095035

Ilyas, S., Cholik, F., Poernomo, A., Ismail, W., Arifudin, R., Daulay, T., Ismail, A., Koesoemadinata, S., Rabegnatar, I N.S., Soepriyadi, H., Suharto, H.H., Azwar, Z.I., & Ekowardoyo, S. (1987). Petunjuk Teknis bagi Pengoperasian Unit Usaha Pembesaran Udang Windu. Pusat Penelitian dan Pengembangan Perikanan, Jakarta, 100 hlm. Ismail, A., Poernomo

Ismail, A., Poernomo, A., Sunyoto, P., Wedjatmiko, Dharmadi, & Budiman, R.A.I. (1993). Pedoman Teknis Usaha Pembesaran Ikan Bandeng di Indonesia. Pusat Penelitian dan Pengembangan Perikanan, Jakarta, 73 hlm

Iswan, S., Zhiddiq, S. dan Maru, R. (2019). Evaluasi kesesuaian lahan untuk tanaman cengkeh (Eugenia Aromatica L) di DAS Takapala Sub DAS Hulu Jeneberang Kabupaten Gowa. Journal of UNM Geographic 2(2):121-129, doi:10.26858/ugj.v2i2.11575

Jamatia, K., Mazumder, R., Ikbal, A. M. A., & Manna, K. (2024). Chromolaena odorata (L.) RM King & H. Rob. (Asteraceae): A Comprehensive Scientific Review of Phytochemistry, Pharmacology, and its medicinal potential. *Pharmacological Research-Natural Products*, 100098.

Jong, J., & Pereira, A. (2021). Evaluating the opportunities for smallholder livestock keepers in Timor Leste.

Karthik, M., Suri, J., Saharan, N., & Biradar, R.S. (2005). Brackish water aquaculture site selection in Palghar Taluk, Thane district of Maharashtra, India, using the techniques of remote sensing and geographical information system. Aquacultural Engineering, 32: 285- 302.

La N, Catacutan DC, Roshetko JM, Mercado AR, Tran HM, Vu TH, Thuong PH, Do VH, Phuong NM. (2016). Agroforestry Guide for Sloping Lands in Northwest Viet Nam. Viet Nam: World Agroforestry Centre (ICRAF). 33p

Liu, Z. Y., Yang, H. L., Yan, Y. Y., Seerengaraj, V., Zhang, C. X., Ye, J. D., and Sun, Y. Z. (2021). Supplementation of Tributyrin, Alone and in Combination with Fructooligosaccharide in High Soybean Meal Diets for Shrimp (Litopenaeus vannamei): Effects on Growth, Innate Immunity and Intestinal Morphology. Aquaculture Nutrition, 27(2) : 592-603.

López-Angarita J, Hunnam KJ, Pereira M, Mills DJ, Pant J, Teoh SJ, Eriksson H, Amaral L and Tilley A. (2019). Fisheries and aquaculture of Timor-Leste in 2019: Current knowledge and opportunities. Penang, Malaysia: WorldFish. Program Report: 2019-15.

MAF. (2018). Final Country Report of the Land Degradation Neutrality Target Setting Programme in Timor-Leste.

Mills DJ, Tilley A, Pereira M, Hellebrandt D, Fernandes AP and Cohen PJ. (2017). Livelihood diversity and dynamism in Timor-Leste: Insights for coastal resource governance and livelihood development. Marine Policy vol 82, 206-215.

Ministry of Agriculture and Fisheries. (2022). National strategy and technical guidelines agroforestry development TimorLeste (DRAFT). Dili, Timor-Leste: Ministry of Agriculture and Fisheries.

Molyneux, N., Da Cruz, G. R., Williams, R. L., Andersen, R., & Turner, N. C. (2012). Climate change and population growth in Timor Leste: Implications for food security. *Ambio*, *41*(8), 823-840. DOI 10.1007/s13280-012-0287-0

Mugwedi, L. (2020). Harnessing opportunities provided by the invasive Chromolaena odorata to keep it under control. *Sustainability*, *12*(16), 6505.

Muhammad, Z. N. (2021). *Potensi dan strategi pengembangan peternakan sapi potong dilahan bekas tambang emas martabe PT. Agincourt Resources Kecamatan Batang Toru Kabupaten Tapanuli Selatan* (Doctoral dissertation, Universitas Andalas).

Mustafa, A., Rachmansyah, & Hanafi, A. (2007a). Kelayakan lahan untuk budi daya perikanan pesisir. Dalam Prosiding Simposium Nasional Hasil Riset Kelautan dan Perikanan tahun 2007. Badan Riset Kelautan dan Perikanan, Jakarta, hlm. 1-29.

Mustafa, A., Radiarta, I N., & Rachmansyah. (2011). Profil dan Kesesuaian Lahan Akuakultur Mendukung Minapolitan. Sudradjat, A. (Ed.) Pusat Penelitian dan Pengembangan Perikanan Budidaya, Jakarta, 91 hlm.

Mustafa, A., Sapo, I., Hasnawi, & Sammut, J. (2007b). Hubungan antara faktor kondisi lingkungan dan produktivitas tambak untuk penajaman kriteria kelayakan lahan: 1. Kualitas air. J. Ris. Akuakultur, 2(3): 289-302.

National Statistic Directorate, Ministry of Finance. (2019). Timor Leste Agriculture Census 2019. Government of the Democratic Republic of Timor Leste.

National Statistics Directorate, Ministry of Finance. (2019). *Timor-Leste Agriculture Census 2019*. Government of the Democratic Republic of Timor-Leste.

Neely, C., Sutherland, K., & Johnson, J. (2004). Sustainable livelihoods and rural development: A new approach to poverty alleviation. International Institute for Environment and Development.

Pant, J., Philipps, M., Andrew, N. (2020). Aquaculture in Timor-Leste. Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security.

Pant, J., Teoh, S. J., Gomes, J., Pereira, M., & Kam, S. P. (2020). Report of the 2nd Timor-Leste National Aquaculture Forum. *Monographs*.

Paudel, S., Baral, H., Rojario, A., Bhatta, K. P., & Artati, Y. (2022). Agroforestry: Opportunities and Challenges in Timor-Leste. *Forests*, *13*(1). https://doi.org/10.3390/f13010041

Payne, D., O'reilly, M., & Williamson, D. (1993). The K88 fimbrial adhesin of enterotoxigenic Escherichia coli binds to beta 1-linked galactosyl residues in glycosphingolipids. *Infection and immunity*, *61*(9), 3673-3677.

Peniwiratri, L., & Arbiwati, D. (2022, April). Potential of kirinyuh (Chromolaena odorata) and cow manure for available phosphor supply on sandy beach soil and P uptake by onion (Allium cepa L.). In *IOP Conference Series: Earth and Environmental Science* (Vol. 1018, No. 1, p. 012026). IOP Publishing.

Poernomo, A. (1979). Budidaya udang di tambak. Dalam Soegiarto, A., Toro, V., & Soegiarto, K.A. (Eds.) Udang: Biologi, Potensi, Budidaya, Produksi, dan Udang sebagai Bahan Makanan di Indonesia. Lembaga Oseanologi Nasional-Lembaga Ilmu Pengetahuan Indonesia, Jakarta, hlm. 77-174.

Poernomo, A. (1988). Pembuatan Tambak Udang di Indonesia. Seri Pengembangan No. 7. Balai Penelitian Perikanan Budidaya Pantai, Maros, 40 hlm

Ponce-Palafox, J., Martinez-Palacios, C.A., & Ross, L.G. (1997). The effect of salinity and temperature on the growth and survival rates of white shrimp, Penaeus vannamei, Boone, 1931. Aquaculture, 157: 107-115.

Poxton, M. (2003). Water quality. In Lucas, J.S. & Southgate, P.C. (Eds.) Aquaculture: Farming Aquatic Animals and Plants. Blackwell Publishing Ltd., Oxford, p. 47-73.

Priyanto, D. (2016). Strategi pengembalian wilayah Nusa Tenggara Timur sebagai sumber ternak sapi potong. *Jurnal Litbang Pertanian*, *35*(4), 167-178.

Quintarelli, V., Radicetti, E., Allevato, E., Stazi, S. R., Haider, G., Abideen, Z., Bibi, S., Jamal, A., & Mancinelli, R. (2022). Cover Crops for Sustainable Cropping Systems: A Review. *Agriculture*, *12*(12). https://doi.org/10.3390/agriculture12122076

Risna, D., Jamili, M. A., & Syam, J. (2022). Sistem Perkandangan Ayam Broiler di Closed House Chandra Munarda Kabupaten Takalar. *Jurnal Sains dan Teknologi Industri Peternakan*, *2*(1), 16-22.

Ritung, S., Nugroho, K., Mulyani, A., & Suryani, E. (2011). Petunjuk teknis evaluasi lahan untuk komoditas pertanian. *Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian, Puslitbangtanak, Badan Penelitian dan Pengembangan Pertanian. Bogor. hlm*, *159*.

Rokhayati, U. A., & Evadewi, F. D. (2023). Evaluasi Manajemen Pemberian Pakan Terhadap Budi Daya Ternak Sapi Potong Di Kecamatan Bongomeme Kabupaten Gorontalo. Media Peternakan, 24(2).

Rokhayati, U. A., & Evadewi, F. D. (2023). Evaluasi Manajemen Pemberian Pakan Terhadap Budi Daya Ternak Sapi Potong Di Kecamatan Bongomeme Kabupaten Gorontalo. *Media Peternakan*, *24*(2).

Rusdi, M., Roosli, R., & Ahamad, M. S. S. (2015). Land suitability evaluation for settlement based on soil bearing capacity in Banda Aceh, Indonesia. *Advances in Environmental Biology*, 53-57.

Salvador, M., Bhujel, R. C., Shrestha, K., DoCarmo, A. D., & Pant, J. (2024). Fish production and socio-economic benefits of small-scale aquaculture in Timor-Leste after and during project implementation. *Journal of Applied Aquaculture*, *36*(1), 24-46.

Sawyer, C.N. & McCarty, P.L. (1978). Chemistry for Environmental Engineering. Third edition. McGraw-Hill Book Company, New York, 532 pp.

Schmidt, F.H. & Ferguson, J.H.A. (1951). Rainfall type based on wet and dry period ratios for Indonesia with Western New Gurinea. Verhandelingen, 42: 77 pp. plus figures

Silva, H. (1954). Panorama Pecuária de Timor. Revista de Ciências Veterinárias, XLIX, 348-349.

Skerman, V. B. D., QUINN, G. R., Sly, L. I., & Hardy, J. V. (1977). Sheath formation by strains of Herpetosiphon species. *International Journal of Systematic and Evolutionary Microbiology*, *27*(3), 274-278.

Stickney, R.R. (2000). Tilapia Culture. In Stickney, R.R. (Ed.) Encyclopedia of Aquaculture. John Wiley & Sons, Inc., New York, p. 934-941.

Toban, E. W., Sunarta, I., & Trigunasih, N. (2016). Analisis Kinerja Daerah Aliran Sungai Berdasarkan Indikator Penggunaan Lahan Dan Debit Air Pada Das Unda. J. Trop. Agroecotechnol, 5, 394-404.

Tatipikalawan, J. M. (2017). Karakteristik sosial ekonomi dan kendala produksi dan pemasaran ternak kambing lakor di Pulau Lakor Provinsi Maluku. Jurnal Budidaya Pertanian, 13(2), 68-73.

Tatoli. (2022, 25 Juli). MAP memberikan pelatihan tentang cara memelihara ikan kepada kelompok petani di Covalima. Diakses dari https://tatoli.tl/2022/07/25/map-fo-formasaun-oinsa-hakiak-ikan-ba-grupu-agrikultor-iha-covalima/?form=MG0AV3

TOMAK. Chicken & egg: The hard choices. Diakses pada 13 Maret 2025, dari https://tomak.org/chicken-egg-the-hard-choices/?form=MG0AV3

Westaway, J., Quintao, V., & de Jesus Marcal, S. (2018). Preliminary checklist of the naturalised and pest plants of Timor-Leste. *Blumea-Biodiversity, Evolution and Biogeography of Plants*, *63*(2), 157-166.

Widarti & Sukaesih. (2015). Keragaman jenis pakan ternak dan ketersediaannya di wilayah sekitar Taman Nasional Gunung Halimun Salak. 1(7): 1565-1569.

Williams, R. L., Bacon, S., Ferreira, A., & Erskine, W. (2018). An approach to characterise agricultural livelihoods and livelihood zones using national census data in Timor-Leste. *Experimental Agriculture*, *54*(6), 857-873. doi:10.1017/S0014479717000436

Williamson, G. (1993). Pengantar peternakan di daerah tropis.

Wiryanta, B.T.W., Sunaryo, Astuti, & Kurniawan, M.B. (2010). Budi Daya & Bisnis Ikan Nila. PT Agromedia Pustaka, Jakarta, 210 hlm.

RESEARCHER BIOGRAPHIES

A. Researchers from Udayana University

Prof. Dr. Ir. Ni Made Trigunasih, M.P. (Team Leader)

Education: B.Eng./B.Sc. in Agricultural Engineering (Udayana University); M.Sc. in Soil Science (Padjadjaran University); Ph.D. in Agricultural Science (Udayana University).
Academic Rank: Full Professor.
Teaching Experience: 1986–present.
Areas of Expertise: Land resource development grounded in environmental conservation; land suitability evaluation; soil and water conservation; sustainable land-use planning and management.
Collaboration Contact: trigunasih@unud.ac.id |+62 819-3311-8689

Ir. I Dewa Made Arthagama, M.P.

Education: B.Eng./B.Sc. in Agricultural Engineering (Udayana University); M.Sc. in Soil Science (Brawijaya University/ Gadjah Mada University).
Teaching Experience: 1986–present.
Areas of Expertise: Applied soil science and agricultural land management; soil fertility and soil quality improvement; soil–water management for sustainable production systems.

Prof. Dr. Ir. I Made Mega, M.S.

Education: B.Sc. in Soil Science (Udayana University); M.Sc. in Soil Science (Gadjah Mada University); Ph.D. in Agricultural Science (Udayana University).
Academic Rank: Full Professor.
Teaching Experience: 1985–present.
Areas of Expertise: Industrial crop production; crop management and productivity enhancement; management of growth factors and crop production systems.

Ir. I Nyoman Dibia, M.Si

Education: B.Sc. in Soil Science (Udayana University); M.Sc. in Geomorphology (Gadjah Mada University).
Areas of Expertise: Geomorphology and landscape analysis; landform interpretation for land-resource planning; mapping and zoning support based on regional physical characteristics.

Ir. Moh Saifulloh, S.P., M.Sc.

Education: B.Sc. in Soil and Environmental Science, Faculty of Agriculture (Udayana University); M.Sc. in Geography and Remote Sensing (Gadjah Mada University).
Professional Engineer (Insinyur): Geodesy / Regional Mapping.
Areas of Expertise: GIS and remote sensing; thematic mapping and spatial analysis; integration of field data and satellite imagery; geodetic and mapping support for research and territorial management.

Dr. Ir. Ni Luh Gde Sumardani, S.Pt., M.Si., IPM.

Education: B.Sc. in Animal Science (Udayana University); M.Sc. in Reproductive Biology, Graduate School (IPB University); Ph.D. in Animal Science (Udayana University).
Teaching Experience: 2002–present.
Professional Engineer (Insinyur): Animal Husbandry.
Areas of Expertise: Livestock reproductive biology; reproductive and production management; science-based strengthening of livestock systems; improvement of livestock production performance.

I Wayan Darya Kartika, S.Pi., M.Si.

Education: B.Sc. in Fisheries Product Technology (IPB University); M.Sc. in Fisheries Product Technology, Graduate Program (IPB University).
Teaching Experience: 2018–present.
Areas of Expertise: Fisheries product technology (processing and quality assurance); post-harvest handling; product development; value addition for fisheries commodities.

B. Researchers from MAPPF, Timor-Leste

Eng. Celestino Luis Moreira, MP
Areas of Expertise: Land suitability assessment; soil classification; regional potential mapping.
Role/Responsibilities: Technical coordinator for field operations and program development for regional potential mapping and land suitability evaluation in Timor-Leste (2024/2025).

Eng. Cesar Jose da Cruz, PG-GSRNA
Areas of Expertise: Research management; field supervision; monitoring and quality assurance of field observations.
Role/Responsibilities: Research Director responsible for strategic guidance and for ensuring that field observations are implemented in accordance with the work plan and methodological standards.

Eng. Nilton J.A. de Carvalho Ribeiro, M.Sc
Areas of Expertise: Geographic Information Systems (GIS); spatial database management; integration of spatial and attribute datasets.
Role/Responsibilities: GIS and database technician responsible for database preparation, updating, and management, and for providing technical support for analysis, mapping, and reporting.

RESEARCH ASSISTANTS

1. Hagai Bryant Silalahi, S.P.
2. Gieselle E. Immaculata Siahaan, S.P.
3. Santisima Fransiska, S.P.
4. Nindya Oktaviani, S.P.
5. Ni Putu Sindy Wahani Putri, S.P.
6. Ni Made Elyariani, S.P.
7. I Komang Putra Astika, S.P.
8. Ni Luh Manik Sugiantini, S.Pt.
9. Faisal Peru Sihombing, S.Pi.

FIELD SURVEYORS (MAPPF, TIMOR-LESTE)

1. Eng. Deolindo de Oliveira
2. Eng. Armandina Marcal, M.Sc
3. Eng. Julio Correia, MP
4. Eng. Marcos C. Vidal, M.Sc
5. Eng. Juliberto dos Santos, MP
6. Eng. Ida Pereira dos Santos, MP
7. Eng. Leandro C. R. Pereira, M.Sc
8. Eng. Jose da Costa R. Freygen, M.Sc
9. Eng. Julieta Lidia
10. Eng. Pedro Bere
11. Eng. Telesforo F. Moniz
12. Eng. Florindo M. Neto
13. Eng. Inacio Savio Pereira
14. Mario D. Dos Santos Vinhas, L.Ed
15. Eng. Mario Tavares Goncalves
16. Eng. Paulo da Costa

17. Eng. Zito Aquino
18. Eng. Apolinario Ximenes
19. Jacinto Boavida, S.Pt
20. Eng. Francisco Gusmao
21. Eng. Adelia C. G. dos Santos, M.Pt
22. Edson V. X. Da Luz
23. Eng. Antonio Vicente
24. Jorge Amaral
25. Tinoco Vicente
26. Hermenegildo A. da Silva
27. Gilberto Rogerio

Ermera Municipality

Ermera Municipality has strong potential for comprehensive agricultural development, characterized by zones dominated by agroforestry systems (56.22%), followed by dryland agriculture or mixed gardens (25.69%). Protected and conservation forest areas account for 8.32%, while rainfed rice fields cover 9.49% of the area. The extent of irrigated rice fields is extremely limited (0.01%), as are grazing areas, which occupy only 0.28%.

Based on land suitability evaluation, potential wetland food crop commodities include irrigated rice, while dryland food crops comprise sorghum and soybean. The horticultural sector shows promising prospects for fruit commodities such as strawberry, orange, and snakefruit, as well as highland vegetables including carrot and broccoli. For spice and medicinal crops, Ermera Municipality has potential for the development of nutmeg and vanilla. The agricultural industrial sector is dominated by Arabica coffee and Robusta coffee, positioning Ermera Municipality as the largest coffee development center in Timor-Leste, particularly in Letefoho Administrative Post. The forestry sector supports the development of mahogany and teak.

In the livestock sector, Ermera Municipality has potential for the development of cattle, pig, and buffalo, and also presents significant opportunities to be developed as a pilot project for poultry industry development. Freshwater fisheries activities are present in Talimoro Village (Ermera Administrative Post), with leading commodities including catfish and tilapia. Regional development in Ermera Municipality is directed toward multisector integration based on integrated farming systems and aquaculture intensification. Riheu Village is recommended as a pilot project site for sustainable integrated agricultural development, aimed at strengthening national food security, particularly in support of Timor-Leste's integration into ASEAN.