Land Suitability Evaluation & Regional Potential Mapping

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

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

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FOREWORD

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

With deep gratitude to God Almighty for His blessings and grace, we warmly welcome the publication of this book entitled "Land Suitability Evaluation and Mapping of Regional Potential for Agricultural Commodity Development in Aileu District, Timor-Leste." This book is the result of close collaboration between the Ministry of Agriculture, Livestock, Fisheries, and Forestry of Timor-Leste and the Faculty of Agriculture, Udayana University, fully supported by the Government of Timor-Leste through Contract No. 24/MAPPF/IV/2024.

Aileu District is one of the key areas in Timor-Leste with considerable potential in the agricultural sector. The District consists of four Sub-Districts, namely Aileu Vila, Laulara, Liquidoe, and Remexio. With geographical conditions in which around 25.32 % of the area is flat, especially along the southern part, Aileu has substantial potential for the development of the forestry and agricultural sectors that can significantly support economic development in Timor-Leste.

Aileu District also has fertile soils of various types, including Inceptisols, which are dominant with an area of 50.56 %, followed by Mollisols at 9.55 %, Entisols at 2.35 %, and alluvial soils at only 0.79 %. The fertile Inceptisols, with medium to high organic matter content, are suitable for the production of food crops, horticulture, and plantation crops, which will directly increase agricultural production and the local community's economy.

In the current global context, the challenges of food security and climate change require all of us to take concrete steps toward sustainable land resource management. This book comes at the right time to provide both scientific and practical guidance for land management in Aileu District. We hope that it will serve as a primary reference for planning sustainable agricultural development, in line with the achievement of the Sustainable Development Goals (SDGs), particularly in ending hunger (SDG 2), promoting inclusive economic growth (SDG 8), and conserving terrestrial ecosystems (SDG 15).

We extend our highest appreciation to the entire team of researchers, academics, and all parties who have worked hard in preparing this book. May this work bring tangible benefits for community welfare, economic growth, and environmental sustainability in Aileu District and in Timor-Leste as a whole.

Sincerely,

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

PREFACE

We offer our praise and gratitude to God Almighty for His blessings and grace, which have enabled us to complete this book entitled “Land Suitability Evaluation and Mapping of Regional Potential for Agricultural Commodity Development in Aileu District, Timor-Leste.” This book is the outcome of a research collaboration between the Ministry of Agriculture, Livestock, Fisheries, and Forestry of Timor-Leste and the Faculty of Agriculture, Udayana University, supported by the Government of Timor-Leste through Contract No. 24/MAPPF/IV/2024.

Based on spatial data for Timor-Leste, which is predominantly characterized by dryland, this dryland potential, if managed optimally and sustainably, can provide a solution to support national food security programs, enhance economic growth, and reduce poverty through the creation of employment opportunities in rural areas. However, dryland has its own challenges due to its vulnerability to land degradation, such as erosion, landslides, and declining soil fertility, as well as the limited development of land management practices. Therefore, sustainable dryland management is an urgent need to ensure the continuity of productivity and the conservation of land resources.

This study was designed to provide relevant solutions and strategic recommendations for land resource management in Aileu District. With its characteristics that include extensive plains in the southern part of the District, Aileu has substantial potential for the development of the forestry and agricultural sectors, which can significantly support economic development in Timor-Leste. In addition, the presence of Inceptisols, Mollisols, Entisols, and alluvial soils provides strong support for improving sustainable agricultural productivity.

We hope that this book will serve as an important guide for local government, academics, practitioners, and the wider community in managing land effectively and responsibly. We extend our thanks to all parties who have supported the implementation of this research. We also hope that this book will make a tangible contribution to agricultural development, improved community welfare, and environmental conservation in Aileu District and in Timor-Leste as a whole.

Timor-Leste, 2025

Prof. Dr. Ir. Ni Made Trigunasih, M.P.
Expert Leader

EXECUTIVE SUMMARY

A. OVERVIEW OF THE STUDY AREA

This chapter presents a general overview of Aileu District as an important background for evaluating land suitability and development potential for food crops, horticulture, forestry, industrial crops, spices and medicinal plants, livestock feed, and grazing. The information includes demography, soil types, land use, and existing field conditions, based on an in-depth and comprehensive data-driven approach.

1. Demography

Aileu District comprises four Sub-Districts, namely Aileu Vila, Laulara, Liquidoe, and Remexio. The District borders Dili District to the north, Manatuto District to the east, Ermera District to the west, and Ainaro District to the south. With an area of 790.76 km^2, Aileu is inhabited by 61,180 people distributed across various localities. The geographical conditions, dominated by hills and forest, make this District important for development planning based on conservation and sustainable natural resource management.

2. Soil Types: Basis for Land Suitability Evaluation

The dominant soil types in Aileu District are Inceptisols and Mollisols. Inceptisols, which are relatively young soils, are suitable for seasonal crops and horticulture. Mollisols are known as highly fertile soils suitable for intensive agriculture. These soil types are distributed across all four Sub-Districts and strongly influence the crops cultivated and the land management strategies adopted.

3. Geological Formation

The geological formation of the area is dominated by the Aileu Formation (68.37 %), which is distributed across three Sub-Districts, namely Aileu Vila, Laulara, and Remexio. This geological formation affects soil characteristics, topography, and land suitability for various land uses, particularly agriculture and conservation.

4. Land Use: Ecosystem Dynamics and Human Activities

Land use in Aileu District is still dominated by forest areas, which account for 51 % of the total area. The remaining land consists of agricultural areas in the form of dryland fields, mixed gardens, and smallholder plantations. The main commodities cultivated include coffee, orange, and horticultural vegetables.

Agricultural land is generally located on hillside slopes and narrow valley floors along rivers, with further development potential if managed in an integrated and sustainable manner.

5. Slope Gradient: Risks and Potential

The area has topography dominated by steep to very steep slopes, that is, greater than 25 %. This results in a high risk of erosion, especially when land is used for cultivation without conservation measures. Land with low slope gradient is very limited but strategically important for agricultural intensification and infrastructure development. Therefore, soil and water conservation practices are essential in land management.

6. Agroclimatic Zones: Grouping of Regional Potential

Aileu District is divided into three main agroclimatic zones: zone B (humid), zone C (somewhat dry), and zone A (very dry). Zone C is the most extensive and covers almost the entire area, making it suitable for the development of horticulture and seasonal crops. Zone B occurs only in a small part of Remexio, whereas zone A is very limited. This agroclimatic zoning provides an important basis for commodity selection and adaptation of farming systems.

7. Field Conditions: Constraints and Potential

Field observations show that most land has been used for cultivating crops such as coffee, orange, and vegetables. However, the level of utilization remains low and not yet optimal. There is still a large extent of idle land and shrubland that has not been cultivated. In addition, farming methods remain largely traditional, with limited technology and production inputs. This leads to low productivity and farmer income and therefore requires technological interventions and extension support.

8. Utilization of Chromolaena odorata: From Challenge to Opportunity

The invasive weed Chromolaena odorata has spread widely, especially in idle land and shrubland. This plant grows rapidly, is aggressive, and competes with main crops, while also reducing soil fertility. Its presence increases the risk of land fires during the dry season. Management of this weed requires an integrated approach, including mechanical control, economic utilization, and farmer education so that it is not left unmanaged.

B. RESEARCH METHODS

This study used a survey-based approach, including field observations, interviews, and laboratory analyses, to carry out a comprehensive land suitability evaluation. Homogeneous Land Units were used as the basis for delineating the area, derived from thematic maps such as land use, soil type, climate, geology, and slope gradient. Data analysis was supported by Geographic Information System (GIS) technology to produce accurate and informative map visualizations.

Research Procedure

1. Soil Sampling
    a. Composite soil samples were collected at the following depths:
        - **0–30 cm** for seasonal crops
        - **0–60 cm** cm for perennial crops
2. Laboratory Analyses
    The physical and chemical soil parameters analyzed included:
    a. Soil organic carbon (SOC, %) 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 potentiometric method (H2O 1:2.5).
    e. Available P and available K (ppm):
        - *Bray-1 method for pH < 7 (with conversion to mg/g).*
        - *Olsen method for pH > 7 (with conversion to mg/100 g).*
    f. Salinity (dS/m) using a potentiometer (H2O 1:2.5).
    g. Cation exchange capacity (CEC, cmol(+) kg^-1) and base saturation (%) using 1 N NH4OAc at pH 7.
    h. Soil fertility status based on the PPT method (1995).
    i. Erosion hazard, assessed through field observations and the Universal Soil Loss Equation (USLE).

Stages of Land Suitability Classification

1. Actual Land Suitability Classification
    The initial classification was carried out to assess land suitability under existing conditions without improvements.

2. Recommended Land Improvements

   Improvement measures were identified to address limiting factors, including management of inputs such as fertilizers and soil and water conservation techniques.

3. Potential Land Suitability

   Land suitability was assessed after considering improvements, in order to maximize land potential.

4. Zoning of Commodity Development Potential

   Zoning was determined by integrating the Agroecological Zones of Aileu District, based on land suitability and specific agroecosystems.

C. CHARACTERISTICS OF AGRICULTURAL AND FOREST LAND

1. Temperature

Air temperature is a key parameter in land suitability evaluation, with analysis based on the integration of field measurements and the SRTM Digital Elevation Model (DEM) using the Braak approach. Air temperature in Aileu District generally falls within the > 21 to 24 °C category, particularly in Aileu Vila Sub-District, which is located in highland areas. Temperature tends to be lower at higher elevations because the air is thinner and retains less heat. Laulara Sub-District has areas with temperatures in the > 24 to 26 °C range, indicating warmer zones. The > 18 to 21 °C category is also widely distributed and again dominated by Aileu Vila Sub-District.

2. Rainfall

Rainfall analysis based on CHIRPS data shows that rainfall in Aileu District is highly variable. Aileu Vila Sub-District dominates the 2,000 to 2,500 mm category due to its higher topography. Remexio and Aileu Vila Sub-Districts dominate the 1,500 to 2,000 mm category, while Laulara Sub-District is dominated by rainfall of 1,000 to 1,500 mm. This variation reflects differences in elevation and position relative to the sea, which influence rainfall distribution.

3. Dry Months

Most of Aileu District experiences 5 to 6 dry months, especially in Aileu Vila and Remexio Sub-Districts. More than 6 dry months occur only in Laulara Sub-District, indicating areas with a longer dry season. Distance from the coastline and topographic position are key factors controlling the distribution of dry months. These patterns directly affect cropping strategies and water management.

4. **Elevation**

Most of Aileu District lies at higher elevations, particularly in Aileu Vila, Remexio, and Liquidoe Sub-Districts. High-elevation areas are important for conservation and water catchment, but they are less suitable for intensive agriculture. Smaller parts of Laulara and Liquidoe Sub-Districts are at low to medium elevations, which are more suitable for agriculture and settlement. Land use planning must balance ecological functions with development needs.

5. **Drainage**

Soil drainage in Aileu District is generally good, especially in Aileu Vila and Liquidoe Sub-Districts. This is largely due to Inceptisols, which have granular structure and adequate pore space. Poorly drained soils occur only in some parts of Aileu Vila, and moderately well drained conditions occur in Remexio Sub-District. These conditions support plant growth by providing sufficient soil aeration.

6. **Coarse Fragment**

Coarse fragment content of less than 3 % dominates in Aileu Vila Sub-District, indicating soil textures that are favorable for agriculture. The 3 to 15 % category is widely distributed across the district and is still considered safe for cultivation. Remexio Sub-District is dominated by the 35 to 60 % coarse fragment category, indicating coarser soils. Contents greater than 60 % occur only in a small part of Aileu Vila Sub-District.

7. **Effective Soil Depth**

Soil depth of 30 to 60 cm occurs only in Aileu Vila Sub-District and is one of the dominant categories there. Depths of 60 to 90 cm also dominate in Aileu Vila. Depths of 90 to 120 cm are widely distributed across all Sub-Districts and dominate in Remexio and Laulara. Effective soil depth is influenced by erosion, topography, and rock weathering.

8. **Surface Rock**

Most of the area has surface rock content of less than 5 %, which dominates in Aileu Vila Sub-District. This indicates land that is relatively free of rock and suitable for agriculture. Surface rock contents of 5 to 15 % and 15 to 40 % are also found in Aileu Vila, while contents greater than 40 % occur in Aileu Vila, Liquidoe, and Remexio Sub-Districts. High surface rock content can restrict root penetration and soil tillage.

9. Rock Outcrops

Rock outcrops of less than 5 % dominate, especially in Aileu Vila Sub-District, indicating land conditions that are generally favorable for agriculture. Categories of 5 to 15 % and 15 to 25 % rock outcrops are also found in Aileu Vila. Rock outcrops greater than 25 % are the next most prevalent category after < 5 %, and occur in Aileu Vila and Remexio Sub-Districts. Areas with high rock outcrop density are prone to erosion and have significant limitations for cultivation.

10. Flood Hazard

Most of the area has no flood hazard due to generally good drainage. Aileu Vila and Laulara Sub-Districts dominate the "no flood hazard" category. Low to very low flood hazard is also found in several Sub-Districts. High flood hazard occurs only in a small part of Aileu Vila and Liquidoe Sub-Districts.

11. Soil Texture

The dominant soil texture is clay loam, with 28.2 % clay, 42.7 % silt, and 28.9 % sand. Aileu Vila Sub-District has clay textures, whereas Laulara Sub-District has silty clay loam textures. Liquidoe and Remexio Sub-Districts are dominated by clay textures, which have good capacity to retain water and nutrients. Soil texture affects drainage and the soil's ability to retain moisture.

12. Soil pH

Soil pH in Aileu District ranges from 5.11 to 5.55, classified as acidic to slightly acidic. The highest pH occurs in Aileu Vila (5.55), and the lowest in Liquidoe (5.11). Soil acidity influences nutrient availability and microbial activity. Acid soils tend to limit phosphorus availability and can cause metal toxicity.

13. Total Nitrogen

Total nitrogen content is classified as moderate, with the highest value in Aileu Vila (0.41 %) and the lowest in Liquidoe (0.34 %). Total nitrogen is influenced by organic matter and microbial activity. Most nitrogen is still in organic forms that are not immediately available to plants. Mineralization processes are required to convert nitrogen into forms that can be taken up by crops.

14. Available Phosphorus

Available phosphorus content varies among Sub-Districts, with the highest value in Aileu Vila (4.14 ppm) and the lowest in Liquidoe (3.44 ppm). Available phosphorus is affected by pH, organic matter, and microbial activity. Although total phosphorus may be high, only a small fraction is available to plants. Phosphorus availability is particularly important during the early growth stages of crops.

15. Available Potassium

Available potassium is very high in all Sub-Districts, with the highest value in Remexio (14.61 me/100 g) and the lowest in Aileu Vila (3.95 me/100 g Potassium is important for water regulation and plant physiological processes. Clay soils have greater capacity to retain potassium than sandy soils. High available potassium supports optimal growth when other nutrients are also adequate.

16. Electrical Conductivity and Potential Toxicity

Electrical conductivity (EC) values are very low to low, with the highest value in Aileu Vila (0.58 dS m^-1) and the lowest in Liquidoe (0.38 dS m^-1). EC reflects the salt content of the soil, which, if excessive, can interfere with plant water uptake. Low salinity soils support optimal plant growth. Potential toxicity remains low and does not threaten land fertility.

D. SOIL FERTILITY STATUS

Based on the results of soil fertility status analysis in Aileu District, about 53.05 % of the area, or 389.58 km², falls into the low fertility category, while another 276.56 km² (37.66 %) is classified as very low. This indicates nutrient limitations and the need for interventions such as fertilization or land rehabilitation. Only a small portion of the area has moderate fertility, namely 57.91 km² (7.89 %), and very little is classified as high, at 10.29 km² (1.40 %).

The spatial distribution of soil fertility in each Sub-District also shows significant variation. Aileu Vila Sub-District and Laulara Sub-District are dominated by low fertility, with areas of 183.23 km² (24.95 %) and 60.35 km² (8.22 %), respectively. Meanwhile, Liquidoe Sub-District and Remexio Sub-District have larger areas with very low fertility, at 93.38 km² (12.72 %) and 88.64 km² (12.07 %), respectively, indicating a need for more intensive soil fertility management in these two areas.

E. EROSION AND AGROFORESTRY-BASED CONSERVATION

1. Soil Erosion

Soil erosion analysis plays an important role in land suitability evaluation for agriculture because erosion not only reduces soil productivity but also disrupts ecosystem sustainability and causes environmental degradation. In Aileu District, erosion severity ranges from very slight to very severe, influenced by factors such as topography, soil type, vegetation cover, and land management practices.

Remexio Sub-District falls into the very severe erosion category because it is dominated by steep slopes and Inceptisols, which are naturally more prone to erosion due to their easily disintegrated structure and clay-dominated texture. This condition is exacerbated by limited vegetation cover and the lack of land conservation techniques, so that high surface runoff can easily transport soil particles and accelerate the loss of fertile topsoil.

In contrast, areas such as Aileu Vila Sub-District exhibit very slight erosion because they lie in relatively flat terrain. However, when slope gradient increases to 2 to 5 %, erosion risk rises significantly, potentially reaching up to eight times higher at a slope of 10 %, and continues to increase as slope angle becomes steeper. Therefore, soil conservation strategies tailored to local conditions are required to control erosion rates and maintain land functions sustainably.

2. Agroforestry-Based Conservation

Agroforestry-based conservation is a key and effective approach to addressing soil erosion in Aileu 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**: Reducing surface runoff and maintaining soil moisture.
b) **Improving soil fertility**: Through the contribution of organic matter from crop residues, including leaves and plant litter.
c) **Managing water sustainably**: Retaining water in 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 to protect soil from surface runoff.
b) **Improved water infiltration**: Tree root systems increase soil capacity 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 harvests.

3. Implementation of Agroforestry in Aileu District

Agroforestry systems implemented in Aileu District vary by agroecological zone. Examples of effective agroforestry-based conservation systems include:

a) **Alley cropping**: Planting crops between rows of trees on steep slopes to reduce erosion.

b) **Living hedges**: Using erosion-tolerant plants such as Vetiver Root to reinforce slopes.

c) **Live stakes**: Using perennial plants such as Leucaena as living stakes to control erosion, combined with pepper and other climbing crops.

d) **Layered planting**: Combining trees, shrubs, and groundcover 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) **Increase agroforestry practices** in erosion-prone zones, such as Aileu Vila, Laulara, Liquidoe, and Remexio Sub-Districts.

b) **Implement spatial data based management** to identify priority locations for conservation interventions.

c) **Strengthen farmer** capacity through training and adoption of modern agroforestry techniques.

d) **Reinforce soil conservation** policies by integrating agroecology-based approaches into land use planning.

F. AGRICULTURAL LAND SUITABILITY

1. Land Suitability Evaluation

a. Aileu Vila Sub-District

- Food crops that can be developed include soybean, peanut, sweet potato, and others.
- Horticultural vegetable crops such as shallot, chili, and broccoli can be developed on land with land suitability classes from moderately suitable (S2) to marginally suitable (S3). Horticultural fruit crops such as mango, Custard Apple, and pineapple also show potential in Aileu Vila Sub-District, as do horticultural flower crops such as rose, Aster, and Sunflower.
- Spice and medicinal plants such as Aromatic Ginger and Vetiver Root can be developed.

- Industrial crops such as Robusta Coffee and Sugarcane are considered moderately suitable.

b. **Laulara Sub-District**

- Development of dryland food crops and horticultural vegetables such as shallot, chili, and eggplant is recommended. Horticultural fruit crops such as orange, mango, and Custard Apple, as well as horticultural flower crops such as rose, Aster, and Sunflower, are considered moderately suitable for local land conditions and have good development potential.
- Spice and medicinal plants such as Cardamom and Vetiver Root can be developed in Laulara Sub-District.
- Industrial crops such as Robusta Coffee and Sugarcane have fairly good suitability.

c. **Liquidoe Sub-District**

- Liquidoe Sub-District has high potential for several food crops, such as soybean, peanut, and sweet potato, which fall into the moderately suitable class.
- In the industrial crop sector, Robusta Coffee and Sugarcane can be developed in Liquidoe Sub-District.

  Horticultural vegetables such as shallot, Bell Pepper, and chili have high potential with moderately suitable (S2) land suitability. Fruit crops such as guava, soursop, and breadfruit also show promising potential. Horticultural flower crops such as rose, Aster, and Sunflower can also be developed.
- Spice and medicinal plants such as Lemongrass, Vanilla, and Candlenut have fairly good potential.

d. **Remexio Sub-District**

- Remexio Sub-District has significant potential for the development of Robusta Coffee and Sugarcane.
- Food crops such as soybean, peanut, and sweet potato also have moderately suitable (S2) land suitability.
- In the horticulture sector, vegetable crops such as shallot, chili, and Bell Pepper show good development potential. Fruit crops such as guava, soursop, and breadfruit are also moderately suitable for cultivation. Flower crops such as rose, Aster, and Sunflower can also be developed.
- Spice and medicinal plants such as Lemongrass, Vanilla, and Candlenut can be recommended.

2. Zoning For Agricultural Commodity Development In Aileu District

This study aimed to evaluate the potential and land suitability of various land-use types in Aileu District, Timor-Leste, as a basis for planning sustainable territorial management. The analysis considered biophysical aspects, topography, soil types, and the ecological and economic functions associated with each land-use category.

a) **Dryland agriculture** covers 134.02 km², distributed on slopes of 0 to 45 % and elevations of 100 to 1,500 m above sea level, with moderately fertile Inceptisols. The monomodal climate with a 5 to 6 month dry period requires adaptive water management and drought-tolerant varieties. Commodities include cassava, peanut, chili, tomato, banana, and Robusta Coffee. Conservation techniques such as terracing and cover vegetation are strongly recommended to maintain land stability.

b) **Rainfed rice fields** cover 49.32 km² on slopes of 0 to 25 % and elevations of 800 to 1,200 m above sea level, with Entisols, Inceptisols, and Mollisols. The monomodal climate and 5 to 6 month dry season affect productivity, making water management critical. The use of farm ponds and drought-tolerant varieties is recommended to address water limitations. These rice fields are distributed across several Sub-Districts, particularly in Aileu Vila Sub-District.

c) **Irrigated rice fields** cover 12.07 km² and are found only in Aileu Vila Sub-District on slopes of 5 to 25 % and elevations of 800 to 1,200 m above sea level. The monomodal climate and limited water sources demand efficient irrigation systems. Optimization of irrigation networks and water-saving technologies such as drip irrigation are essential to maintain rice productivity. The main challenges are steep topography and limited irrigation infrastructure.

d) **Grazing areas** cover 8.25 km² on flat to gently sloping land with slopes of 0 to 5 % and elevations of 100 to 900 m above sea level. Rotational grazing is recommended to reduce the impact of trampling, which can accelerate erosion. Forage banks of Elephantgrass and the planting of tree legumes help maintain feed supply and improve soil structure. Integration of livestock and crops enhances food security and the efficiency of integrated farming systems.

G. SOLUTIONS FOR THE "DYING ORANGE" PROBLEM IN LIQUIDOE SUB-DISTRICT

These recommendations focus on addressing three main problems: soil toxicity, low nutrient retention capacity, and nutrient deficiency.

1. Neutralization of Soil Toxicity

- **Problem:** Soil pH is very acidic (4.8 to 5.0), releasing toxic aluminum (Al^3+) that damages plant roots.
- **Solution:** Application of **dolomite** ($CaMg(CO_3)_2$) is essential. Dolomite is selected because it has a dual function: raising pH (neutralizing Al^3+) and supplying calcium (Ca) and magnesium (Mg), which are severely deficient.
- **Rate and timing:** The recommended rate is **1.5 to 2.0 kg per tree**. To raise pH from 4.8 to the safe target range (pH 5.5 to 6.0), lime (dolomite) requirements generally range from **2.0 to 4.0 ton/ha (2,000 to 4,000 kg/ha).** This rate is assumed to be broadcast evenly and incorporated into the soil to a depth of 15 to 20 cm across the entire area. Application is ideally carried out 2 to 4 weeks **before** NPK fertilization so that the soil is more neutral when fertilizer is applied.

2. Building the Soil Foundation (SOC)

- **Problem:** Low soil organic carbon (SOC) makes the soil hard and unable to retain fertilizer and water (low cation exchange capacity, CEC).
- **Solution:** Addition of large amounts of **organic matter** (compost or well-decomposed manure) at the outset.
- **Rate & Timing:** The initial rate required is **10 to 20 kg** per tree. This organic material can be applied together with dolomite within the tree basin area (under the canopy).

3. Basal Phosphorus Fertilization (Addressing Fixation)

- **Problem:** Phosphorus (P) in these acidic soils is strongly "fixed" by Al and Fe and therefore unavailable to plants.
- **Solution:** Application of P fertilizer (such as **SP-36**) will be much more effective if **mixed** directly with the organic matter applied in Step 2.
- **Rate and timing:** The rate is **150 to 250 g SP-36 per tree**. Mixing with organic matter helps protect P from being fixed by the soil. This is carried out once at the beginning of the rainy season.

4. **Efficient Maintenance Fertilization (N and K)**

- **Problem:** Nitrogen (N) and potassium (K) are easily lost through leaching because the soil still has limited capacity to retain nutrients (CEC remains low).
- **Solution:** The total annual fertilizer rate (200 to 300 g urea plus 150 to 250 g KCl per tree) should not be applied in a single dose.
- **Method of application:** N and K fertilizers need to be split into three applications (for example, every 4 months). This method ensures that nutrients can be taken up efficiently by the plants before they are leached by rainfall.

H. FORESTRY POTENTIAL

Aileu District has significant potential for the development of forestry commodities, with land suitability ranging from S2 (moderately suitable) to S3 (marginally suitable). Melaleuca is classified as moderately suitable and is the most recommended commodity, while other species such as Teak, Mahogany, Agathis, Albizia, Acacia, Leucaena, Eucalyptus, and Pine remain feasible for development through adaptive management and silvicultural techniques.

The biophysical conditions of Aileu support the implementation of agroforestry systems and protection forests, with about 72.37 % of the area located on slopes of 5 to 45 % and elevations of 800 to 1,500 m above sea level. Under a monomodal climate, these conditions favor conservation-oriented cropping patterns focused on sustainability. Key commodities such as coffee play a dual role in maintaining ecological functions and improving community livelihoods. Robusta Coffee is recommended because it is more adaptive to local conditions, while Arabica coffee can still be developed with appropriate technical interventions, including selection of cooler sites, use of tolerant varieties, and the application of shade systems and soil conservation.

One strategic commodity with high economic and cultural value is sandalwood (*Santalum album* L.), which produces high-value essential oil and has important cultural significance for the people of Timor-Leste. Although its land suitability is classified as S3 (marginally suitable), sandalwood development remains promising through appropriate cultivation techniques, careful site selection, and maintenance of host trees. These efforts are in line with the national sandalwood inventory program of the Government of Timor-Leste, which aims to strengthen sustainable forest resource management, increase local economic value, and support long-term investment in the forestry sector of Aileu.

I. LIVESTOCK POTENTIAL IN AILEU DISTRICT

Remexio Sub-District has the highest ecological suitability, while Laulara Sub-District has the lowest. For poultry, however, land suitability is very high and relatively uniform across the district.

The climatic conditions of Aileu District, with an average temperature of 21.36 °C and annual rainfall of 1,935.36 mm, are highly favorable for livestock productivity and sustainable forage growth. Environmental factors such as temperature and rainfall play a major role in regulating livestock heat balance, feed availability, drinking water supply, and disease risk. Extreme temperatures, whether hot or cold, can cause stress in livestock, negatively affecting feed intake, productivity, growth, and disease resistance. Therefore, optimal environmental management is crucial to support successful livestock development in this area.

J. FISHERIES POTENTIAL IN AILEU DISTRICT

There is one main area that serves as the center of aquaculture activities. Aileu Vila Sub-District is a highland area whose main constraints for aquaculture include slope gradient, length of the dry season, and rainfall, all of which limit aquaculture development. Low water temperatures restrict the growth of tropical fish such as gourami and tilapia, while common carp is more tolerant of these conditions.

Brackish-water commodities are not recommended because of low salinity and limited access to seawater. Although most land is only marginally suitable, technical improvements such as terraced ponds and water quality management can increase land suitability, particularly for freshwater fish such as gourami, catfish, common carp, and tilapia. Aquaculture in this area is still small-scale and traditional, with non-technical constraints such as low market demand, limited capital, and weak integration with other sectors that hinder development. The inland geographical position far from the coast further restricts commodity choices, so development priorities should focus on freshwater aquaculture, accompanied by improved environmental management and technology.

K. RECOMMENDATIONS FOR THE AGRICULTURE SECTOR

1. Land Potential and Spatial Distribution

The territory of Aileu District shows localized diversity in agronomic potential. Clusters of irrigated rice fields are suitable for development in Aileu Vila Sub-District (Seloi Craic, Hoholau, Liurai, Seloi Malere, Fahiria, Saboria, Lausi, Fatubosa), while rainfed rice fields are suitable in Bandudato and Fatubosa. Intensive grazing pasture is found in Bandudato and Aisirimou, dominated by Elephantgrass (*Pennisetum purpureum*) and gamal (*Gliricidia sepium*). Spatial planning can therefore be directed toward irrigation blocks, grazing corridors, and efficient cultivation mosaics that follow contour lines and water sources.

2. Food Diversification and Cool-Highland Horticulture

Food crops (sweet potato, cassava, corn, taro, kacang tundis, porang) are widely distributed and interspersed with cool-climate vegetables (lettuce, water spinach, pakchoy, shallot, garlic, broccoli, chayote, Caisim, chili, cabbage, cauliflower, tomato, Long Beans, carrot). This combination strengthens local carbohydrate sources, enables seasonal rotation, and supplies urban markets from high-elevation zones with cool microclimates.

3. Economically Valuable Tropical Fruit

Jackfruit, banana, rambutan, mango, breadfruit, avocado, guava, orange (sweet, mandarin, pomelo, lime, limau), pineapple, soursop, snakefruit, and papaya are widely distributed and ready to be upgraded in value through strengthened post-harvest handling (grading, packaging) and improved access to cold chains so that quality losses and price volatility can be reduced.

4. Industrial Crops and Arabica Coffee

Coconut, areca nut, and Arabica coffee occur throughout the district. For Arabica coffee, soil and water conservation practices on slopes, shade from timber trees, and quality certification will increase productivity, improve cherry quality, and enhance access to premium markets.

5. Landscape Buffers: Forestry Vegetation

Groups of Pine, bamboo, kapok, gamal, Acacia, casuarina, Eucalyptus, Teak, Mahogany, Leucaena, calliandra, Sandalwood, tamarind, agarwood, sugar palm, and Albizia are distributed in Aileu Vila, Laulara Sub-District (Talitu, Madabeno), Liquidoe Sub-District (Faturilau), and Remexio Sub-District (Faturasa, Liurai, Talutaque). These clusters function as erosion-control belts, sources of organic matter, and microclimate stabilizers that reinforce the productivity of surrounding cultivated land.

6. Local Spice and Medicinal Agroforestry

The integration of Candlenut, Pepper, Turmeric, Clove, betel, Ginger, and Lemongrass with horticulture and forestry in Fahiria, Acubilitoho, Faturasa, and Acumau demonstrates an adaptive mixed-farming model. This pattern maintains soil fertility, suppresses erosion, reduces crop failure risk, and adds income streams (for example: orange–coffee–banana–spices–tubers; Candlenut–orange–Teak/Pine–coffee–calliandra; Clove–tubers–banana–avocado–mango–coffee–corn).

7. Priority Commodities and Production Clusters

Irrigated Rice, cassava, corn, banana, orange, rambutan, pineapple, leafy vegetables and cabbage-group crops, chili, and Arabica coffee are designated as priority commodities. Establishing location-specific production clusters, providing technical support, supplying improved seed, and developing tiered marketing contracts will secure economies of scale, price stability, and access to premium markets.

8. Land Improvement, Water Conservation, and Integrated Erosion Control

Sustainable productivity requires balanced fertilization based on soil testing, addition of organic matter (compost or manure), terracing and contour-aligned planting, groundcover or legume strips, thick mulching, and water conservation through farm ponds, reservoirs, and rainwater wells or storage reservoirs. This integrated package increases water and nutrient storage capacity, protects topsoil, and buffers the impacts of drought on both sloping and flat land.

9. Nutrient Management and Cropping Patterns

Gaps in fertilization practices, which generally rely only on fallen leaves at land preparation with minimal maintenance, need to be addressed through simple standard operating procedures (rates, timing, and methods of application), location-specific soil test demonstration plots, and staged nutrient recommendation cards throughout the season. A shift from single-crop monoculture to rice–rice–secondary crops rotation (for example corn or legumes) will improve soil structure, break pest cycles, and stabilize yields.

10. Specific Issu: Dieback in Rambutan

Management is directed toward orchard sanitation, selective pruning, balancing K, Ca, and Mg nutrients, shade regulation, and monitoring of pests and diseases. Integrated control demonstration plots are recommended to break inoculum sources, restore shoot vigor, and reduce yield losses.

11. Strengthening Capcity, Infrastructure, and Input Policies

Thematic farmer field schools (nutrients, micro-irrigation, Integrated Pest Management/PHT) and simple visual modules need to be aligned with improvements to farm access roads, post-harvest facilities (grading, packaging, cold chain), strengthening of cooperatives or off-takers, and policies on targeted fertilizer subsidies, incentives for organic matter (composters or dedicated pits), and microcredit for water conservation equipment so that good practices are adopted rapidly and farm production costs remain manageable.

12. Implementation Phasing and Principles of Sustainability

Quick wins include soil-test-based fertilization SOPs, rice–secondary crops rotation demonstration plots, mulching and legume strips, and improvement of small water channels. In the medium term, priorities include village-scale ponds or reservoirs, block-scale terracing, spice–coffee agroforestry, and partnerships for premium horticulture. All expansion of cultivated land must be aligned with conservation zoning, water-saving principles, maintenance of long-term soil fertility, and diversification of commodities to support the economic resilience of farm households.

L. RECOMMENDATIONS FOR THE LIVESTOCK SECTOR

1) Strategic Potential in Remexio Sub-District, Aileu District

Remexio Sub-District shows substantial potential to be developed as a breeding center for high-quality livestock in Timor-Leste, based on the results of a comprehensive evaluation of land suitability and ecological conditions.

2) Land Suitability for Forage Crops

The land suitability analysis for forage crops indicates that this area has fertile soils that support the sustainable growth of high-quality livestock forage, which forms the primary foundation for livestock productivity.

3) Availability of Natural Resources

Geographical conditions and the availability of natural resources, including access to water and natural vegetation, support year-round provision of livestock feed.

4) Optimal Climatic Conditions

Temperature and rainfall in Remexio Sub-District are relatively stable, creating a micro-environment that is ideal for livestock growth, health, and reproduction.

5) Reduced Risk of Stress and Disease

Stable climatic conditions significantly reduce the risk of heat stress and disease transmission in livestock, which often constitute major constraints to farm performance.

6) Support for Genetic Quality of Breeding Stock

A conducive environment supports genetic viability and increases the growth rate of breeding stock, thereby ensuring the genetic quality of the livestock produced.

7) Development as a High-Quality Breeding Center

Developing breeding facilities in Remexio Sub-District will optimize the production of high-quality livestock breeding stock that meets national needs for livestock genetic resources.

8) Center for Innovation and Modern Livestock Technology

This area has the potential to become a center for research, development, and application of modern livestock technologies, including integrated breeding systems and climate-responsive housing management.

9) Living Laboratory for Innovation

This center can function as a living laboratory for testing best practices, feed innovations, and livestock reproduction management systems within the local context of Timor-Leste.

10) Knowledge Transfer and Training

The facilities will enable knowledge transfer to local farmers, extension officers, and academics, thereby encouraging the adoption of sustainable livestock farming practices.

11) National Demonstration Model

Remexio Sub-District has the potential to become a national demonstration model for sustainable livestock development that can be replicated in other regions of Timor-Leste.

12) Contribution to National Food Security

By producing high-quality livestock breeding stock on a large scale, this center will make a significant contribution to increasing livestock populations and strengthening national food security.

M. RECOMMENDATIONS FOR THE FISHERIES SECTOR

Based on technical and socio-economic assessments, Seloi Craic Village is recommended as the location for an Ecotourism-Based Integrated Aquaculture Pilot Project. This selection is based on:

1. The presence of a natural lake with stable water
2. Access that allows integration of the fisheries sector with tourism and agriculture.
3. Ecological conditions that are suitable for the development of conservation-oriented farming systems.

As an alternative, Lahae Village is recommended as the location for a Community-Based Rice–Fish Farming Pilot, with catfish and gourami as leading commodities.

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

1) Implement programs to identify and activate idle land for aquaculture though participatory approaches with community groups.
2) Develop empowerment programs for farmer groups, particularly in areas where activities are stagnant or have been abandoned.
3) Develop local markets and fish distribution chains to increase demand and selling prices.
4) Promote the establishment of aquaculture farmer organizations and provide technical training on farm management and product processing.
5) Facilitate local markets through trade partnership schemes with cooperatives, development of fresh fish markets, and integration with village tourism activities.
6) Promote cross-sector collaboration, particularly among the agriculture, tourism, and environment services, to design sustainable fisheries zones based on local carrying capacity and community empowerment.
7) Develop research and technological innovation for adaptive aquaculture in sloping and highland areas, including culture systems using tarpaulin-lined ponds and mini net cages.

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FOREWORD

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

With deep gratitude to God Almighty for His blessings and grace, we warmly welcome the publication of this book entitled "Land Suitability Evaluation and Regional Potential Mapping for the Development of Agricultural, Livestock, Fisheries, and Forestry Commodities in Aileu District, Timor-Leste." This book is the result of close collaboration between the Ministry of Agriculture, Livestock, Fisheries, and Forestry of Timor-Leste and the Faculty of Agriculture, Udayana University, fully supported by the Government of Timor-Leste through Contract No. 24/MAPPF/IV/2024.

Aileu District is one of the key areas in Timor-Leste with considerable potential in the agricultural sector. The district consists of four Sub-Districts, namely Aileu Vila, Laulara, Liquidoe, and Remexio. With geographical conditions in which around 25.32 % of the area is flat, especially along the southern part, Aileu has substantial potential for the development of the forestry and agricultural sectors that can significantly support economic development in Timor-Leste.

Aileu District also has fertile soils of various types, including Inceptisols, which are dominant with an area of 50.56 %, followed by Mollisols at 9.55 %, Entisols at 2.35 %, and alluvial soils at only 0.79 %. The fertile Inceptisols, with medium to high organic matter content, are suitable for the production of food crops, horticulture, and plantation crops, which will directly increase agricultural production and the local community's economy.

In the current global context, the challenges of food security and climate change require all of us to take concrete steps toward sustainable land resource management. This book comes at the right time to provide both scientific and practical guidance for land management in Aileu District. We hope that it will serve as a primary reference for planning sustainable agricultural development, in line with the achievement of the Sustainable Development Goals (SDGs), particularly in ending hunger (SDG 2), promoting inclusive economic growth (SDG 8), and conserving terrestrial ecosystems (SDG 15).

We extend our highest appreciation to the entire team of researchers, academics, and all parties who have worked hard in preparing this book. May this work bring tangible benefits for community welfare, economic growth, and environmental sustainability in Aileu District and in Timor-Leste as a whole.

Sincerely,

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

EXECUTIVE SUMMARY

A. OVERVIEW OF THE STUDY AREA

This chapter presents a general overview of Aileu District as an important background for evaluating land suitability and development potential for food crops, horticulture, forestry, industrial crops, spices and medicinal plants, livestock feed, and grazing. The information includes demography, soil types, land use, and existing field conditions, based on an in-depth and comprehensive data-driven approach.

1. Demography

Aileu District comprises four Sub-Districts, namely Aileu Vila, Laulara, Liquidoe, and Remexio. The District borders Dili District to the north, Manatuto District to the east, Ermera District to the west, and Ainaro District to the south. With an area of 790.76 km², Aileu is inhabited by 61,180 people distributed across various localities. The geographical conditions, dominated by hills and forest, make this District important for development planning based on conservation and sustainable natural resource management.

2. Soil Types: Basis for Land Suitability Evaluation

The dominant soil types in Aileu District are Inceptisols and Mollisols. Inceptisols, which are relatively young soils, are suitable for seasonal crops and horticulture. Mollisols are known as highly fertile soils suitable for intensive agriculture. These soil types are distributed across all four Sub-Districts and strongly influence the crops cultivated and the land management strategies adopted.

3. Geological Formation

The geological formation of the area is dominated by the Aileu Formation (68.37 %), which is distributed across three Sub-Districts, namely Aileu Vila, Laulara, and Remexio. This geological formation affects soil characteristics, topography, and land suitability for various land uses, particularly agriculture and conservation.

4. Land Use: Ecosystem Dynamics and Human Activities

Land use in Aileu District is still dominated by forest areas, which account for 51 % of the total area. The remaining land consists of agricultural areas in the form of dryland fields, mixed gardens, and smallholder plantations. The main commodities cultivated include coffee, orange, and horticultural vegetables.

Agricultural land is generally located on hillside slopes and narrow valley floors along rivers, with further development potential if managed in an integrated and sustainable manner.

5. Slope Gradient: Risks and Potential

The area has topography dominated by steep to very steep slopes, that is, greater than 25 %. This results in a high risk of erosion, especially when land is used for cultivation without conservation measures. Land with low slope gradient is very limited but strategically important for agricultural intensification and infrastructure development. Therefore, soil and water conservation practices are essential in land management.

6. Agroclimatic Zones: Grouping of Regional Potential

Aileu District is divided into three main agroclimatic zones: zone B (humid), zone C (somewhat dry), and zone A (very dry). Zone C is the most extensive and covers almost the entire area, making it suitable for the development of horticulture and seasonal crops. Zone B occurs only in a small part of Remexio, whereas zone A is very limited. This agroclimatic zoning provides an important basis for commodity selection and adaptation of farming systems.

7. Field Conditions: Constraints and Potential

Field observations show that most land has been used for cultivating crops such as coffee, orange, and vegetables. However, the level of utilization remains low and not yet optimal. There is still a large extent of idle land and shrubland that has not been cultivated. In addition, farming methods remain largely traditional, with limited technology and production inputs. This leads to low productivity and farmer income and therefore requires technological interventions and extension support.

8. Utilization of Chromolaena odorata: From Challenge to Opportunity

The invasive weed *Chromolaena odorata* has spread widely, especially in idle land and shrubland. This plant grows rapidly, is aggressive, and competes with main crops, while also reducing soil fertility. Its presence increases the risk of land fires during the dry season. Management of this weed requires an integrated approach, including mechanical control, economic utilization, and farmer education so that it is not left unmanaged.

B. RESEARCH METHODS

This study used a survey-based approach, including field observations, interviews, and laboratory analyses, to carry out a comprehensive land suitability evaluation. Homogeneous Land Units were used as the basis for delineating the area, derived from thematic maps such as land use, soil type, climate, geology, and slope gradient. Data analysis was supported by Geographic Information System (GIS) technology to produce accurate and informative map visualizations.

Research Procedure

1. Soil Sampling
   a. Composite soil samples were collected at the following depths:
      - 0–30 cm for seasonal crops
      - 0–60 cm cm for perennial crops
2. Laboratory Analyses

   The physical and chemical soil parameters analyzed included:
   a. Soil organic carbon (SOC, %) 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 potentiometric method (H2O 1:2.5).
   e. Available P and available K (ppm):
      - *Bray-1 method for pH < 7 (with conversion to mg/g).*
      - *Olsen method for pH > 7 (with conversion to mg/100 g).*
   f. Total Phosphorus (mg/100 g) and Total Potassium (mg/100 g) determined using the 25 % HCl method.
   g. Total Zinc (ppm) determined using the DTPA extraction method and Available Zinc (ppm) determined using the HNO3- : HClO4 digestion method.
   h. Total Sulfur (ppm) and Available Sulfur (ppm) determined using the spectrophotometric method.
   i. Salinity (dS/m) using a potentiometer (H2O 1:2.5).
   j. Cation exchange capacity (CEC, cmol(+) kg^-1) and base saturation (%) using 1 N NH4OAc at pH 7.
   k. Soil fertility status based on the PPT method (1995).
   l. Erosion hazard, assessed through field observations and the Universal Soil Loss Equation (USLE).

Stages of Land Suitability Classification

1. Actual Land Suitability Classification
   The initial classification was carried out to assess land suitability under existing conditions without improvements.
2. Recommended Land Improvements
   Improvement measures were identified to address limiting factors, including management of inputs such as fertilizers and soil and water conservation techniques.
3. Potential Land Suitability
   Land suitability was assessed after considering improvements, in order to maximize land potential.
4. Zoning of Commodity Development Potential
   Zoning was determined by integrating the Agroecological Zones of Aileu District, based on land suitability and specific agroecosystems.

C. CHARACTERISTICS OF AGRICULTURAL AND FOREST LAND

1. Temperature

Air temperature is a key parameter in land suitability evaluation, with analysis based on the integration of field measurements and the SRTM Digital Elevation Model (DEM) using the Braak approach. Air temperature in Aileu District generally falls within the > 21 to 24 °C category, particularly in Aileu Vila Sub-District, which is located in highland areas. Temperature tends to be lower at higher elevations because the air is thinner and retains less heat. Laulara Sub-District has areas with temperatures in the > 24 to 26 °C range, indicating warmer zones. The > 18 to 21 °C category is also widely distributed and again dominated by Aileu Vila Sub-District.

2. Rainfall

Rainfall analysis based on CHIRPS data shows that rainfall in Aileu District is highly variable. Aileu Vila Sub-District dominates the 2,000 to 2,500 mm category due to its higher topography. Remexio and Aileu Vila Sub-Districts dominate the 1,500 to 2,000 mm category, while Laulara Sub-District is dominated by rainfall of 1,000 to 1,500 mm. This variation reflects differences in elevation and position relative to the sea, which influence rainfall distribution.

3. Dry Months

Most of Aileu District experiences 5 to 6 dry months, especially in Aileu Vila and Remexio Sub-Districts. More than 6 dry months occur only in Laulara Sub-District, indicating areas with a longer dry season. Distance from the coastline and topographic position are key factors controlling the distribution of dry months. These patterns directly affect cropping strategies and water management.

4. **Elevation**

Most of Aileu District lies at higher elevations, particularly in Aileu Vila, Remexio, and Liquidoe Sub-Districts. High-elevation areas are important for conservation and water catchment, but they are less suitable for intensive agriculture. Smaller parts of Laulara and Liquidoe Sub-Districts are at low to medium elevations, which are more suitable for agriculture and settlement. Land use planning must balance ecological functions with development needs.

5. **Drainage**

Soil drainage in Aileu District is generally good, especially in Aileu Vila and Liquidoe Sub-Districts. This is largely due to Inceptisols, which have granular structure and adequate pore space. Poorly drained soils occur only in some parts of Aileu Vila, and moderately well drained conditions occur in Remexio Sub-District. These conditions support plant growth by providing sufficient soil aeration.

6. **Coarse Fragment**

Coarse fragment content of less than 3% dominates in Aileu Vila Sub-District, indicating soil textures that are favorable for agriculture. The 3 to 15% category is widely distributed across the district and is still considered safe for cultivation. Remexio Sub-District is dominated by the 35 to 60% coarse fragment category, indicating coarser soils. Contents greater than 60% occur only in a small part of Aileu Vila Sub-District.

7. **Effective Soil Depth**

Soil depth of 30 to 60 cm occurs only in Aileu Vila Sub-District and is one of the dominant categories there. Depths of 60 to 90 cm also dominate in Aileu Vila. Depths of 90 to 120 cm are widely distributed across all Sub-Districts and dominate in Remexio and Laulara. Effective soil depth is influenced by erosion, topography, and rock weathering.

8. **Surface Rock**

Most of the area has surface rock content of less than 5 %, which dominates in Aileu Vila Sub-District. This indicates land that is relatively free of rock and suitable for agriculture. Surface rock contents of 5 to 15 % and 15 to 40 % are also found in Aileu Vila, while contents greater than 40 % occur in Aileu Vila, Liquidoe, and Remexio Sub-Districts. High surface rock content can restrict root penetration and soil tillage.

9. Rock Outcrops

Rock outcrops of less than 5% dominate, especially in Aileu Vila Sub-District, indicating land conditions that are generally favorable for agriculture. Categories of 5 to 15% and 15 to 25% rock outcrops are also found in Aileu Vila. Rock outcrops greater than 25% are the next most prevalent category after < 5%, and occur in Aileu Vila and Remexio Sub-Districts. Areas with high rock outcrop density are prone to erosion and have significant limitations for cultivation.

10. Flood Hazard

Most of the area has no flood hazard due to generally good drainage. Aileu Vila and Laulara Sub-Districts dominate the “no flood hazard” category. Low to very low flood hazard is also found in several Sub-Districts. High flood hazard occurs only in a small part of Aileu Vila and Liquidoe Sub-Districts.

11. Soil Texture

The dominant soil texture is clay loam, with 28.2 % clay, 42.7 % silt, and 28.9 % sand. Aileu Vila Sub-District has clay textures, whereas Laulara Sub-District has silty clay loam textures. Liquidoe and Remexio Sub-Districts are dominated by clay textures, which have good capacity to retain water and nutrients. Soil texture affects drainage and the soil’s ability to retain moisture.

12. Soil pH

Soil pH in Aileu District ranges from 5.11 to 5.55, classified as acidic to slightly acidic. The highest pH occurs in Aileu Vila (5.55), and the lowest in Liquidoe (5.11). Soil acidity influences nutrient availability and microbial activity. Acid soils tend to limit phosphorus availability and can cause metal toxicity.

13. Total Nitrogen

Total nitrogen content is classified as moderate, with the highest value in Aileu Vila (0.41 %) and the lowest in Liquidoe (0.34 %). Total nitrogen is influenced by organic matter and microbial activity. Most nitrogen is still in organic forms that are not immediately available to plants. Mineralization processes are required to convert nitrogen into forms that can be taken up by crops.

14. Available Phosphorus

Available phosphorus content varies among Sub-Districts, with the highest value in Aileu Vila (4.14 ppm) and the lowest in Liquidoe (3.44 ppm). Available phosphorus is affected by pH, organic matter, and microbial activity. Although total phosphorus may be high, only a small fraction is available to plants. Phosphorus availability is particularly important during the early growth stages of crops.

15. Available Potassium

Available potassium is very high in all Sub-Districts, with the highest value in Remexio (14.61 me/100 g) and the lowest in Aileu Vila (3.95 me/100 g Potassium is important for water regulation and plant physiological processes. Clay soils have greater capacity to retain potassium than sandy soils. High available potassium supports optimal growth when other nutrients are also adequate.

16. Electrical Conductivity and Potential Toxicity

Electrical conductivity (EC) values are very low to low, with the highest value in Aileu Vila (0.58 dS m^-1) and the lowest in Liquidoe (0.38 dS m^-1). EC reflects the salt content of the soil, which, if excessive, can interfere with plant water uptake. Low salinity soils support optimal plant growth. Potential toxicity remains low and does not threaten land fertility.

D. SOIL FERTILITY STATUS

Based on the results of soil fertility status analysis in Aileu District, about 53.05 % of the area, or 389.58 km², falls into the low fertility category, while another 276.56 km² (37.66 %) is classified as very low. This indicates nutrient limitations and the need for interventions such as fertilization or land rehabilitation. Only a small portion of the area has moderate fertility, namely 57.91 km² (7.89 %), and very little is classified as high, at 10.29 km² (1.40 %).

The spatial distribution of soil fertility in each Sub-District also shows significant variation. Aileu Vila Sub-District and Laulara Sub-District are dominated by low fertility, with areas of 183.23 km² (24.95 %) and 60.35 km² (8.22 %), respectively. Meanwhile, Liquidoe Sub-District and Remexio Sub-District have larger areas with very low fertility, at 93.38 km² (12.72 %) and 88.64 km² (12.07 %), respectively, indicating a need for more intensive soil fertility management in these two areas.

E. EROSION AND AGROFORESTRY-BASED CONSERVATION

1. Soil Erosion

Soil erosion analysis plays an important role in land suitability evaluation for agriculture because erosion not only reduces soil productivity but also disrupts ecosystem sustainability and causes environmental degradation. In Aileu District, erosion severity ranges from very slight to very severe, influenced by factors such as topography, soil type, vegetation cover, and land management practices.

Remexio Sub-District falls into the very severe erosion category because it is dominated by steep slopes and Inceptisols, which are naturally more prone to erosion due to their easily disintegrated structure and clay-dominated texture. This condition is exacerbated by limited vegetation cover and the lack of land conservation techniques, so that high surface runoff can easily transport soil particles and accelerate the loss of fertile topsoil.

In contrast, areas such as Aileu Vila Sub-District exhibit very slight erosion because they lie in relatively flat terrain. However, when slope gradient increases to 2 to 5%, erosion risk rises significantly, potentially reaching up to eight times higher at a slope of 10%, and continues to increase as slope angle becomes steeper. Therefore, soil conservation strategies tailored to local conditions are required to control erosion rates and maintain land functions sustainably.

2. Agroforestry-Based Conservation

Agroforestry-based conservation is a key and effective approach to addressing soil erosion in Aileu 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**: Reducing surface runoff and maintaining soil moisture.
b) **Improving soil fertility**: Through the contribution of organic matter from crop residues, including leaves and plant litter.
c) **Managing water sustainably**: Retaining water in 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 to protect soil from surface runoff.
b) **Improved water infiltration**: Tree root systems increase soil capacity 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 harvests.

3. Implementation of Agroforestry in Aileu District

Agroforestry systems implemented in Aileu District vary by agroecological zone. Examples of effective agroforestry-based conservation systems include:

a) **Alley cropping**: Planting crops between rows of trees on steep slopes to reduce erosion.

b) **Living hedges**: Using erosion-tolerant plants such as Vetiver Root to reinforce slopes.

c) **Live stakes**: Using perennial plants such as Leucaena as living stakes to control erosion, combined with pepper and other climbing crops.

d) **Layered planting**: Combining trees, shrubs, and groundcover 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) **Increase agroforestry practices** in erosion-prone zones, such as Aileu Vila, Laulara, Liquidoe, and Remexio Sub-Districts.

b) **Implement spatial data based management** to identify priority locations for conservation interventions.

c) **Strengthen farmer** capacity through training and adoption of modern agroforestry techniques.

d) **Reinforce soil conservation** policies by integrating agroecology-based approaches into land use planning.

F. AGRICULTURAL LAND SUITABILITY

1. Land Suitability Evaluation

a. Aileu Vila Sub-District

- Food crops that can be developed include soybean, peanut, sweet potato, and others.
- Horticultural vegetable crops such as shallot, chili, and broccoli can be developed on land with land suitability classes from moderately suitable (S2) to marginally suitable (S3). Horticultural fruit crops such as mango, Custard Apple, and pineapple also show potential in Aileu Vila Sub-District, as do horticultural flower crops such as rose, Aster, and Sunflower.

- Spice and medicinal plants such as Aromatic Ginger and Vetiver Root can be developed.
- Industrial crops such as Robusta Coffee and Sugarcane are considered moderately suitable.

b. Laulara Sub-District

- Development of dryland food crops and horticultural vegetables such as shallot, chili, and eggplant is recommended. Horticultural fruit crops such as orange, mango, and Custard Apple, as well as horticultural flower crops such as rose, Aster, and Sunflower, are considered moderately suitable for local land conditions and have good development potential.
- Spice and medicinal plants such as Cardamom and Vetiver Root can be developed in Laulara Sub-District.
- Industrial crops such as Robusta Coffee and Sugarcane have fairly good suitability.

c. Liquidoe Sub-District

- Liquidoe Sub-District has high potential for several food crops, such as soybean, peanut, and sweet potato, which fall into the moderately suitable class.
- In the industrial crop sector, Robusta Coffee and Sugarcane can be developed in Liquidoe Sub-District.

  Horticultural vegetables such as shallot, Bell Pepper, and chili have high potential with moderately suitable (S2) land suitability. Fruit crops such as guava, soursop, and breadfruit also show promising potential. Horticultural flower crops such as rose, Aster, and Sunflower can also be developed.
- Spice and medicinal plants such as Lemongrass, Vanilla, and Candlenut have fairly good potential.

d. Remexio Sub-District

- Remexio Sub-District has significant potential for the development of Robusta Coffee and Sugarcane.
- Food crops such as soybean, peanut, and sweet potato also have moderately suitable (S2) land suitability.
- In the horticulture sector, vegetable crops such as shallot, chili, and Bell Pepper show good development potential. Fruit crops such as guava, soursop, and breadfruit are also moderately suitable for cultivation. Flower crops such as rose, Aster, and Sunflower can also be developed.

- Spice and medicinal plants such as Lemongrass, Vanilla, and Candlenut can be recommended.

2. Zoning For Agricultural Commodity Development In Aileu District

This study aimed to evaluate the potential and land suitability of various land-use types in Aileu District, Timor-Leste, as a basis for planning sustainable territorial management. The analysis considered biophysical aspects, topography, soil types, and the ecological and economic functions associated with each land-use category.

a) **Dryland agriculture** covers 134.02 km², distributed on slopes of 0 to 45 % and elevations of 100 to 1,500 m above sea level, with moderately fertile Inceptisols. The monomodal climate with a 5 to 6 month dry period requires adaptive water management and drought-tolerant varieties. Commodities include cassava, peanut, chili, tomato, banana, and Robusta Coffee. Conservation techniques such as terracing and cover vegetation are strongly recommended to maintain land stability.
b) **Rainfed rice fields** cover 49.32 km² on slopes of 0 to 25 % and elevations of 800 to 1,200 m above sea level, with Entisols, Inceptisols, and Mollisols. The monomodal climate and 5 to 6 month dry season affect productivity, making water management critical. The use of farm ponds and drought-tolerant varieties is recommended to address water limitations. These rice fields are distributed across several Sub-Districts, particularly in Aileu Vila Sub-District.
c) **Irrigated rice fields** cover 12.07 km² and are found only in Aileu Vila Sub-District on slopes of 5 to 25 % and elevations of 800 to 1,200 m above sea level. The monomodal climate and limited water sources demand efficient irrigation systems. Optimization of irrigation networks and water-saving technologies such as drip irrigation are essential to maintain rice productivity. The main challenges are steep topography and limited irrigation infrastructure.
d) **Grazing areas** cover 8.25 km² on flat to gently sloping land with slopes of 0 to 5 % and elevations of 100 to 900 m above sea level. Rotational grazing is recommended to reduce the impact of trampling, which can accelerate erosion. Forage banks of Elephantgrass and the planting of tree legumes help maintain feed supply and improve soil structure. Integration of livestock and crops enhances food security and the efficiency of integrated farming systems.

G. SOLUTIONS FOR THE "DYING ORANGE" PROBLEM IN LIQUIDOE SUB-DISTRICT

These recommendations focus on addressing three main problems: soil toxicity, low nutrient retention capacity, and nutrient deficiency.

1. Neutralization of Soil Toxicity

- **Problem:** Soil pH is very acidic (4.8 to 5.0), releasing toxic aluminum (Al^3+) that damages plant roots.
- **Solution:** Application of **dolomite** ($CaMg(CO_3)_2$) is essential. Dolomite is selected because it has a dual function: raising pH (neutralizing Al^3+) and supplying calcium (Ca) and magnesium (Mg), which are severely deficient.
- **Rate and timing:** The recommended rate is **1.5 to 2.0 kg per tree**. To raise pH from 4.8 to the safe target range (pH 5.5 to 6.0), lime (dolomite) requirements generally range from **2.0 to 4.0 ton/ha (2,000 to 4,000 kg/ha).** This rate is assumed to be broadcast evenly and incorporated into the soil to a depth of 15 to 20 cm across the entire area. Application is ideally carried out 2 to 4 weeks **before** NPK fertilization so that the soil is more neutral when fertilizer is applied.

2. Building the Soil Foundation (SOC)

- **Problem:** Low soil organic carbon (SOC) makes the soil hard and unable to retain nutrients and water (low cation exchange capacity, CEC).
- **Solution:** Addition of large amounts of **organic matter** (compost or well-decomposed manure) at the outset.
- **Rate & Timing:** The initial rate required is **10 to 20 kg** per tree. This organic material can be applied together with dolomite within the tree basin area (under the canopy).

3. Basal Phosphorus Fertilization (Addressing Fixation)

- **Problem:** Phosphorus (P) in these acidic soils is strongly "fixed" by Al and Fe and therefore unavailable to plants.
- **Solution:** Application of P fertilizer (such as **SP-36**) will be much more effective if **mixed** directly with the organic matter applied in Step 2.
- **Rate and timing:** The rate is **150 to 250 g SP-36 per tree**. Mixing with organic matter helps protect P from being fixed by the soil. This is carried out once at the beginning of the rainy season.

4. **Efficient Maintenance Fertilization (N and K)**

- **Problem:** Nitrogen (N) and potassium (K) are easily lost through leaching because the soil still has limited capacity to retain nutrients (CEC remains low).
- **Solution:** The total annual fertilizer rate (200 to 300 g urea plus 150 to 250 g KCl per tree) should not be applied in a single dose.
- **Method of application:** N and K fertilizers need to be split into three applications (for example, every 4 months). This method ensures that nutrients can be taken up efficiently by the plants before they are leached by rainfall.

H. FORESTRY POTENTIAL

Aileu District has significant potential for the development of forestry commodities, with land suitability ranging from S2 (moderately suitable) to S3 (marginally suitable). Melaleuca is classified as moderately suitable and is the most recommended commodity, while other species such as Teak, Mahogany, Agathis, Albizia, Acacia, Leucaena, Eucalyptus, and Pine remain feasible for development through adaptive management and silvicultural techniques.

The biophysical conditions of Aileu support the implementation of agroforestry systems and protection forests, with about 72.37 % of the area located on slopes of 5 to 45 % and elevations of 800 to 1,500 m above sea level. Under a monomodal climate, these conditions favor conservation-oriented cropping patterns focused on sustainability. Key commodities such as coffee play a dual role in maintaining ecological functions and improving community livelihoods. Robusta Coffee is recommended because it is more adaptive to local conditions, while Arabica coffee can still be developed with appropriate technical interventions, including selection of cooler sites, use of tolerant varieties, and the application of shade systems and soil conservation.

One strategic commodity with high economic and cultural value is sandalwood (*Santalum album* L.), which produces high-value essential oil and has important cultural significance for the people of Timor-Leste. Although its land suitability is classified as S3 (marginally suitable), sandalwood development remains promising through appropriate cultivation techniques, careful site selection, and maintenance of host trees. These efforts are in line with the national sandalwood inventory program of the Government of Timor-Leste, which aims to strengthen sustainable forest resource management, increase local economic value, and support long-term investment in the forestry sector of Aileu.

I. LIVESTOCK POTENTIAL IN AILEU DISTRICT

Remexio Sub-District has the highest ecological suitability, while Laulara Sub-District has the lowest. For poultry, however, land suitability is very high and relatively uniform across the district.

The climatic conditions of Aileu District, with an average temperature of 21.36 °C and annual rainfall of 1,935.36 mm, are highly favorable for livestock productivity and sustainable forage growth. Environmental factors such as temperature and rainfall play a major role in regulating livestock heat balance, feed availability, drinking water supply, and disease risk. Extreme temperatures, whether hot or cold, can cause stress in livestock, negatively affecting feed intake, productivity, growth, and disease resistance. Therefore, optimal environmental management is crucial to support successful livestock development in this area.

J. FISHERIES POTENTIAL IN AILEU DISTRICT

There is one main area that serves as the center of aquaculture activities. Aileu Vila Sub-District is a highland area whose main constraints for aquaculture include slope gradient, length of the dry season, and rainfall, all of which limit aquaculture development. Low water temperatures restrict the growth of tropical fish such as gourami and tilapia, while common carp is more tolerant of these conditions.

Brackish-water commodities are not recommended because of low salinity and limited access to seawater. Although most land is only marginally suitable, technical improvements such as terraced ponds and water quality management can increase land suitability, particularly for freshwater fish such as gourami, catfish, common carp, and tilapia. Aquaculture in this area is still small-scale and traditional, with non-technical constraints such as low market demand, limited capital, and weak integration with other sectors that hinder development. The inland geographical position far from the coast further restricts commodity choices, so development priorities should focus on freshwater aquaculture, accompanied by improved environmental management and technology.

K. RECOMMENDATIONS FOR THE AGRICULTURE SECTOR

1. Land Potential and Spatial Distribution

The territory of Aileu District shows localized diversity in agronomic potential. Clusters of irrigated rice fields are suitable for development in Aileu Vila Sub-District (Seloi Craic, Hoholau, Liurai, Seloi Malere, Fahiria, Saboria, Lausi, Fatubosa), while rainfed rice fields are suitable in Bandudato and Fatubosa. Intensive grazing pasture is found in Bandudato and Aisirimou, dominated by Elephantgrass (*Pennisetum purpureum*) and gamal (*Gliricidia sepium*). Spatial planning can therefore be directed toward irrigation blocks, grazing corridors, and efficient cultivation mosaics that follow contour lines and water sources.

2. Food Diversification and Cool-Highland Horticulture

Food crops (sweet potato, cassava, corn, taro, cowpea, porang) are widely distributed and interspersed with cool-climate vegetables (lettuce, water spinach, pakchoy, shallot, garlic, broccoli, chayote, caisim, chili, cabbage, cauliflower, tomato, long beans, carrot). This combination strengthens local carbohydrate sources, enables seasonal rotation, and supplies urban markets from high-elevation zones with cool microclimates.

3. Economically Valuable Tropical Fruit

Jackfruit, banana, rambutan, mango, breadfruit, avocado, guava, orange (sweet, mandarin, pomelo, lime, limau), pineapple, soursop, snakefruit, and papaya are widely distributed and ready to be upgraded in value through strengthened post-harvest handling (grading, packaging) and improved access to cold chains so that quality losses and price volatility can be reduced.

4. Industrial Crops and Arabica Coffee

Coconut, areca nut, and Arabica coffee occur throughout the district. For Arabica coffee, soil and water conservation practices on slopes, shade from timber trees, and quality certification will increase productivity, improve cherry quality, and enhance access to premium markets.

5. Landscape Buffers: Forestry Vegetation

Groups of Pine, bamboo, kapok, gamal, Acacia, casuarina, Eucalyptus, Teak, Mahogany, Leucaena, calliandra, Sandalwood, tamarind, agarwood, sugar palm, and Albizia are distributed in Aileu Vila, Laulara Sub-District (Talitu, Madabeno), Liquidoe Sub-District (Faturilau), and Remexio Sub-District (Faturasa, Liurai, Talutaque). These clusters function as erosion-control belts, sources of organic matter, and microclimate stabilizers that reinforce the productivity of surrounding cultivated land.

6. Local Spice and Medicinal Agroforestry

The integration of Candlenut, Pepper, Turmeric, Clove, betel, Ginger, and Lemongrass with horticulture and forestry in Fahiria, Acubilitoho, Faturasa, and Acumau demonstrates an adaptive mixed-farming model. This pattern maintains soil fertility, suppresses erosion, reduces crop failure risk, and adds income streams (for example: orange–coffee–banana–spices–tubers; Candlenut–orange–Teak/Pine–coffee–calliandra; Clove–tubers–banana–avocado–mango–coffee–corn).

7. Priority Commodities and Production Clusters

Irrigated rice, cassava, corn, banana, orange, rambutan, pineapple, leafy vegetables and cabbage-group crops, chili, and Arabica coffee are designated as priority commodities. Establishing location-specific production clusters, providing technical support, supplying improved seed, and developing tiered marketing contracts will secure economies of scale, price stability, and access to premium markets.

8. Land Improvement, Water Conservation, and Integrated Erosion Control

Sustainable productivity requires balanced fertilization based on soil testing, addition of organic matter (compost or manure), terracing and contour-aligned planting, groundcover or legume strips, thick mulching, and water conservation through farm ponds, reservoirs, and rainwater wells or storage reservoirs. This integrated package increases water and nutrient storage capacity, protects topsoil, and buffers the impacts of drought on both sloping and flat land.

9. Nutrient Management and Cropping Patterns

Gaps in fertilization practices, which generally rely only on fallen leaves at land preparation with minimal maintenance, need to be addressed through simple standard operating procedures (rates, timing, and methods of application), location-specific soil test demonstration plots, and staged nutrient recommendation cards throughout the season. A shift from single-crop monoculture to rice–rice–secondary crops rotation (for example corn or legumes) will improve soil structure, break pest cycles, and stabilize yields.

10. Specific Issu: Dieback in Rambutan

Management is directed toward orchard sanitation, selective pruning, balancing K, Ca, and Mg nutrients, shade regulation, and monitoring of pests and diseases. Integrated control demonstration plots are recommended to break inoculum sources, restore shoot vigor, and reduce yield losses.

11. Strengthening Capcity, Infrastructure, and Input Policies

Thematic farmer field schools (nutrients, micro-irrigation, Integrated Pest Management/PHT) and simple visual modules need to be aligned with improvements to farm access roads, post-harvest facilities (grading, packaging, cold chain), strengthening of cooperatives or off-takers, and policies on targeted fertilizer subsidies, incentives for organic matter (composters or dedicated pits), and microcredit for water conservation equipment so that good practices are adopted rapidly and farm production costs remain manageable.

12. Implementation Phasing and Principles of Sustainability

Quick wins include soil-test-based fertilization SOPs, rice–secondary crops rotation demonstration plots, mulching and legume strips, and improvement of small water channels. In the medium term, priorities include village-scale ponds or reservoirs, block-scale terracing, spice–coffee agroforestry, and partnerships for premium horticulture. All expansion of cultivated land must be aligned with conservation zoning, water-saving principles, maintenance of long-term soil fertility, and diversification of commodities to support the economic resilience of farm households.

L. RECOMMENDATIONS FOR THE LIVESTOCK SECTOR

1) Strategic Potential in Remexio Sub-District, Aileu District

Remexio Sub-District shows substantial potential to be developed as a breeding center for high-quality livestock in Timor-Leste, based on the results of a comprehensive evaluation of land suitability and ecological conditions.

2) Land Suitability for Forage Crops

The land suitability analysis for forage crops indicates that this area has fertile soils that support the sustainable growth of high-quality livestock forage, which forms the primary foundation for livestock productivity.

3) Availability of Natural Resources

Geographical conditions and the availability of natural resources, including access to water and natural vegetation, support year-round provision of livestock feed.

4) Optimal Climatic Conditions

Temperature and rainfall in Remexio Sub-District are relatively stable, creating a micro-environment that is ideal for livestock growth, health, and reproduction.

5) Reduced Risk of Stress and Disease

Stable climatic conditions significantly reduce the risk of heat stress and disease transmission in livestock, which often constitute major constraints to farm performance.

6) Support for Genetic Quality of Breeding Stock

A conducive environment supports genetic viability and increases the growth rate of breeding stock, thereby ensuring the genetic quality of the livestock produced.

7) Development as a High-Quality Breeding Center

Developing breeding facilities in Remexio Sub-District will optimize the production of high-quality livestock breeding stock that meets national needs for livestock genetic resources.

8) Center for Innovation and Modern Livestock Technology

This area has the potential to become a center for research, development, and application of modern livestock technologies, including integrated breeding systems and climate-responsive housing management.

9) Living Laboratory for Innovation

This center can function as a living laboratory for testing best practices, feed innovations, and livestock reproduction management systems within the local context of Timor-Leste.

10) Knowledge Transfer and Training

The facilities will enable knowledge transfer to local farmers, extension officers, and academics, thereby encouraging the adoption of sustainable livestock farming practices.

11) National Demonstration Model

Remexio Sub-District has the potential to become a national demonstration model for sustainable livestock development that can be replicated in other regions of Timor-Leste.

12) Contribution to National Food Security

By producing high-quality livestock breeding stock on a large scale, this center will make a significant contribution to increasing livestock populations and strengthening national food security.

M. RECOMMENDATIONS FOR THE FISHERIES SECTOR

Based on technical and socio-economic assessments, Seloi Craic Village is recommended as the location for an Ecotourism-Based Integrated Aquaculture Pilot Project. This selection is based on:

1. The presence of a natural lake with stable water
2. Access that allows integration of the fisheries sector with tourism and agriculture.
3. Ecological conditions that are suitable for the development of conservation-oriented farming systems.

As an alternative, Lahae Village is recommended as the location for a Community-Based Rice–Fish Farming Pilot, with catfish and gourami as leading commodities.

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

1) Implement programs to identify and activate idle land for aquaculture though participatory approaches with community groups.
2) Develop empowerment programs for farmer groups, particularly in areas where activities are stagnant or have been abandoned.
3) Develop local markets and fish distribution chains to increase demand and selling prices.
4) Promote the establishment of aquaculture farmer organizations and provide technical training on farm management and product processing.
5) Facilitate local markets through trade partnership schemes with cooperatives, development of fresh fish markets, and integration with village tourism activities.
6) Promote cross-sector collaboration, particularly among the agriculture, tourism, and environment services, to design sustainable fisheries zones based on local carrying capacity and community empowerment.
7) Develop research and technological innovation for adaptive aquaculture in sloping and highland areas, including culture systems using tarpaulin-lined ponds and mini net cages.

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I. INTRODUCTION

New Context: ASEAN, SDGs, and the Backbone of the Economy

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

In this new era, Timor-Leste is required to strengthen the foundations of its economy. The agricultural sector, as the backbone of the economy, plays a central role. The challenge of achieving food self-sufficiency and optimizing the use of natural resources has become a priority.

This food security issue is closely linked to the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), and SDG 13 (Climate Action). To this end, the use of land that is both productive and efficient is essential, and Aileu District has a unique role to play.

Regional Focus: Topographic Challenges and Highland Potential

Aileu District has substantial potential to support national food security, but with highly specific characteristics. The district, which comprises Aileu Vila Sub-District, Laulara Sub-District, Liquidoe Sub-District, and Remexio Sub-District, is dominated by highland topography.

The main challenge is slope gradient. Approximately 73.15 % of the total area has moderately steep to steep slopes (15 to 45 %). This means that conventional flat-land agricultural models cannot be applied. Solutions must be based on conservation and agroforestry to maintain ecosystem stability and reduce erosion risk.

Administrative History: Governance Dynamics and Changes in Regional Status

Aileu District has a historical background closely linked to the dynamics of colonial governance and changes in the administrative structure of Timor-Leste. On 20 April 1859, the Portuguese Governor António Coelho Guerreiro established the administrative division of Timor-Leste into eleven districts. Within this structure, the Aileu area was incorporated as part of Dili District. After World War II, Governor Óscar Ruas changed the status of military command in the region to civilian jurisdiction; however, Aileu remained under the authority of the Dili Council. During the period of Indonesian administration, Aileu was designated as an independent district, and following the independence of Timor-Leste, the area was officially established as one of the Districts within the national governance system.

Technical Basis: Soil Fertility Capital and Geology

Despite its challenging topography, the greatest asset of Aileu District lies in its soils. The area is endowed with highly productive soils:

- **Inceptisols (50.56%):** Dominating the District, these soils are known to be fertile, with medium to high organic matter content, making them ideal for food crops, horticulture, and plantation crops.
- **Mollisols (9.55%):** Distributed in Aileu Vila Sub-District and Liquidoe Sub-District, these soils are known to be very fertile and highly productive for agriculture.

The geological conditions of the area, which are dominated by metamorphic rocks such as Phyllite, Schist, and Amphibolite (covering 68.37 %), also play an important role. Weathering of these rocks contributes to increased soil fertility. However, this geological structure also indicates tectonic dynamics, which implies that soil stability must be taken into account when designing land management systems.

Opportunities for Integrated Sector Development

With fertile soils on sloping land, the main economic opportunities in Aileu shift towards high-value commodities that are suitable for agroforestry and plantation systems.

- **Forestry and plantation crops:** The climate and soil conditions are highly favorable for the development of coffee, orange, and other industrial crops such as teak, acacia, and eucalyptus. This sector not only contributes to the local economy but can also become part of the national export strategy.
- **Livestock:** This sector has substantial potential as a supporting pillar. Extensive land and natural grazing systems can support the development of cattle and goats. The key to success is an integrated crop–livestock farming system, in which agricultural residues are used as animal feed and livestock manure is used as organic fertilizer to improve soil quality.

Management Challenges and the Objective of This Evaluation

Behind its considerable potential, Aileu District also faces real challenges. Land degradation due to erosion on steep slopes, limited agricultural infrastructure, and restricted market access are among the main constraints.

Therefore, the research underpinning this book was designed to evaluate land suitability and map development potential in Aileu District. The primary focus is on the agricultural and plantation sectors, with exploration of livestock as an integrated supporting sector.

This book is expected to provide strategic recommendations for government, academia, and other stakeholders in designing sustainable development policies. In this way, these efforts will support national food security and strengthen inclusive economic growth in Timor-Leste as it enters the new ASEAN era.

II. GENERAL OVERVIEW OF THE AREA

2.1 DEMOGRAPHY

Aileu District consists of four Sub-Districts, namely Aileu Vila Sub-District, Laulara Sub-District, Liquidoe Sub-District, and Remexio Sub-District. Administratively, Aileu District borders Dili District to the north, Manatuto District to the east, Ermera District to the west, and Ainaro District to the south. In astronomical terms, Aileu District is located between 8.25 to 8.42° S and 120.25 to 126.46° E. The administrative map of Aileu District is presented in **Figure 2.1.**

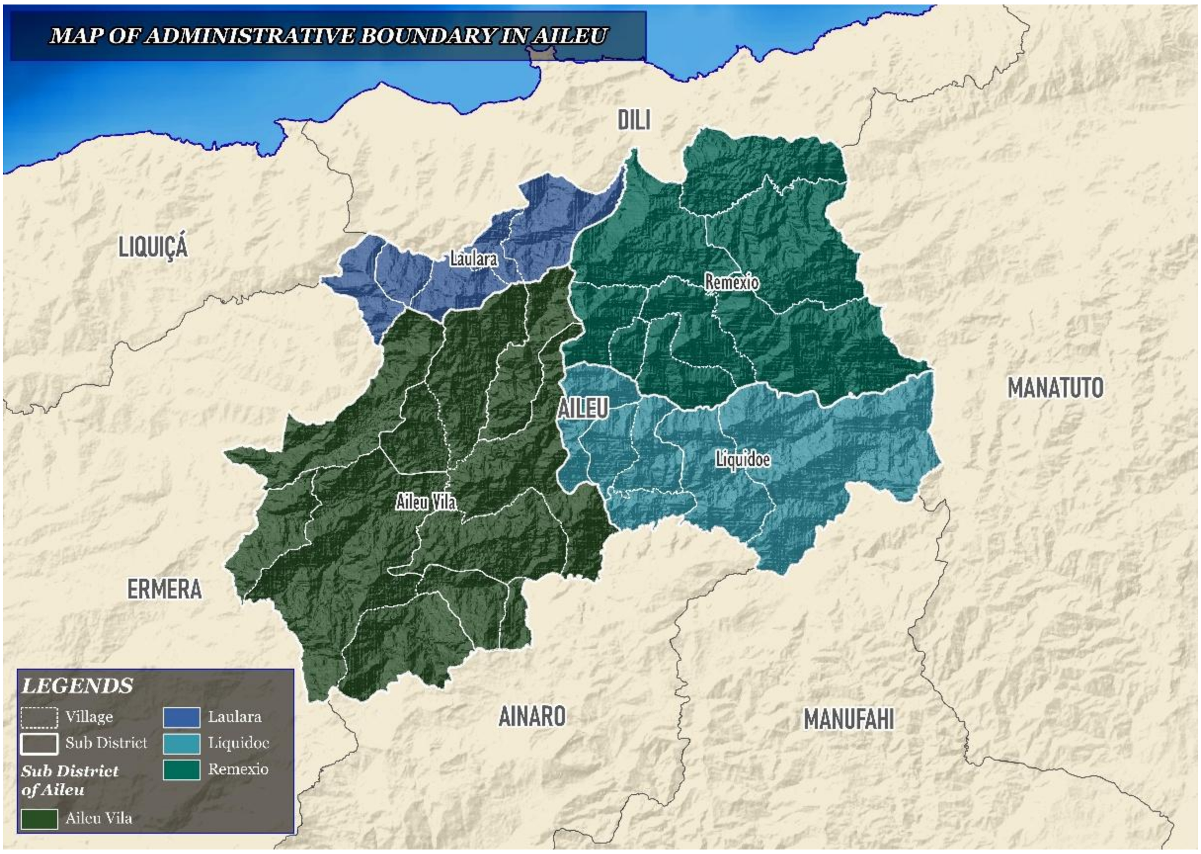


Figure 2.1 Administrative Map of Aileu District

Demographically, Aileu District has a population of 61,180 people distributed over an area of 790.76 km² (Autoridade Munisipal Aileu, 2025). The area is divided into several Sub-Districts, each with different areas and geographic characteristics. Information on the distribution of area by Sub-District is presented in **Table 2.1.**

Table 2.1 Area by Sub-District in Aileu District

Sub-Districts	Land Area (ha)
Aileu Vila	34.359,40
Laulara	7.061,95
Liquidoe	16.094,89
Remexio	21.180,18

Aileu District has a historical background closely associated with the dynamics of colonial administration and changes in the administrative structure of Timor-Leste. On April 20, 1859, Portuguese Governor António Coelho Guerreiro established the administrative division of Timor-Leste into eleven districts. Within that structure, the Aileu area was included as part of Dili District. After World War II, Governor Oscar Ruas changed the status of the military command in this area to a civil jurisdiction, but Aileu remained under the Dili Council. During the Indonesian occupation, Aileu was designated as an independent district, and after the independence of Timor-Leste, the area officially became one of the districts within the national governance system.

2.2 SOIL TYPE

The soil types distributed across Aileu District exhibit significant variation, reflecting the complexity of the terrestrial ecosystem that underpins land suitability evaluation. Mapping these soil types provides an in-depth understanding of land characteristics required to support optimal and sustainable natural resource management. Each District has a distinctive dominance of particular soil types, which has implications for specific, data-driven management strategies.

The soil types present in Aileu District include the soil orders Mollisols, Inceptisols, and Entisols, as well as alluvial soils. The presence of these soils provides considerable opportunities for sustainable and productive agricultural development in Aileu District.

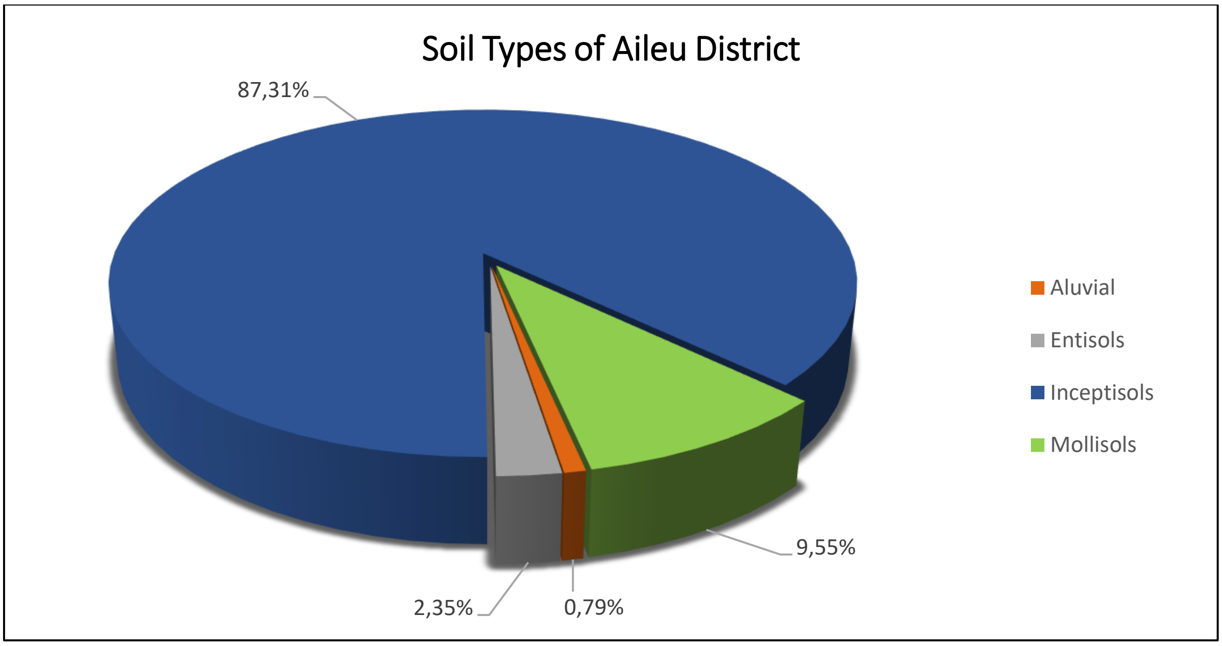
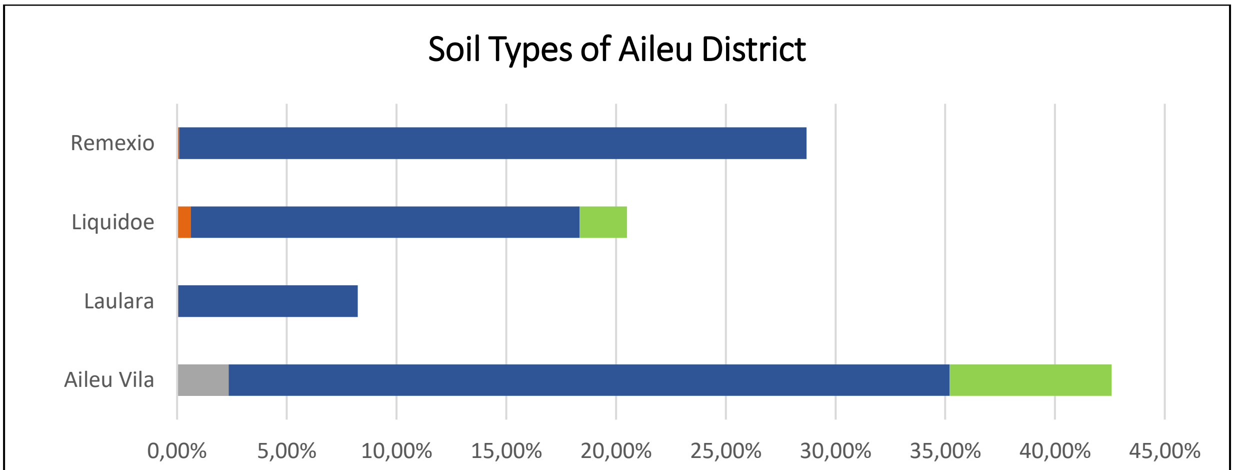


Figure 2.2 Soil Types Graphic of Aileu District



	Aileu Vila	Laulara	Liquidoe	Remexio
Aluvial	0,00%	0,05%	0,64%	0,10%
Entisols	2,35%	0,00%	0,00%	0,00%
Inceptisols	32,84%	8,18%	17,71%	28,58%
Mollisols	7,39%	0,00%	2,16%	0,00%

Area (%)

Figure 2.3 Area of Aileu District by Soil Types

Overall, the analysis of soil type distribution shows that Inceptisols dominate Aileu District, covering 87,31% of the total area. As soils with moderate horizon development, Inceptisols offer high potential for general agricultural activities, although optimal soil fertility management is required. Mollisols, which cover 9,55% of the total area, are known to be highly fertile and support intensive management to sustain land productivity. Entisols, which cover 2,35%, are found in areas with low soil development, such as steep slopes, and therefore require conservation interventions to reduce erosion risk (Rossiter, 1996). Although alluvial soils cover only 0,79% of the total area, they have substantial potential for the development of irrigation systems in alluvial zones. These soils often form from river deposits and are suitable for rice and other food crops.

The diversity of soil types provides an important basis for location-specific management strategies. The presence of alluvial soils in flat areas opens opportunities for water-based agricultural management. In contrast, Inceptisols and Entisols can provide additional flexibility, although conservation approaches are required in certain areas with extreme topographic conditions. The area of each soil type by Sub-District and in total is presented in **Figure 2.2** and **Figure 2.3**, while the distribution map is presented in **Figure 2.4.**

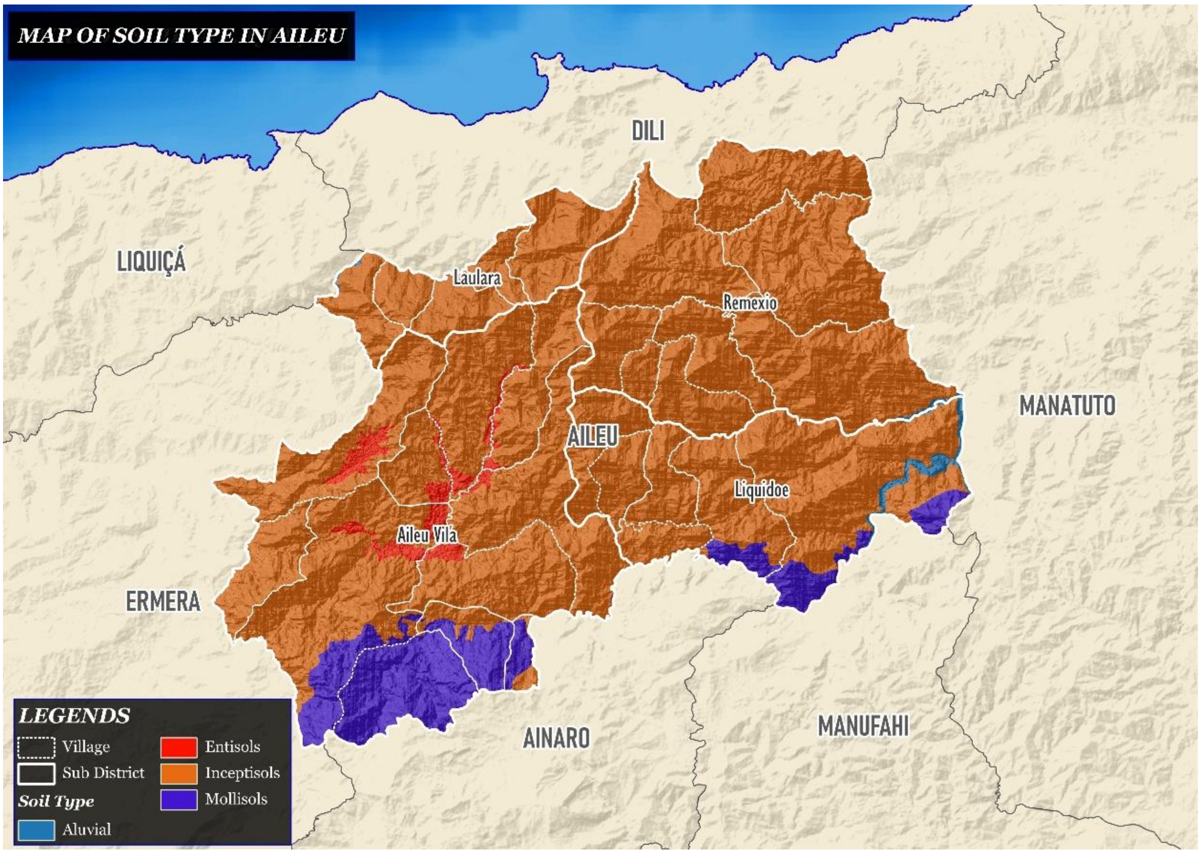


Figure 2.4 Soil Types Map of Aileu District

2.3 GEOLOGICAL FORMATION

The distribution of geological formations in the study area shows significant diversity. Each formation contributes uniquely to soil characteristics and influences the potential and constraints of land for agricultural development. This analysis shows that the Aileu Formation (68,37 %) and the Maubisse

Formation (30,28 %) dominate Aileu District, followed by the Ainaro Formation (0,48 %), the Lolotoi Formation (0,38 %), the Wailuli Formation (0,34 %), and the Aitutu Formation (0,15 %), as presented in **Figure 2.5** and **Figure 2.6**. The spatial distribution of geological formations in Aileu District is presented in **Figure 2.7.**

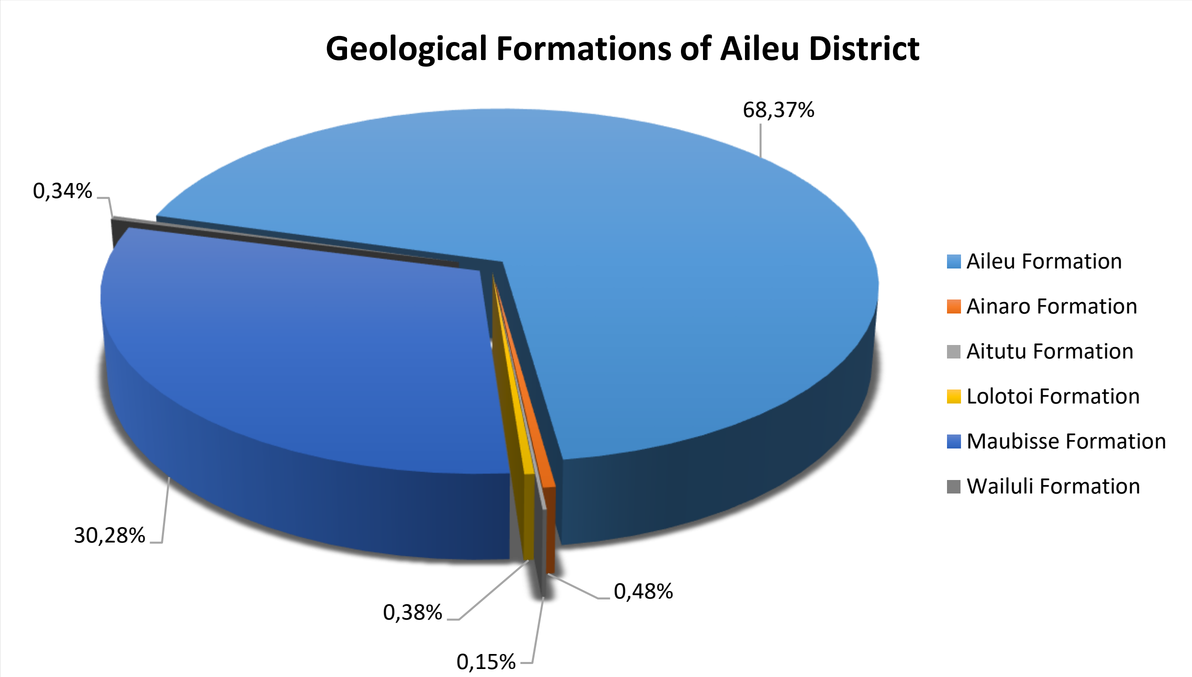
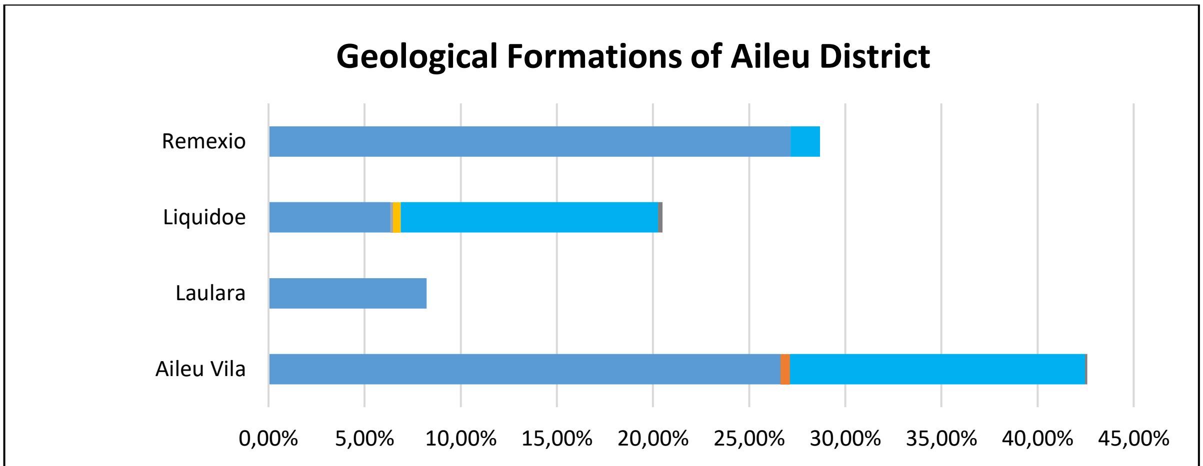


Figure 2.5 Geological Formation of Aileu District



	Aileu Vila	Laulara	Liquidoe	Remexio
Aileu Formation	26,64%	8,23%	6,35%	27,16%
Ainaro Formation	0,48%	0,00%	0,00%	0,00%
Aitutu Formation	0,00%	0,00%	0,15%	0,00%
Lolotoi Formation	0,00%	0,00%	0,38%	0,00%
Maubisse Formation	15,36%	0,00%	13,39%	1,53%
Wailuli Formation	0,10%	0,00%	0,23%	0,00%

Figure 2.6 Area of Aileu District by Geological Formations

The Aileu Formation is found across most of Aileu, covering 68,37 % with a total area of 72.604 ha, providing a range of soil characteristics relevant for agricultural management under differing environmental conditions. This formation dominates the study area with the largest coverage, namely 20.022 ha in Remexio Sub-District and 19.640 ha in Aileu Vila Sub-District. The principal rocks in this formation include phyllite, schist, amphibolite, and slate, which are metamorphic rocks. Volcanic rocks also occur, although in smaller amounts. This composition indicates intensive metamorphism and past volcanic activity, which are important indicators for understanding tectonic conditions and soil stability in the area.

The Maubisse Formation accounts for 30,28 %, or 22.323 ha, of the total area. This formation has a high carbonate content, which supports the development of soils with good chemical buffering capacity (Brady & Weil, 2017). The dominant rocks are reef limestone, distributed in Aileu Vila (11.324 ha), Liquidoe (9.872 ha), and Remexio (1.127 ha). The presence of this formation evidences a past shallow marine environment, which indicates carbonate deposition processes and also suggests potential mineral resources, such as limestone for the construction industry.

The Ainaro Formation covers 0,48 %, or 355 ha, located in Aileu Vila Sub-District. Its principal characteristics are conglomerate, sand, and clay. These rocks indicate a younger sedimentary depositional environment, which provides potential for soils with particular permeability and fertility levels. This is relevant in the context of land suitability evaluation for agriculture or light infrastructure.

The Lolotoi Formation occurs only in Liquidoe with an area of 281 ha (0,38%). This formation consists of metamorphic rocks such as phyllite, schist, and gneiss. It has complex lithology and is often found in mountainous areas with steep topography, which requires intensive conservation approaches to support soil stability (Rossiter, 1996).

The Wailuli Formation covers 250 ha (0,34 %) of Aileu District. Rocks in this formation include sandstone, shale, siltstone, and limestone. Its distribution is relatively limited, with 77 ha in Aileu Vila Sub-District and 173 ha in Liquidoe. The presence of these rocks can provide important information on the soil's water-holding capacity, which relates to wate resource management potential in land evaluation.

The Aitutu Formation covers only 0,15 % (111 ha) of the total area and is found only in Liquidoe Sub-District. The rock types include calcilutite, marl, calcareous shale, and calcarenite. These characteristics indicate deposition processes in a deep marine environment, which is relevant for understanding the geological history and soil capability of the area.

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

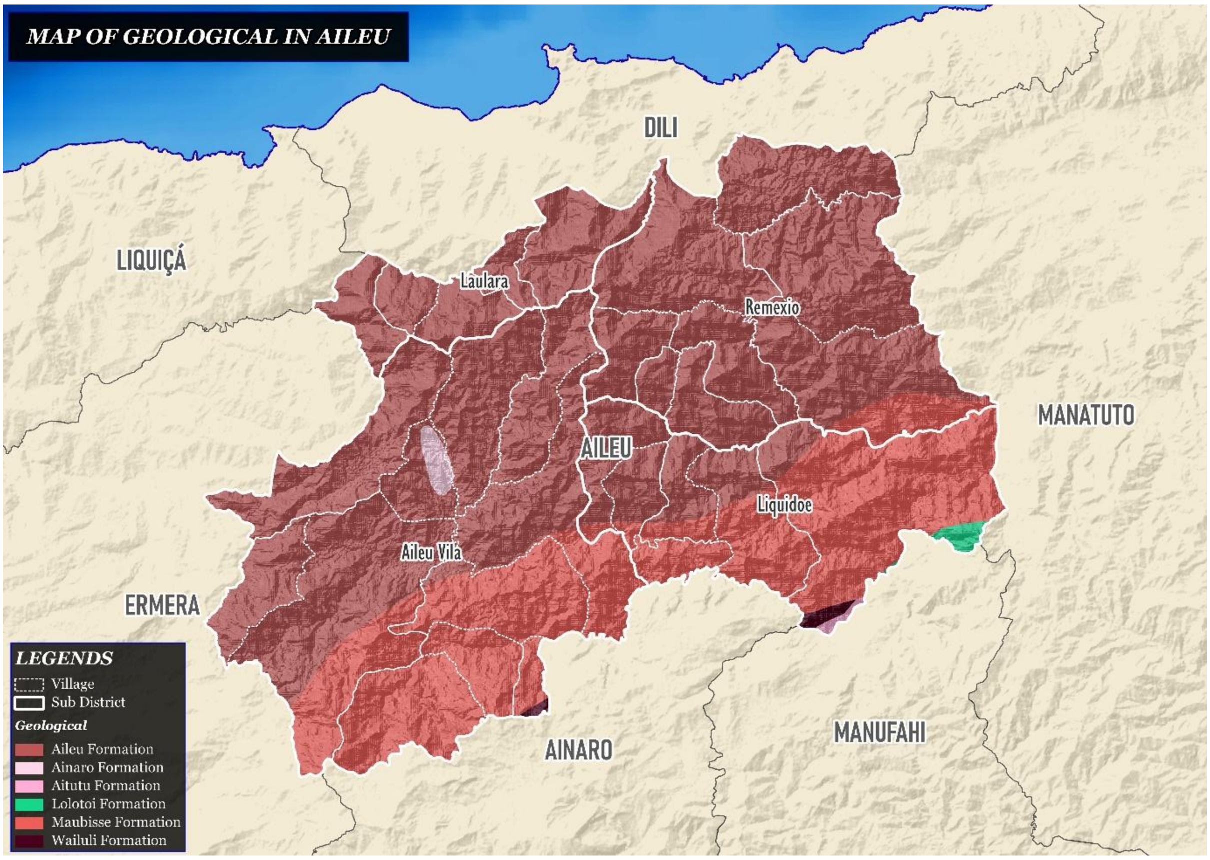


Figure 2.7 Geological Formation Map of Aileu District

2.4 LAND USE

The distribution of land use in Aileu District comprises various land categories according to their designated functions, providing a basis for developing agricultural commodities and higher-value economic commodities.

Agricultural Land in Aileu District covered 3,53 % of the total area and consisted of dryland arable, rice fields, and shifting cultivation areas. Dryland

Arable for food crops occurred only in Aileu Vila Sub-District, covering 2,20 % of the total area. Rice Fields covered 1,21 %, with the largest share in Aileu Vila Sub-District at 1,20 %, while Remexio Sub-District accounted for 0,01 %. Rice fields were not found in Laulara and Liquidoe Sub-Districts. Shifting Cultivation Areas occurred only in Aileu Vila Sub-District, covering 0,12 % of the total area.

Commercial Agriculture covered 13,04 % of the total area, divided into Estate Crops and Smallholder Estate Crops. Estate Crops covered 5,88 % of the total area and were distributed in Aileu Vila Sub-District (6,20 %), Laulara Sub-District (0,84 %), and Remexio Sub-District (0,13 %), while none were found in Liquidoe Sub-District. Smallholder Estate Crops covered 7,16 % and were distributed in Laulara Sub-District (0,73 %) and Remexio Sub-District (5,15 %), indicating an important role in supporting community-based economies.

Dryland Not In Use, such as Grassland, was found only in Aileu Vila Sub-District, covering 0,29 %. This category supports grazing activities and natural ecosystems.

Forested Land dominated 81,29 % of the total area, reflecting the important ecological function of environmental conservation. Dry Lowland Forest, Mixed covered 1,70 % of the area and was found only in Aileu Vila Sub-District. Highland Forest, Single Species covered 27,88 % of the total area, with the largest distribution in Aileu Vila Sub-District at 18,29 %, followed by Liquidoe at 4,96 %, Remexio at 4,35 %, and Laulara with the smallest area at 0,29 %. These forests contribute to slope stability in hilly terrain and support the hydrological cycle. Lowland Forest, Single Species formed the largest share of forested land at 51,03 %. Remexio Sub-District had the largest distribution at 18,98 %, followed by Liquidoe at 15,08 %, Aileu Vila at 10,62 %, and Laulara at 6,35 %. Montane Forest had the smallest coverage at 0,67 % and occurred only in Aileu Vila Sub-District.

Areas classified as River were distributed across all Sub-Districts, with the largest share in Aileu Vila Sub-District (0,56 %), followed by Liquidoe (0,46 %), Remexio (0,07 %), and Laulara (0,04 %). Rivers are important for meeting water needs for communities and ecosystems.

Villages and Mixed Gardens were found in Aileu Vila Sub-District, covering 0,05 %. Cities and Large Towns also occurred only in Aileu Vila Sub-District, covering 0,68 %. Area by land-use type is presented in **Figure 2.8** and **Figure 2.9**.

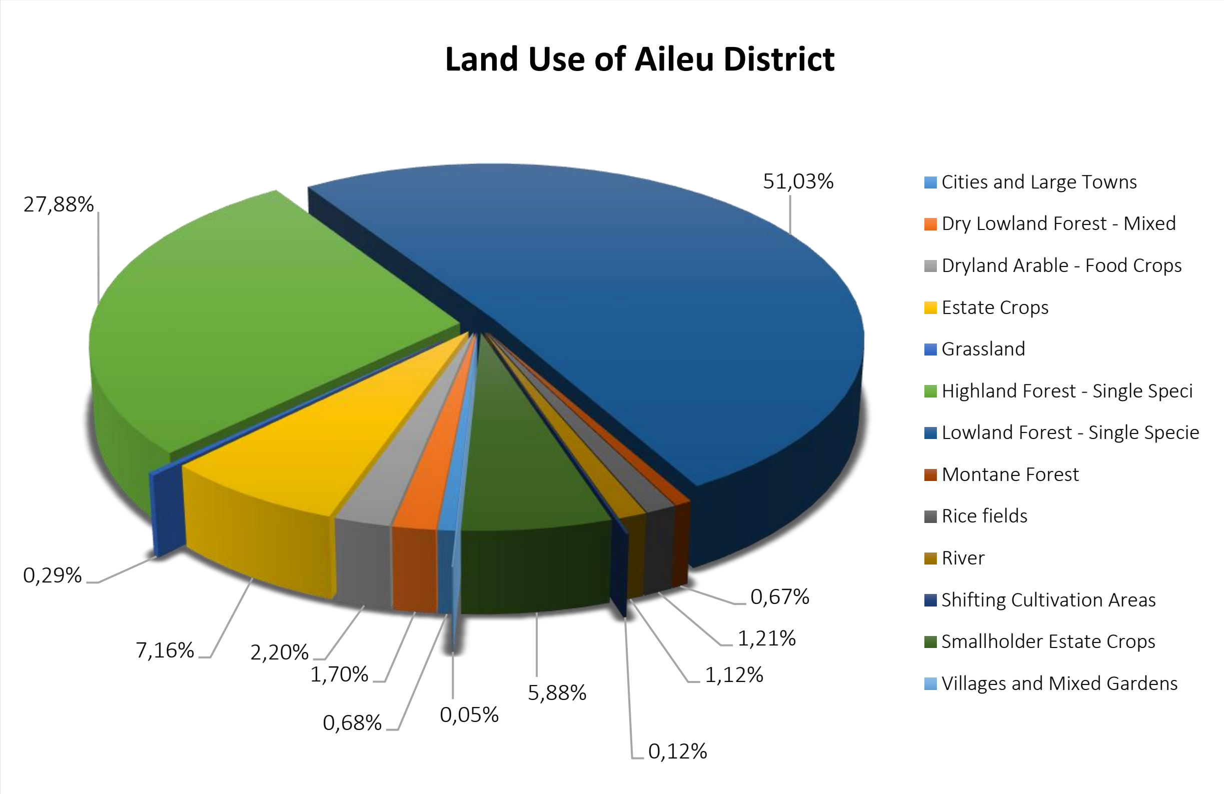
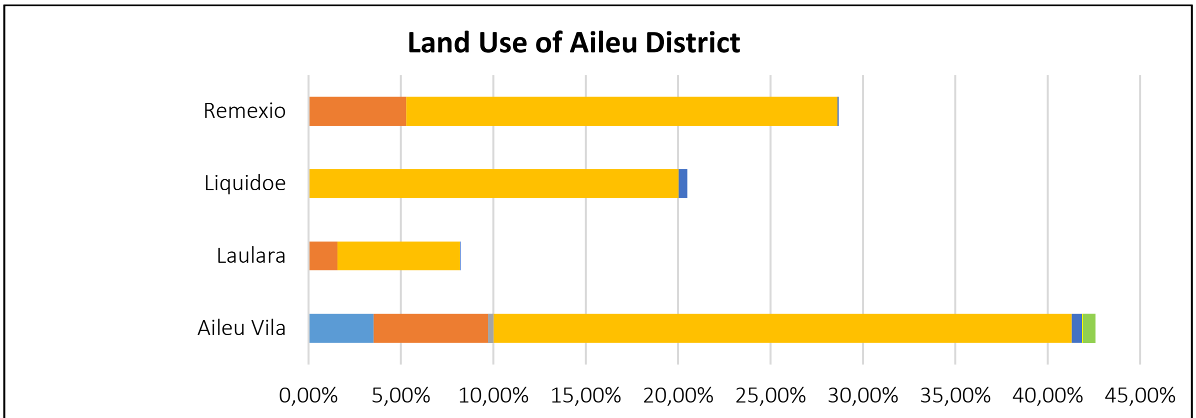


Figure 2.8 Land use Graphic of Aileu District



	Aileu Vila	Laulara	Liquidoe	Remexio
Agricultural Land	3,52%	0,00%	0,00%	0,01%
Commercial Agriculture	6,20%	1,56%	0,00%	5,28%
Dryland Not In Use	0,29%	0,00%	0,00%	0,00%
Forested Land	31,28%	6,63%	20,04%	23,33%
River	0,56%	0,04%	0,46%	0,07%
Rural Settlement	0,05%	0,00%	0,00%	0,00%
Settlements and Industrial	0,68%	0,00%	0,00%	0,00%

Figure 2.9 Area of Aileu District by Land Use

The diversity of land use in Aileu District indicates substantial opportunities for developing agriculture and forestry by utilizing the designated land-use areas; however, achieving optimal development requires adherence to sustainability principles, efficient use, and sound conservation. The land-use map of Aileu District is presented in **Figure 2.10.**

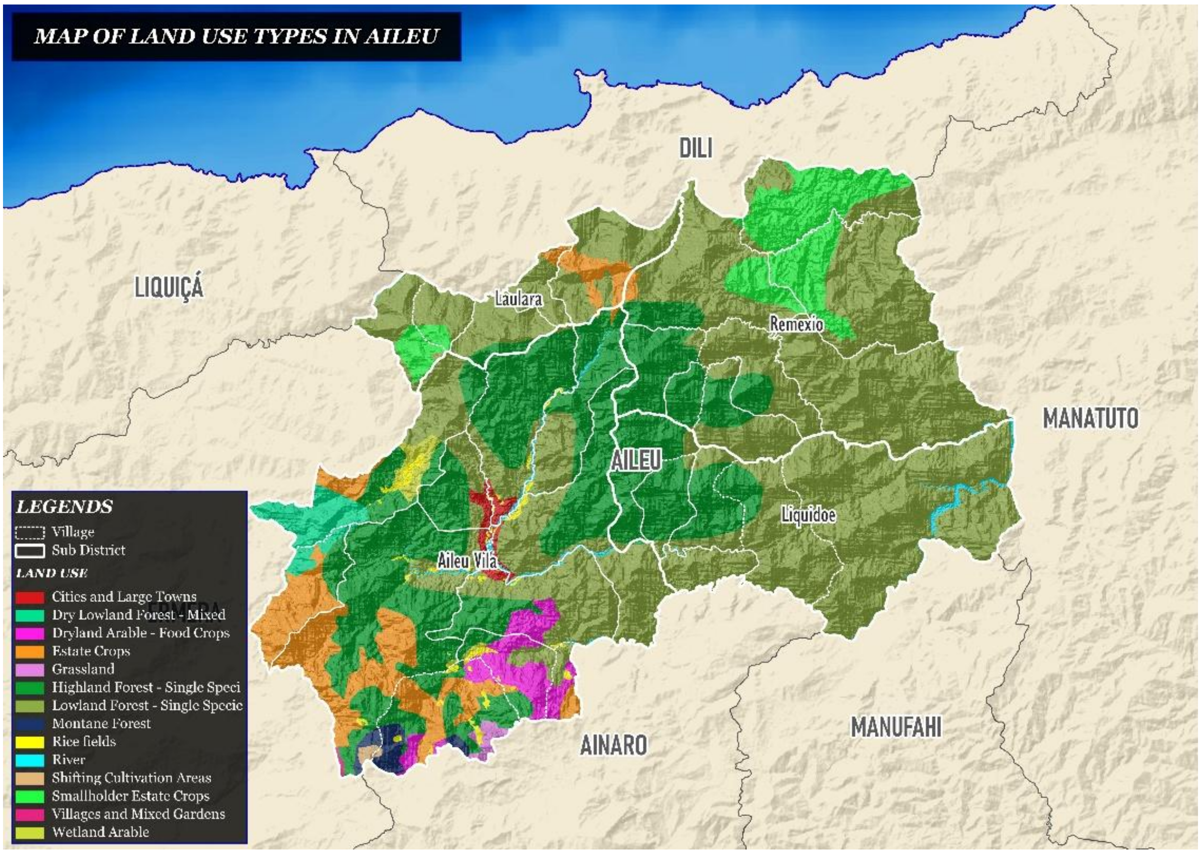


Figure 2.10 Land Use Map of Aileu District

2.5 SLOPE GRADIENT

The distribution of slope gradient classes in Aileu District provides important information on topography with implications for land management, soil erosion potential, and natural resource conservation. Slope gradients are grouped into five categories, namely flat (0-8 %), gentle (8-15 %), moderately steep (15-25 %), steep (25-45 %), and very steep (>45 %). This variation reflects the complexity of the area, which influences both potential and challenges in land management for agricultural purposes.

Areas with flat slopes (0-8 %) had the most limited distribution across all Sub-Districts, totaling 24,19 km² or 4,96 % of the district, with the largest area in Aileu Vila Sub-District at 24,19 km² (3,28 %). This terrain is suitable for settlement development, infrastructure, or urban-based economic activities due to its relatively even topography and better accessibility. Laulara Sub-District had a very small area in this class at only 0,71 km² (0,10 %), which may correspond to specific micro-sites such as river valleys. In Liquidoe and Remexio Sub-Districts, this class covered 5,88 km² (0,80 %) and 5,79 km² (0,79 %), respectively, indicating very limited potential for intensive development.

The gentle slope class (8-15 %) covered 49,75 km² (8,78 %) of the total area, providing greater flexibility in land use, particularly for more intensive agriculture. Aileu Vila Sub-District recorded the largest area in this class at 34,49 km² (4,68 %), which can be utilized for activities that require moderately sloping land. Laulara Sub-District accounted for only 1,79 km² (0,24 %), indicating limited distribution of moderate topography. In Liquidoe and Remexio Sub-Districts, areas in this class reached 13,47 km² (1,83 %) and 14,92 km² (2,03 %), respectively, each with potential for community-based management or conservation activities.

The 15-25 % slope class covered 171,42 km² (23,26 %) of Aileu District, indicating optimal potential for conservation-oriented agriculture and agroforestry. Aileu Vila Sub-District had the largest area at 81,18 km² (11,02 %), followed by Remexio at 45,20 km² (6,13 %) and Liquidoe at 38,42 km² (5,21 %). These areas offer a balance between productive use and environmental stewardship. Laulara Sub-District covered only 6,63 km² (0,90 %), the smallest extent, indicating a focus on steeper slopes in Laulara.

The 25-45 % slope class dominated much of the area across all Sub-Districts, indicating consistently hilly to steep topography with potential for land conservation measures and protective vegetation. Aileu Vila Sub-District had the largest area at 148,21 km², followed by Remexio with 113,89 km² (15,45 %), Liquidoe 73,92 km² (10,03 %), and Laulara 31,66 km² (4,30 %). These areas require targeted management interventions to prevent soil degradation from erosion.

Very steep slopes (>45 %) were widespread in Remexio and Aileu Vila Sub-Districts, covering 31,70 km² (4,30 %) and 25,64 km² (3,48 %), respectively. Laulara and Liquidoe Sub-Districts also had areas in this category, at 19,89 km² (2,70 %) and 19,38 km² (2,63 %). These areas have substantial limitations for intensive activities and are more appropriate for conservation or protective vegetation.

Slope gradient data for Aileu District are presented in **Figure 2.11** and **Figure 2.12**, and the spatial distribution map of slope gradients in Aileu District is presented in **Figure 2.13.**

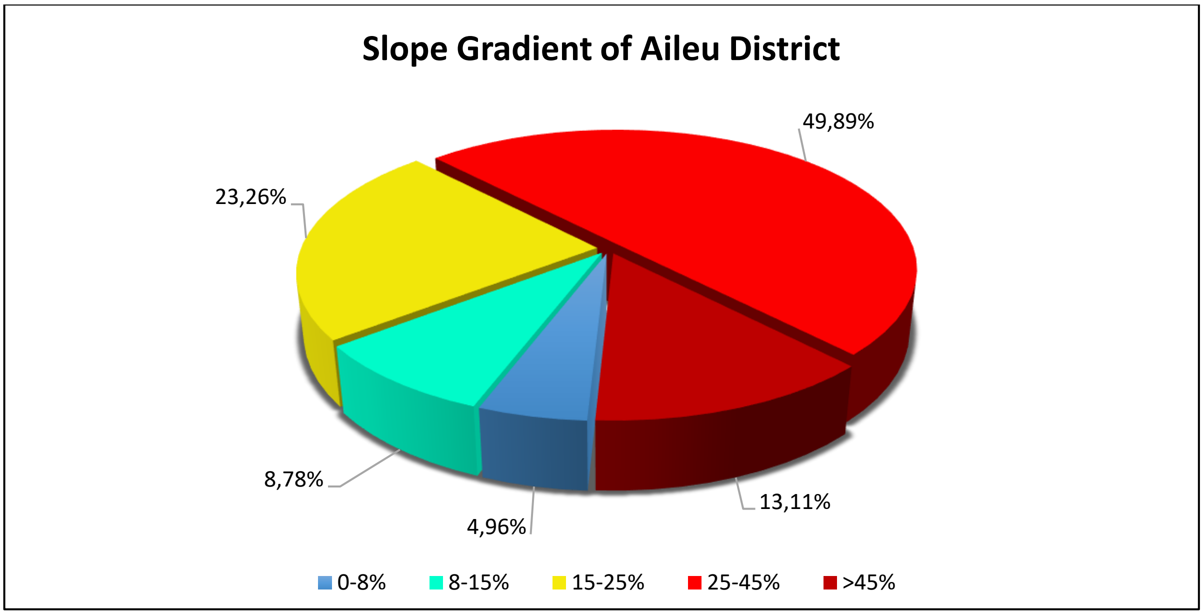
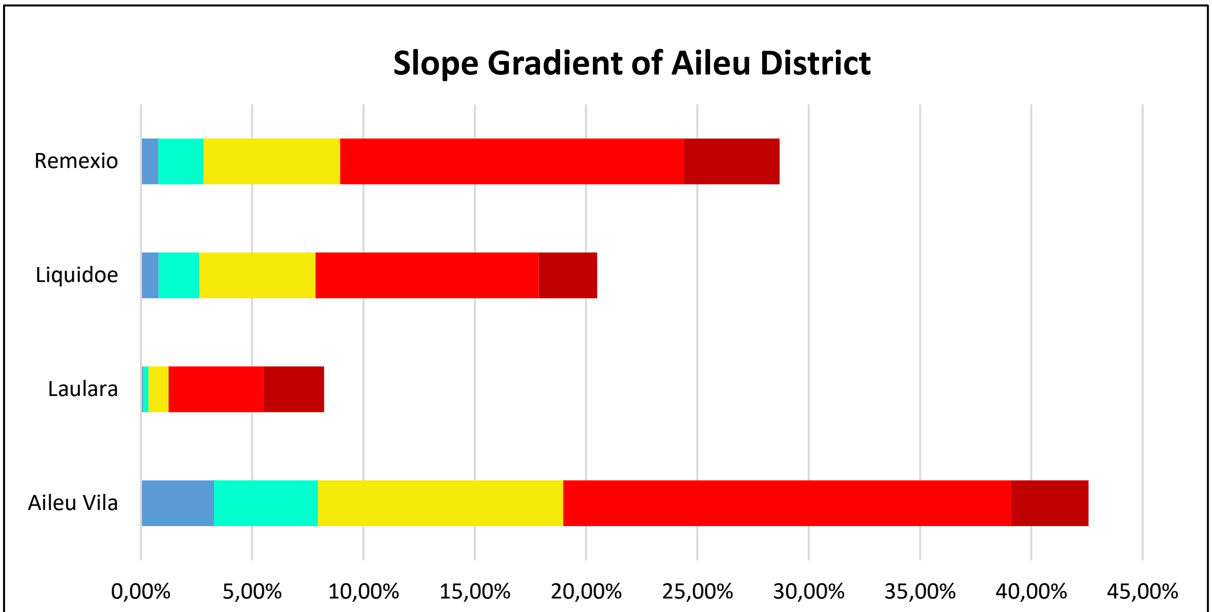


Figure 2.11 Slope Gradient Graphic of Aileu District



	Aileu Vila	Laulara	Liquidoe	Remexio
0-8%	3,28%	0,10%	0,80%	0,79%
8-15%	4,68%	0,24%	1,83%	2,03%
15-25%	11,02%	0,90%	5,21%	6,13%
25-45%	20,11%	4,30%	10,03%	15,45%
>45%	3,48%	2,70%	2,63%	4,30%

Figure 2.12 Slope Gradient by Sub-District in Aileu District

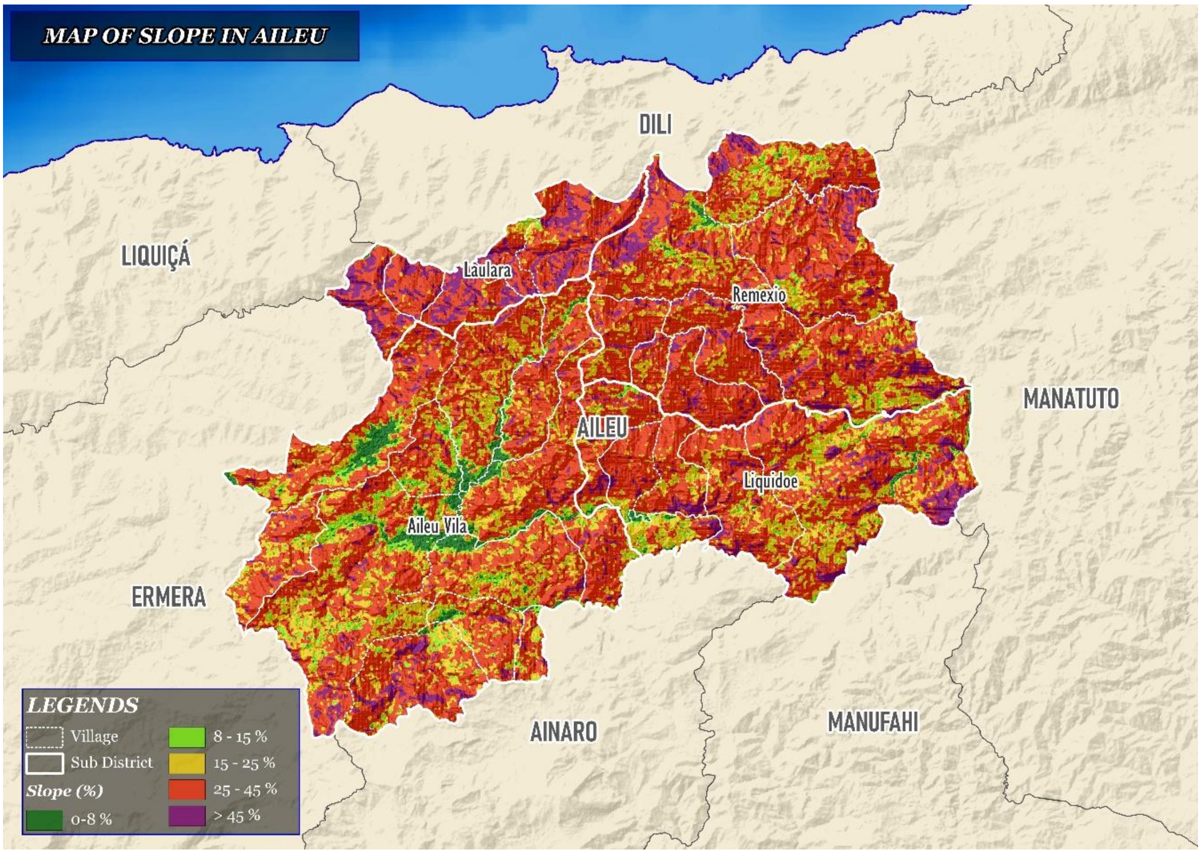


Figure 2.13 Slope Gradient Map of Aileu District

2.6 AGROCLIMATIC ZONES

The agroclimatic zones in Aileu District were classified based on elevation and rainfall patterns, as summarized in the Agriculture Land Use Information System (ALGIS), which adopts the framework of Fox (2003). This approach is relevant for natural resource management and also provides a scientific framework for sustainable land suitability evaluation (Molyneux *et al*., 2013; Williams *et al*., 2017). The total area by agroclimatic zone in Aileu District is presented in **Figure 2.14,** the agroclimatic zones by Sub-District are presented in **Figure 2.15,** and the spatial distribution of agroclimatic zones in Aileu District is presented in **Figure 2.16.**

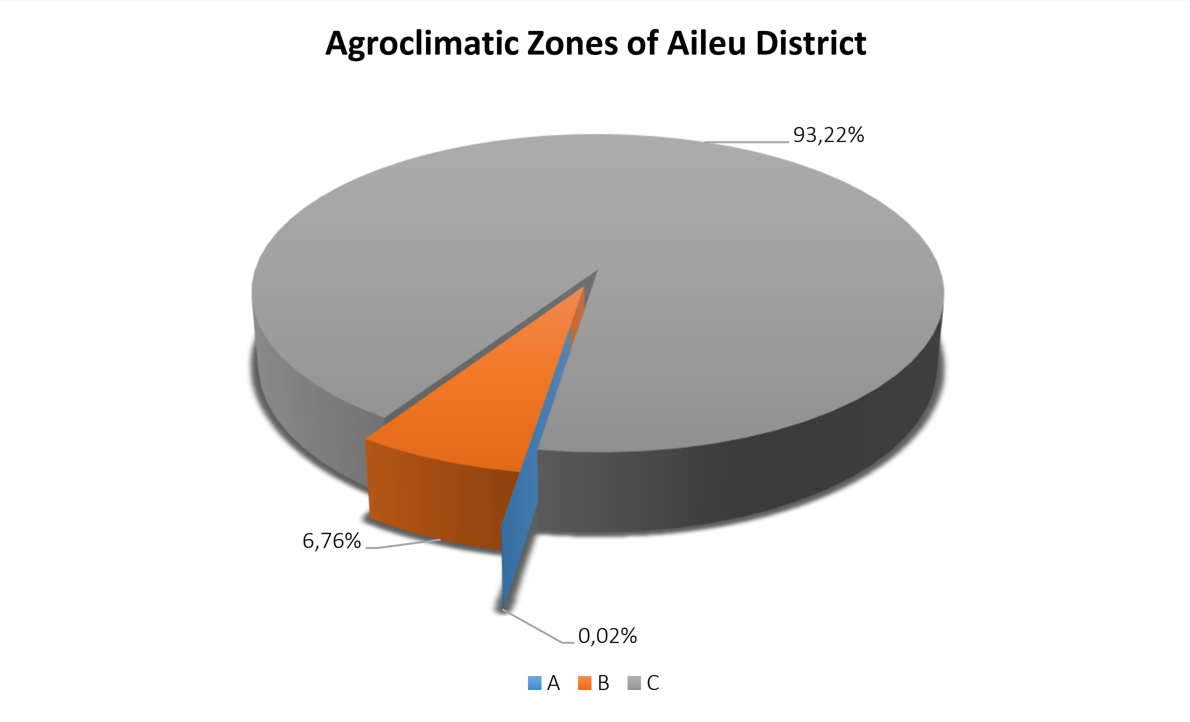
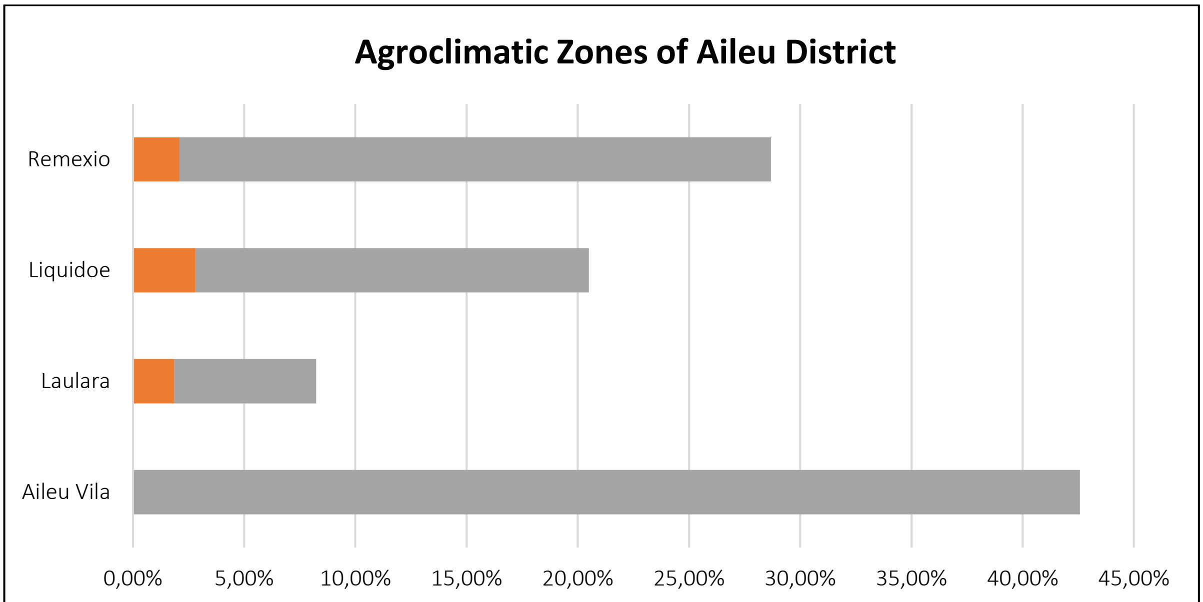


Figure 2.14 Agroclimatic Zones Graphic of Aileu District



	Aileu Vila	Laulara	Liquidoe	Remexio
A	0,00%	0,00%	0,00%	0,02%
B	0,00%	1,86%	2,83%	2,07%
C	42,58%	6,37%	17,68%	26,60%

Figure 2.15 Agroclimatic Zones by Sub-District in Aileu District

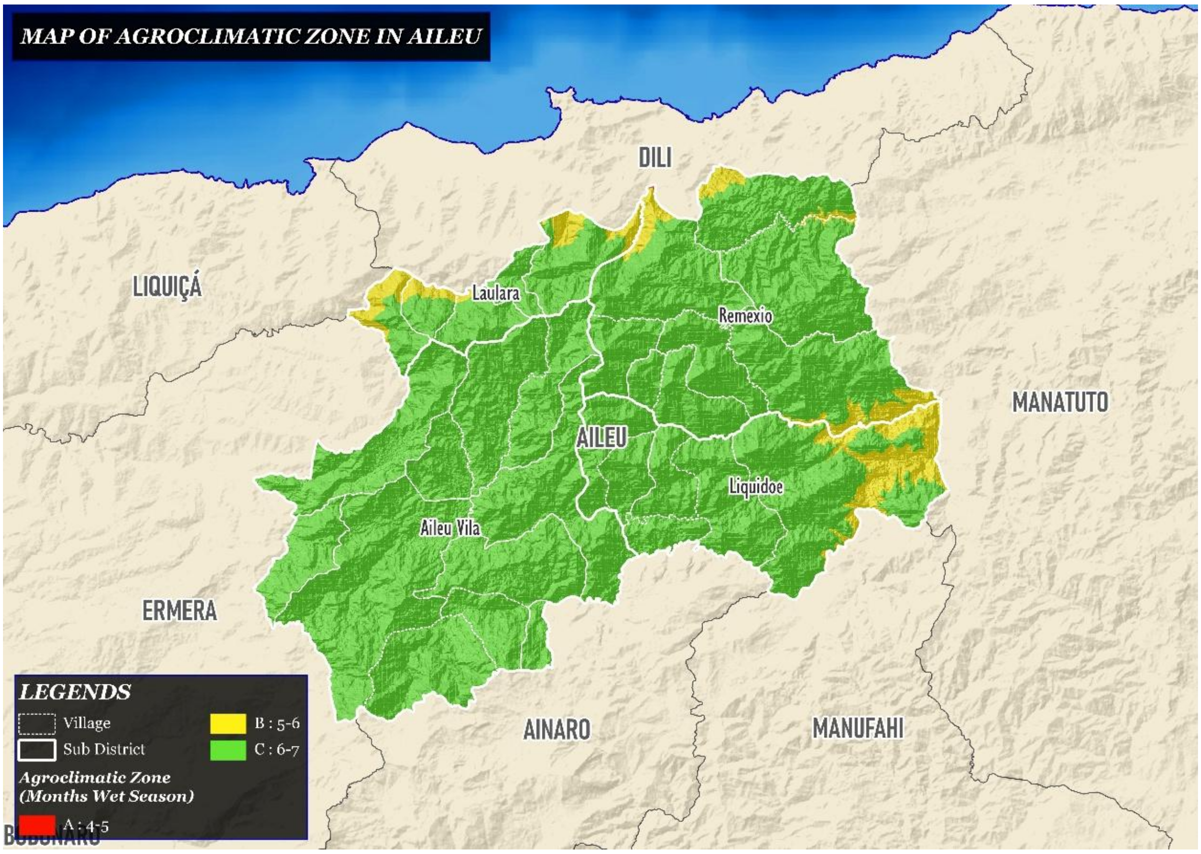


Figure 2.16 Agroclimatic Zones Map of Aileu District

Zone A had the smallest extent and was found only in Remexio Sub-District with an area of 0,12 km² (0,02 %) of the total District. This zone supports vegetation tolerant of extreme agroclimatic conditions and offers specific opportunities for micro-ecosystem conservation or cultivation of suitable crops.

Zone B covered a larger area than Zone A and occurred in three Sub-Districts: Laulara, Liquidoe, and Remexio. Laulara Sub-District covered 13,74 km² (1,86 %), suitable for conservation activities based on protective vegetation. Liquidoe Sub-District covered 20,83 km² (2,83 %,) offering potential for agroforestry to maintain soil stability. Remexio Sub-District covered 15,29 km² or 2,07 %, providing flexibility for ecosystem protection while using land efficiently.

Zone C dominated Aileu District and covered substantial areas across all Sub-Districts. Aileu Vila Sub-District covered 313,96 km² (42,58 %), making it the principal area for planned intensive agriculture. Remexio Sub-District covered 196,09 km² (26,60 %), with strong potential for agroforestry and environmental conservation. Laulara Sub-District covered 46,96 km² (6,37 %), supporting productivity-based activities despite its relatively small area. Liquidoe Sub-District covered 130,33 km² (17,68 %), providing considerable opportunities for agroclimate-based land management. The agroclimatic zone chart for Aileu District is presented in **Figure 2.16.**

Overall, the distribution of agroclimatic zones in Aileu District shows the dominance of Zone C, which indicates considerable potential for intensive agriculture and sustainable conservation management. Zone B had a smaller extent but remains important for supporting soil and ecosystem protection. Zone A, limited to Remexio, had specific potential for crops tolerant of extreme agroclimatic conditions and is an integral component of environmental conservation strategies.

2.7 EXISTING FIELD CONDITIONS

The landforms in Aileu District comprise alluvial and fluvial landforms, denudational hills, and denudational mountains. Field observations indicated extensive idle land (land not currently utilized) with substantial potential to be developed into productive land. This potential was supported by adequate water availability from rainfall and rivers, as well as the possibility of using shallow wells and small reservoirs.

In general, vegetation growth in the area indicated reasonably good fertility. However, the application of appropriate agronomic practices remained limited, including plant spacing, crop combinations, and plant care such as pruning, weeding, and fertilization (organic, inorganic, and biofertilizers) across all land-use types.

Figure 2.17 Land for Agricultural Development in Aileu District
(Source: Researcher’s documentation, 2025)

Aileu District has agricultural and forestry potential that plays an important role in the local economy. Priority commodities, particularly coffee and oranges, are the main contributors to household income. Coffee is cultivated across all Sub-Districts and commands a high market value, making it a strategic commodity in local and export trade. Oranges are grown in various areas, serving as an economic source and supporting regional food security. In forest areas, three principal industrial tree species dominate, namely teak, acacia, and eucalyptus **(Figure 2.19).** These trees play significant roles in the wood industry, supplying raw materials for construction and a range of wood-based products. In addition to their economic contribution, the three species also provide ecological functions, including erosion control, soil conservation, and habitat maintenance for local biodiversity.

In mixed gardens, communities cultivate various horticultural and food crops, such as pineapple, caisim, eggplant, chili, guava, and cassava. This diversification increases farmers' income, meets local food needs, and yields processed products with higher economic value. Diverse cultivation also supports the sustainability of the agricultural system by strengthening the region's ecological and economic resilience.

Figure 2.18 Development of Coffee Cultivation in Aileu District
(Source: Researcher's documentation, 2025)

Figure 2.19 Eucalyptus Trees
(Source: Researcher's documentation, 2025)

Figure 2.20 Pineapples
(Source: Researcher's documentation, 2025)

Field observations found that former rice fields now planted with cassava and banana had potential to be restored as rice fields (**Figure 2.21**). Restoring these areas could significantly increase food crop production. In Laulara Sub-District, there were extensive areas with potential to be developed as livestock grazing sites. Manure from these areas could be used as organic fertilizer, providing additional benefits for agriculture in the region. Field observations indicated that in Fatisi Village, rambutan cultivation faced a problem of suboptimal fruiting. In addition, former rice fields currently planted with cassava, corn, and banana had potential to be rehabilitated as productive rice fields (**Figure 2.21**). Restoring these areas could increase food production capacity, improve land-use efficiency, and support regional food security. This effort would require analysis of soil fertility, water availability, and integration with irrigation systems to ensure production sustainability.

In Aileu District there were also extensive areas with potential to be used as livestock grazing. Utilizing this land would not only support the livestock sector but also provide agronomic benefits through the production of organic fertilizer. Manure could be used to improve soil fertility, enhance soil structure, and strengthen water retention, thereby contributing to increased agricultural productivity.

Figure 2.21 Former Rice Fields Restored with Cassava, Corn, and Banana
(Source: Researcher’s documentation, 2025)

However, land management in Aileu District faced several constraints. Access to potential land was often hindered by extreme terrain conditions, complicating agricultural activities and land management. In addition, land with steep slope gradients had high soil erosion rates (Figure 2.22), indicated by thin topsoil and landslides. The erosion that occurred had the potential to reduce land productivity and accelerate soil degradation. Limited adoption of conservation techniques, such as terracing and ground cover vegetation, exacerbated conditions and increased the risk of soil fertility loss.

To maintain land sustainability, an integrated conservation strategy was required, comprising mechanical and vegetative approaches. The combination of these techniques could strengthen soil structure, reduce the impacts of erosion, and increase land-use efficiency to support long-term agricultural productivity.

Figure 2.22 Erosion observed in the field
(Source: Researcher's documentation, 2025)

In general, land management practices applied by farmers remain very limited. Indicators of this condition include:

1) The absence of adequate production inputs, such as improved seed, resulting in persistently low crop yields.
2) Low use of fertilizers, both organic and inorganic, which affects crop quality and yield.
3) Limited application of appropriate cultivation techniques, including plant spacing, effective planting methods, and orderly plant arrangement.
4) Minimal attention to crop care, pruning, and field sanitation, all of which contribute to suboptimal production outcomes.

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

2.8 *Chromolaena odorata*

Chromolaena odorata (**Figure 2.23**) commonly known as Siam weed, is a flowering weed in the family *Asteraceae* that thrives in tropical and subtropical regions. Its spread, particularly in developing countries such as Timor-Leste, especially in Aileu District, has significant impacts on the environment and the local economy.

Figure 2.23 *C. odorata* in Aileu District
(Source: Researcher's documentation, 2025)

This species has distinctive morphological characteristics, including cylindrical, hairy stems; simple leaves with serrated margins; and inflorescences that are bluish when young and turn brown at maturity (**Figure 2.24**). Chemically, *C. odorata* contains active compounds such as flavonoids, tannins, alkaloids, saponins, and essential oils (Jamatia *et al.*, 2024). These constituents provide substantial potential as raw materials for traditional medicines for conditions such as diabetes, burns, hypertension, and skin infections (Jamatia *et al.*, 2024).

Figure 2.24 Leaf and Flower Structure of *Chromolaena odorata*
(Source: https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:57443-2/images)

III. RESEARCH METHODS

The study was conducted in Aileu District, Timor-Leste, with the primary objective of evaluating land suitability for agricultural development. Data were collected through field surveys, laboratory analyses, and the use of geospatial information systems. The research was carried out from May to June 2025 and comprised direct field observations, soil sampling, interviews with local farmers, and geographic information system (GIS)-based mapping. All stages were organized systematically to generate accurate information that can serve as a basis for planning sustainable land management.

3.1 RESEARCH DESIGN

A. Methodological Approach

This study employed quantitative and qualitative approaches. The quantitative approach aimed to obtain numerical data for statistical analysis, whereas the qualitative approach was used to explore farmers' experiences and perceptions related to agricultural practices in the study area (Trigunasih, 2016). The research methods included field observations and laboratory analyses, encompassing soil sampling and interviews with local communities.

B. Determination of Sampling Points

Sampling points were determined using a Village-based approach that considered various factors, including land-use practices, agricultural traditions, and community dynamics. This approach was designed to represent the homogeneous land units present in the area, thereby producing relevant results that accurately reflected field conditions. Soil samples were collected randomly and compositely using the boring method. Each land unit was represented by one composite soil sample, collected at 0 to 30 cm depth for annual crops and 30 to 60 cm for perennial crops. Each soil sample weighed 1 kg for subsequent laboratory analysis.

C. Soil Morphological Observations

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

D. Interviews and Questionnaires

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

E. Land Suitability Evaluation

Field survey results, climate data, and laboratory results were tabulated and evaluated using the agroecosystem land suitability assessment system based on the criteria of Ritung *et al*. (2011). The classification method referred to the FAO (1976) system with a matching approach, namely matching land characteristics with the growth requirements of the evaluated crops. The agricultural commodities evaluated in this study included food crops, horticultural crops, industrial crops, forestry species, spices and medicinal plants, forage feed, and grazing.

3.2 RESEARCH PROCEDURES

A. Literature Review

The literature review stage was conducted to collect relevant secondary data to support this study. The data collected included administrative maps of the study area, geographic conditions, agricultural land area, and agricultural commodity production. The climate data examined included temperature, rainfall, dry months, and humidity. In addition, previous research relevant to land suitability evaluation was reviewed to strengthen the study's theoretical foundation.

B. Land Unit Analysis

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

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

C. Field Survey

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

Interviews with local farmers were also conducted to obtain additional information on agricultural practices and challenges in land management. Observations covered environmental factors affecting agricultural productivity, such as soil drainage, effective soil depth, erosion risk, flood risk, and surface rock outcrops (Ritung *et al*., 2011).

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

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

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

D. Laboratory Soil Analysis

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

a. Soil Organic Carbon (SOC) by Walkley dan Black method (%).
b. Total N by the Kjeldahl method (%).
c. Soil texture by the pipette method.
d. Soil pH by the potentiometric method (H_2O 1:2,5).
e. Available P (ppm) and Available K (ppm) by the Bray^{-1} method when soil pH was below 7 and by the Olsen method when soil pH was above 7, with unit conversion (mg/100 g)
f. Total Phosphorus (mg/100 g) and Total Potassium (mg/100 g) determined using the 25 % HCl method.
g. Total Zinc (ppm) determined using the DTPA extraction method and Available Zinc (ppm) determined using the HNO3- : HClO4 digestion method.
h. Total Sulfur (ppm) and Available Sulfur (ppm) determined using the spectrophotometric method.
i. Salinity (dS/m) by the potentiometric method (H_2O 1:2,5).
j. CEC (cmol) dan BS (%) using NH_4OAc 1N 7 pH as the extractant.
k. Determination of soil fertility status based on the PPT (1995) method.
l. Erosion hazard using the Universal Soil Loss Equation (USLE).

E. Land Suitability Analysis

Field observations and laboratory results were tabulated into agroecosystem land characteristics/qualities. Agroecosystem land suitability was then analyzed by matching land characteristics/qualities to the growth requirements of bamboo, teak, mahogany, pine, coffee, cacao, and coconut, to obtain land suitability classes based on the criteria of Ritung *et al*. (2011). Classification of land suitability was carried out to the land unit level.

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

F. Agricultural Commodity Development Planning

Commodity planning was based on potential land suitability for the agricultural commodities to be developed, with the highest land suitability for each crop as the primary parameter. Other parameters included prevailing land use in each homogeneous land unit and farm feasibility.

G. Land-Use Recommendations

Land-use recommendations were made at the land unit level, based on the highest land suitability ratings followed by lower classes, treatment of limiting factors, and improvement measures for each homogeneous land unit in the Sub-Districts of Aileu District. Preparation of digital maps using a geographic information system facilitated information display. The information included agroecosystem land suitability, land-use recommendations, and agricultural commodity zoning. Land suitability maps were prepared based on homogeneous land units and the results of agroecosystem land suitability classification.

The classified land suitability for each evaluated crop group was mapped. Crop-specific land suitability was presented in agricultural commodity zoning maps, while land-use planning was presented in land-use recommendation maps. The research flowchart is presented in **Figure 3.1.**

H. Data Analysis Using Geographic Information System Technology

The land suitability information system consisted of spatial data (homogeneous land unit maps) and attribute data (land suitability classes). Combining these components produced an information system using QGIS 3.10. The outputs comprised land suitability classes for food crops, horticultural crops, industrial crops, forestry species, spices and medicinal plants, forage feed, and grazing, based on the evaluation results. The land suitability maps, together with databases and land resource information, were compiled using land suitability data and criteria, in line with evolving uses such as varieties, cultivation technology, and land management.

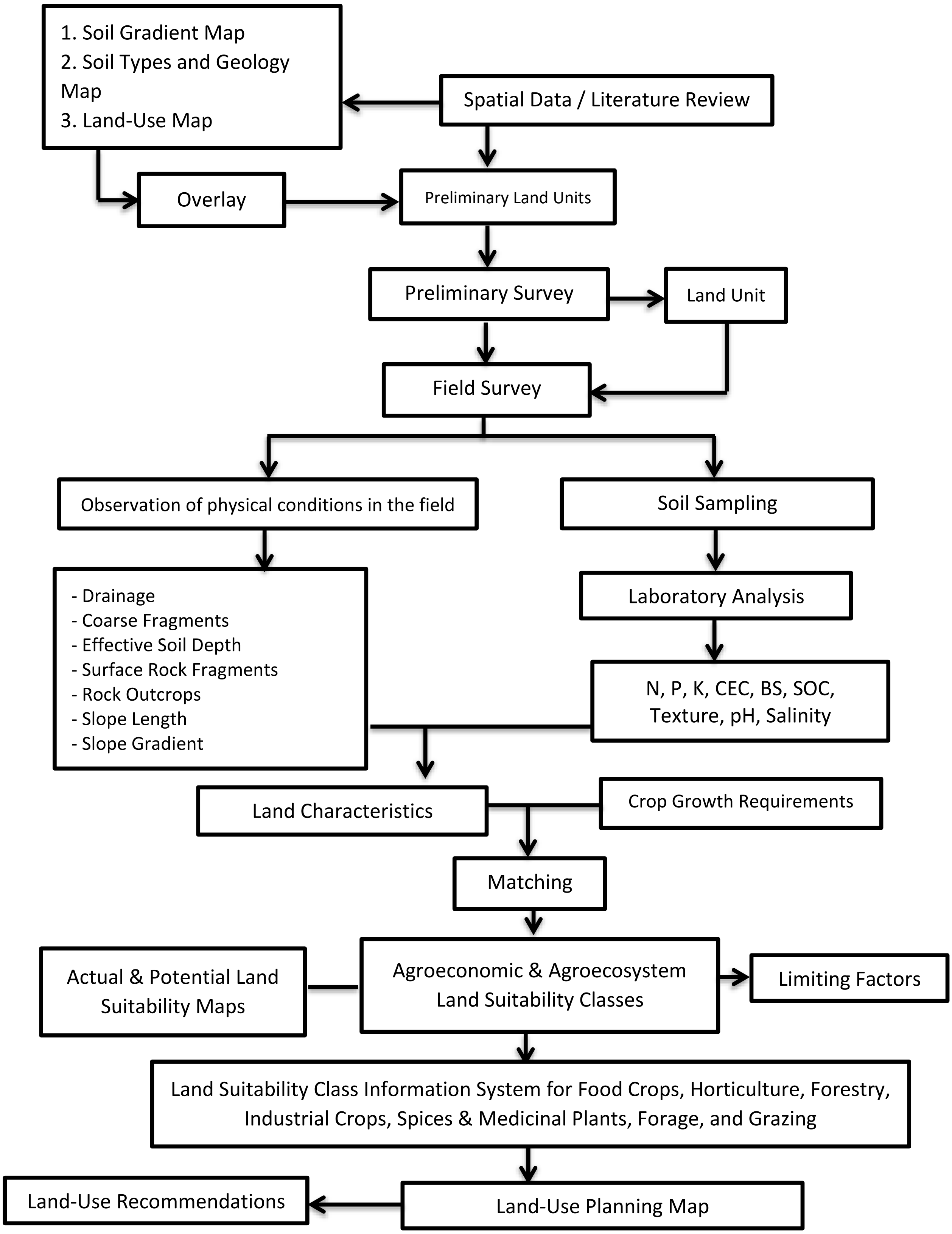


Figure 3.1 Research Process Flowchart

The land-use planning map was derived from land suitability classification and commodity zoning. The land-use planning map is a thematic digital map that provides guidance on land use for various commodities, including food crops, horticultural crops, industrial crops, forestry species, spices and medicinal plants, forage feed, and grazing. The digital map is the result of converting primary and secondary data and information from raster and analog forms into digital data. Advantages of digital map data include ease of correcting errors, ease of copying, long-term storage, and the ability to measure distance and area on the screen without field measurements, which would require considerable time and cost (Nugroho and Yarianto SBS, 2010). The outputs include digital maps in analog or hard-copy form in *.jpeg format that can be printed, and digital maps in *.dbf or shapefile *.shp formats that are integrated, easy to copy, and informative. Map marginal information presents the map title, followed in order by the map author's name, a scale bar, and a legend box displaying homogeneous land units, the study area, soil types, slope gradients, and land use, as well as the data source, latitude and longitude coordinates, and the datum system used.

3.3 GEOGRAPHIC INFORMATION SYSTEM TECHNOLOGY

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

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

Across the various definitions of GIS, several common keywords recur, namely geographically referenced data and the analysis of data (spatial and attribute) to generate information for specific aims and objectives. Accordingly, compared with other systems, GIS has the capability to handle data and information from a geographic perspective. This capability is especially relevant for development planning, which is carried out within the context of a particular region.

The term geographic is part of spatial. These two terms are often used interchangeably, giving rise to a third term, geospatial. In the context of GIS, all three carry the same meaning. Use of the word geographic conveys issues concerning the Earth: two- or three-dimensional surfaces (Prahasta, 2005).

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

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

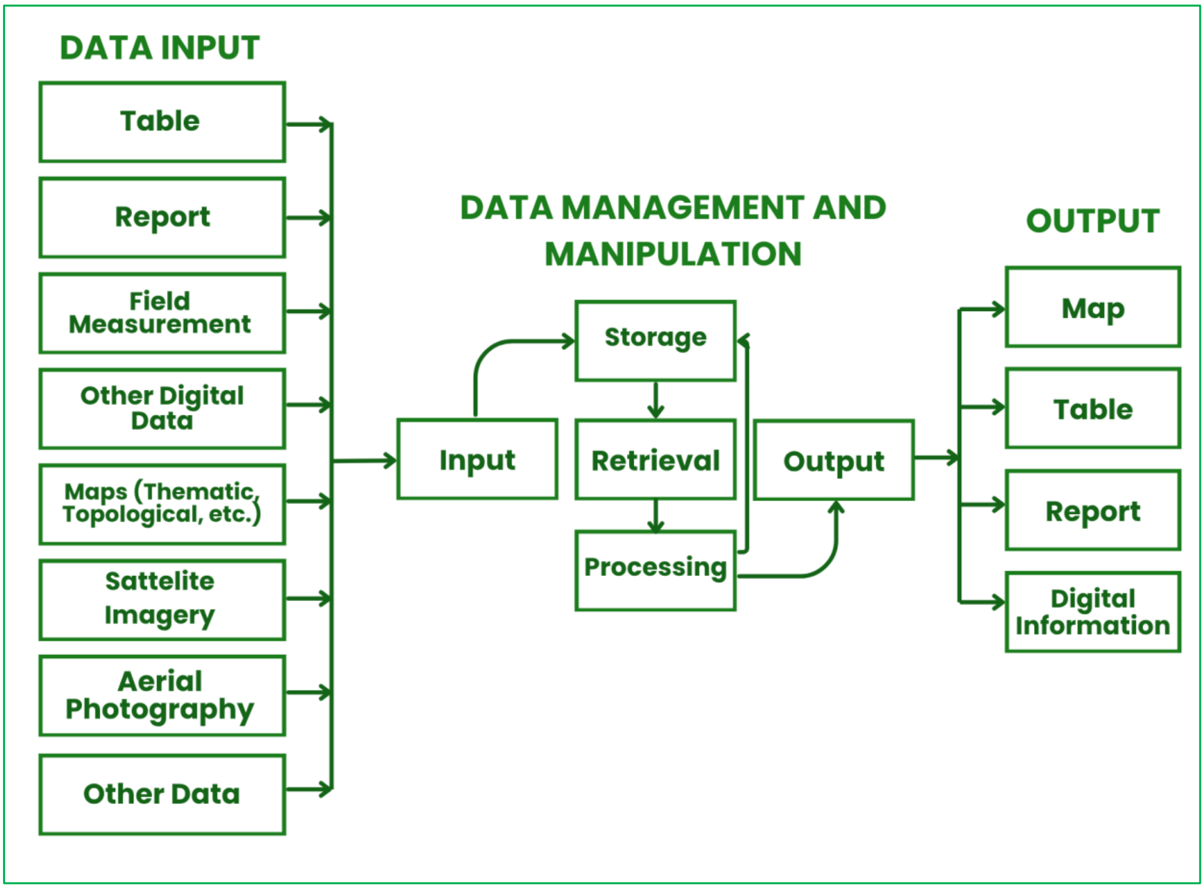


Figure 3.2 Components Constituting GIS
(Source: Prahasta, 2005)

Geographic information systems can be applied in various fields. The system's capabilities include (Prahasta, 2005):

1. Cartographic Capabilities

With this capability, GIS users can create maps and technical figures effectively and efficiently. The cartographic capability comprises digitizing, graphic visualization, interactive line manipulation, and plotting.

2. Data Management Capabilities

GIS can store, process, and manipulate geographically referenced data. This management capability also includes attribute data processing, namely the ability to store and display specific attribute data associated with particular geographic features.

3. Analytical Capabilities

The analytical capability is the ability to interpret and study collected data and information for specific purposes. It includes analysis of engineering functions, prediction/forecasting, computational operations, demographic analysis, sociocultural analysis, analysis of various regions and Districts, presentation of graphs and tabulations, overlay analysis, logical analysis, and selection analysis.

4. Integration of GIS and Multimedia

The ability to integrate GIS and multimedia has been developed by local innovators in Bali. Through integration between multimedia systems and GIS, the final display of GIS analysis results becomes more engaging and facilitates reading and understanding of the results.

A. GIS Processes and Components

GIS essentially performs six processes (Prahasta, 2005):

1. Data Input

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

2. Data Transformation

The types of data used in GIS may need to be transformed or manipulated in several ways to conform to the system. For example, there may be differences in scale, so before data are entered and integrated they must first be transformed to the same scale. This transformation could be temporary for display purposes or permanent for analytical processing.

3. **Editing**

The editing stage is the digital correction stage. Corrections may involve adding or removing arcs or features by editing overshoots or adding undershoots. Editing is also performed to add arcs manually, such as creating polygons, lines, or points.

4. **Data Management**

After spatial data are entered, processing proceeds to descriptive data, which includes annotation (adding text to the coverage), labeling (assigning information to the relevant map), and attributing, namely the stage in which each label ID from the labeling process is assigned additional attributes that provide information about the polygon or arc it represents.

5. **Query and Analysis**

Query in GIS is essentially an analytical process performed in tabular form. Fundamentally, GIS analysis uses spatial analysis. GIS has many strengths in spatial analysis, with two of the most important being:

a) Proximity Analysis

A geographic analysis based on distances between layers. Questions include, for example, how many houses are located in a watershed. In proximity analysis, GIS uses a process called buffering (creating a support layer around a layer at a specified distance) to determine the nearness of relationships among existing components.

b) Overlay Analysis

The process of integrating data from different layers is called overlay. In simple terms, this can be considered a visual operation, but analytically it requires merging more than one layer. An example of overlay or spatial join is the integration of soil, slope, and vegetation data, or land ownership with assessed land tax values.

6. **Visualization**

For some types of geographic operations, the best final output is expressed in maps or graphics. Maps are highly effective for storing and conveying geographic information.

B. GIS Components

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

1. **Hardware**

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

2. **Software**

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

a. Tools for data input and manipulation.
b. A database management system (DBMS).
c. Tools that support geographic query, analysis, and visualization.
d. A graphical user interface (GUI) for accessing the tools.

3. **Data**

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

4. **Human**

GIS technology is not useful without people who operate the system and develop plans that can be applied to real-world conditions. As with other information systems, GIS users have different levels, from technical specialists who design and maintain the system to users who employ GIS to support their daily work.

5. **Methods**

A well-designed GIS aligns a good design plan with real-world rules. Models and implementation methods vary for each problem.

C. Data Processing in GIS

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

1. Base Map Digitizing

Base map digitizing was performed using the Rupabumi Indonesia map at 1:25.000 scale, which served as the basis for conducting the survey and for map digitizing, including data updating. Conversion to digital format was carried out layer by layer with topology.

2. Import Data

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

3. Geometric Correction of Imagery

Geometric correction was required so that satellite imagery had a map reference or coordinate system. Geometric correction can be performed using three methods: image to image (previously corrected imagery), image to ground, in which map coordinates are measured directly in the field using GPS (Global Positioning System), and image to map.

4. Digital Image Processing

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

5. Satellite Image Classification

A digital classification process was also carried out, complemented by a knowledge-based approach for extracting spatial information on land use. Classification employed supervised classification and filtering. The digital classification model, which yields grouping accuracy far superior to the human eye, was complemented by visual interpretation of the Brovey-transformed data. Digital classification was performed by grouping assemblages of objects identified as samples (sampling areas). The image-processing software automatically searched for pixel assemblages similar to the sample areas, thus forming distinct classes. The classified imagery was then validated in the field to identify discrepancies and uncertain pixels. Discrepancies found during field validation were not permitted to exceed 3 % of the test area. The classification results were used to update the digitized Rupabumi Indonesia map using the digital light table effect and raster–vector overlay.

6. Updating Spatial Information

Spatial information on maps was updated using raster–vector overlay, complemented by the light table effect for interpreting and analyzing land-use information. Updates to planimetric spatial information were performed with raster–vector overlay. This integration model combined digital image classification with visual image interpretation to obtain accurate updated spatial data. Specific objects deemed important but not clearly visible in the imagery were mapped using GPS during field surveys. The final output of the updating work was digital spatial land-use data in GIS.

7. Field Survey

Field surveys were conducted to correct interpretation errors made in the laboratory, to investigate spatial information for uncertain objects in the imagery, and to plot the positions of important objects that could not be extracted directly from the imagery.

8. Reinterpretation and Editing

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

9. Edge Matching

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

10. Digital Cartography and Map Production

Cartographic processing was performed fully digitally to produce standard map layouts in accordance with prevailing cartographic principles. The cartographic model in this work referred to the thematic map cartography model issued by Badan Informasi Geospasial.

11. Database Development and Modeling

Database development was carried out for all resulting GIS spatial datasets, consisting of spatial land-use data, attribute data, and the thematic maps produced.

IV. LAND CHARACTERISTICS

4.1 TEMPERATURE

Air temperature is a key factor in land suitability evaluation because it strongly influences the sustainability of natural resource management and the potential for regional development. In this study, the spatial distribution of temperature was analyzed by integrating field measurements with geospatial data from the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM), applying the Braak formula. This analysis provides a comprehensive picture of temperature variability that reflects the complexity of topography, elevation, and microclimate in Timor-Leste.

Results for Aileu District (**Figure 4.1**) indicate dominance by cool to warm conditions, with the >21–24 °C category having the largest share. Among all Sub-Districts, Aileu Vila had the largest area in this category. Because Aileu Vila lies in highland terrain, the air at higher elevations is thinner and therefore absorbs and retains less solar heat, so average daily temperatures tend to be lower than in the lowlands (Ritung *et al*., 2011; Rahma *et al*., 2023).

The >24–26 °C category occurred only in Laulara Sub-District, indicating that only a small part of the district experiences relatively hot conditions, which can affect evapotranspiration rates and water requirements in agricultural systems. The lower-temperature category, >18–21 °C, occurred across all Sub-Districts, with Aileu Vila again dominating this class.

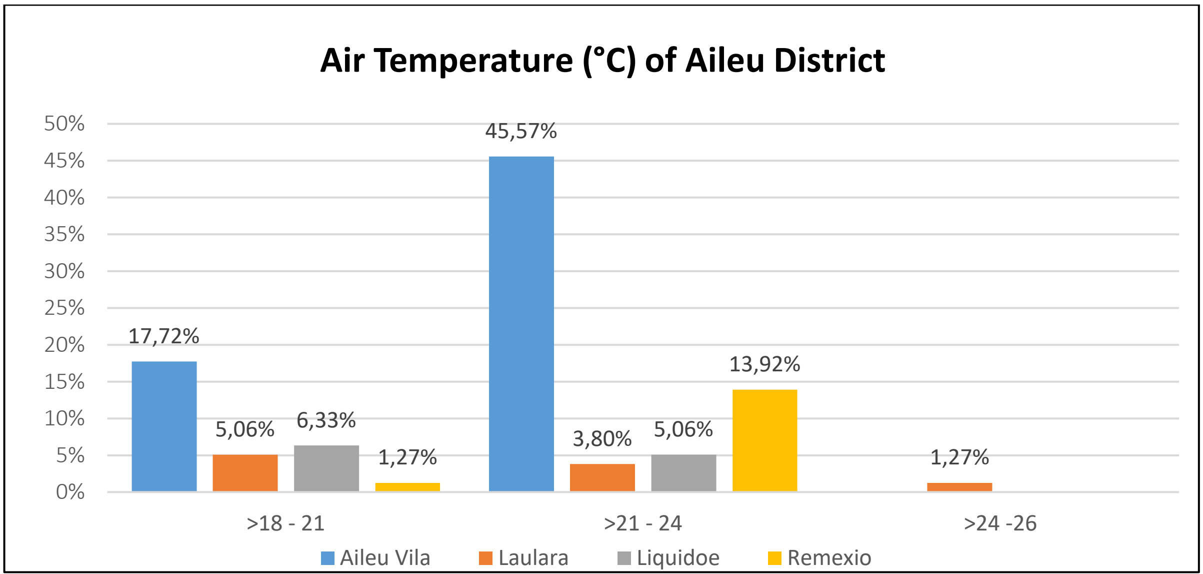


Figure 4.1 Air Temperature Data (°C) of Aileu District

4.2 RAINFALL

Rainfall is an essential element in land suitability evaluation, particularly for determining a region's potential to support agricultural productivity, soil conservation, and water resource management. Field observations of rainfall show spatial variability across the area. Aileu Vila Sub-District was dominated by the 2,000–2,500 mm class, largely because it lies in highland terrain. At higher elevations, moist air is forced upward orographically (ascending along mountain slopes), causing cooling and increased condensation, which enhances the formation of substantial precipitation in these areas (Berg *et al*., 2017). This condition supports abundant water resources, but it requires careful management.

The 1,500–2,000 mm class was most extensive in Remexio Sub-District, followed by Aileu Vila, indicating that much of the area has sufficiently stable water availability to support agriculture. Laulara Sub-District was dominated by the 1,000–1,500 mm class, reflecting a transitional zone commonly found from lowlands into gently hilly terrain. The rainfall chart for Aileu District is presented in **Figure 4.2.** These differences accord with Oldeman's (1975) agroclimatic zoning concept, which posits that the amount and distribution of annual rainfall largely determine cropping patterns, the types of commodities that can be cultivated, and the agronomic technologies required for successful farming systems. Variations in rainfall among Sub-Districts lead to differences in water availability. Therefore, each area should manage and utilize water resources optimally to support more effective agricultural development.

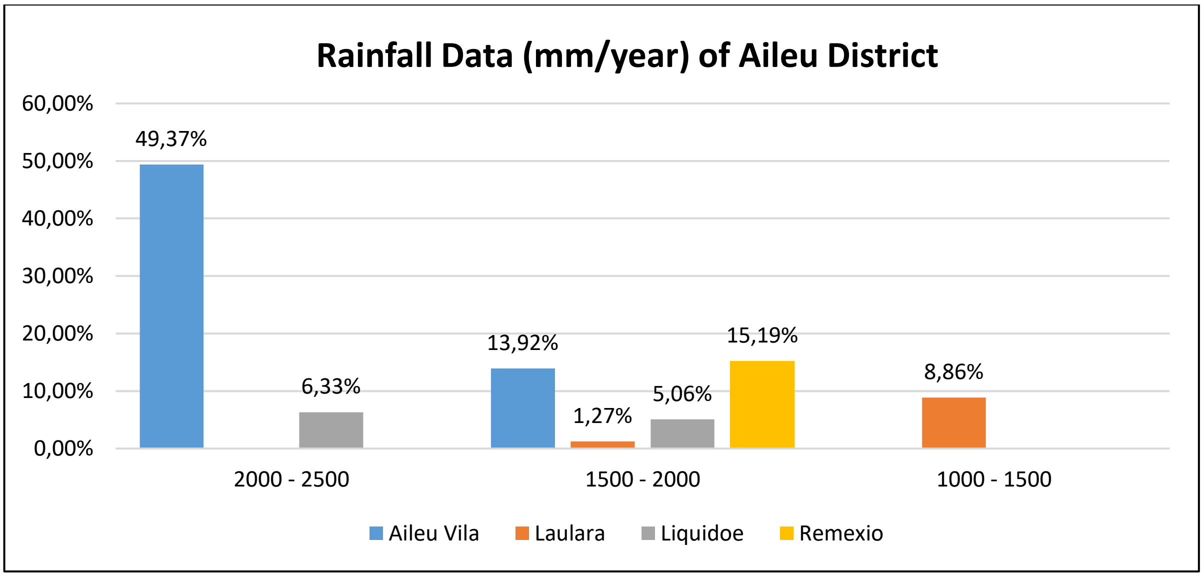


Figure 4.2 Rainfall Data of Aileu District

4.3 DRY MONTHS

The analysis of the distribution of dry months in Aileu District provides a detailed view of the microclimatic conditions that influence land potential in each area. Land characteristics based on the dry-month classification also show variation and differences across regions. Aileu Vila Sub-District exhibits a dominant dry period of 5–6 months, followed by Remexio Sub-District. This condition is influenced by the area's geographical location, which is relatively distant from the coastline, leading to lower rainfall intensity compared to coastal areas. Lesik *et al*. (2020) in regions such as Flores, explained that increased rainfall with elevation occurs only if the area is still within the reach of marine moisture influence. Conversely, in areas sufficiently far from the moisture source, rainfall tends to decrease due to limited water vapor supply from the sea. Therefore, the combination of distance from the coast and topographical position plays a key role in determining rainfall distribution patterns and the length of the dry season in areas like Aileu and Remexio.

The dry-month period of >6 months was found only in Laulara Sub-District. Overall, the Sub-Districts in Aileu District are predominantly categorized by 5–6 months of dry months, indicating significant agroclimatic diversity **(Figure 4.3).**

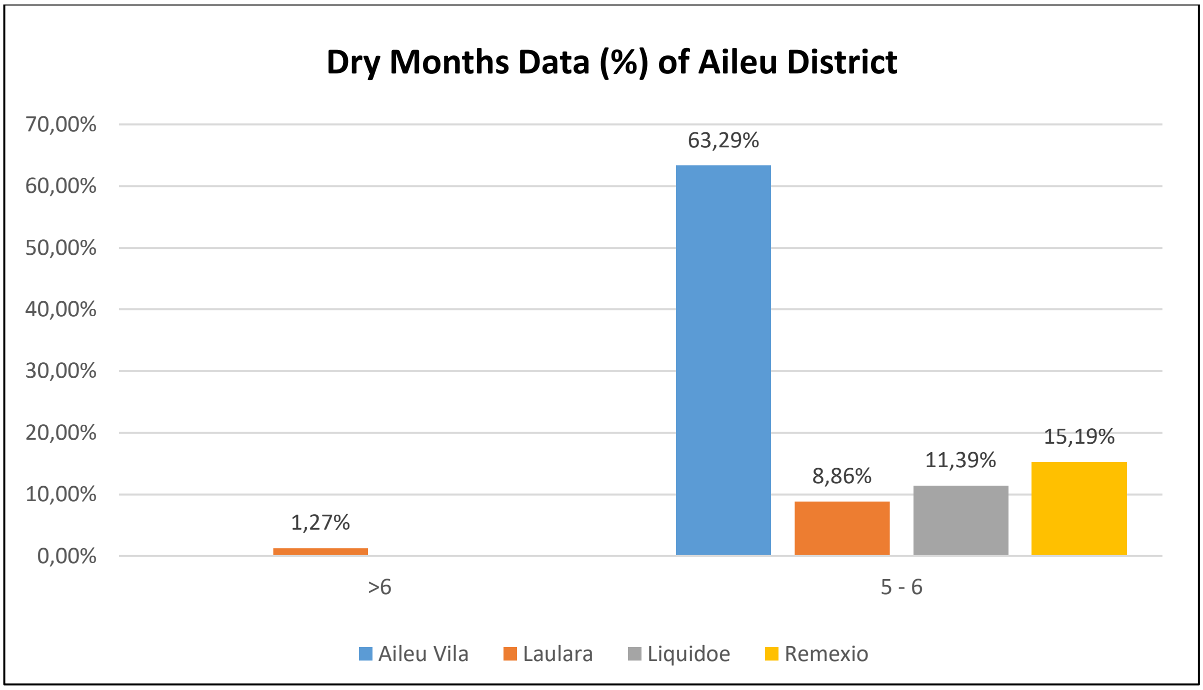


Figure 4.3 Dry Months Data (%) of Aileu District

4.4 ELEVATIONS

The elevation distribution in Aileu District is dominated by high-elevation areas (**Figure 4.4**). Aileu Vila Sub-District has the largest area in this category, followed by Remexio, Liquidoe, and Laulara. This reflects the topographical characteristics of hills and mountains. High-elevation areas have limitations for intensive agriculture and settlement development but are very important for conservation areas, water catchment areas, and ecosystem buffers that maintain natural resource availability.

On the other hand, a small portion of Laulara and Liquidoe Sub-Districts are categorized as low and medium elevation areas. These areas represent the presence of plains or moderate slopes that are more suitable for agricultural activities, particularly dryland farming systems and plantations. Low-elevation land also has potential for settlement development, although it is limited in area. Medium-elevation areas, though relatively small, play an important role in providing transitional spaces between flat lands and mountainous regions.

Overall, the topography of Aileu District shows a dominance of high elevations, strengthening its function as a water catchment area, forested zones, and ecosystem buffers. The limited low and medium-elevation areas can be utilized for agricultural and settlement activities but require careful management to avoid disrupting the ecological functions of the mountainous regions.

Therefore, land-use strategies in Aileu must emphasize a balance between conservation functions and local development needs (FAO, 2007; BPS Timor-Leste, 2023).

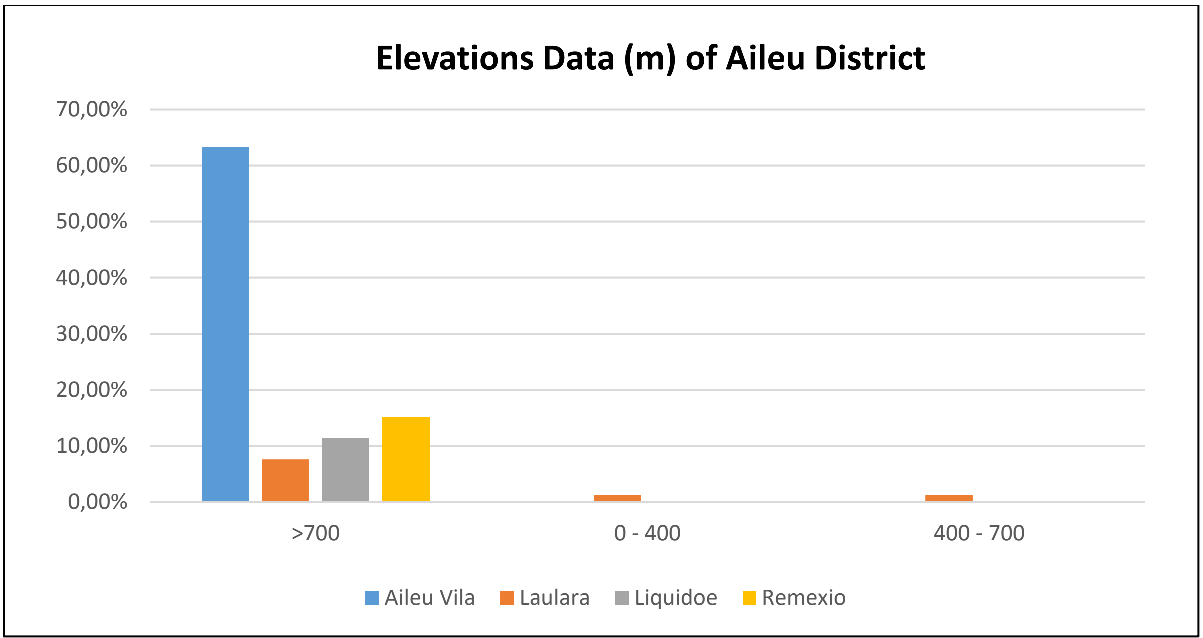


Figure 4.4 Elevations Data of Aileu District

4.5 DRAINAGE

Field observations of drainage characteristics in Aileu District show a dominance of land with well-drained soil. Aileu Vila Sub-District is the most dominant in this category, with the highest proportion of well-drained areas, followed by Liquidoe Sub-District. This condition is attributed to the predominance of Inceptisols in the area, which have a stable and loose soil structure, friable texture, and abundant mesopores, allowing water to infiltrate efficiently and minimizing surface runoff. This reflects the natural adaptation of the soil to moderate to low rainfall and topography that tends to be undulating to steep.

Moderately impaired drainage was found only in Aileu Vila Sub-District. Moderately well-drained soil was found in Remexio Sub-District. Somewhat rapid drainage was observed in Aileu Vila, Laulara, and Remexio Sub-Districts. The drainage chart for Aileu District is presented in **Figure 4.5.**

Soils with well drained are necessary for supporting plant growth, particularly by providing adequate aeration for roots to absorb nutrients efficiently (Wirosoedarmo *et al.*, 2011). The dominant drainage category in Aileu

District is well drained, which influences the availability of oxygen in the soil, allowing water to be efficiently distributed to meet plant water requirements.

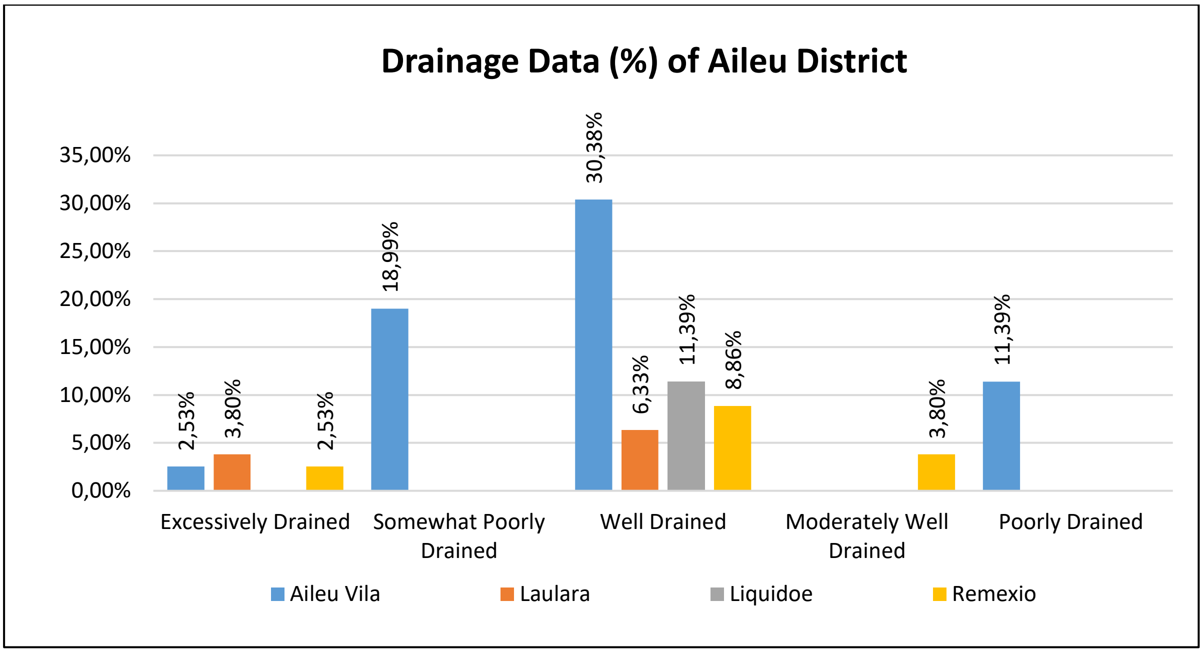


Figure 4.5 Drainage Data (%) of Aileu District

4.6 COARSE FRAGMENTS

The characteristics of coarse fragments in 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 Aileu District shows significant variability in distribution across the region. The category with the highest percentage is <3%, which is dominant and found only in Aileu Vila Sub-District, indicating that most areas have soil with a low content of coarse fragments.

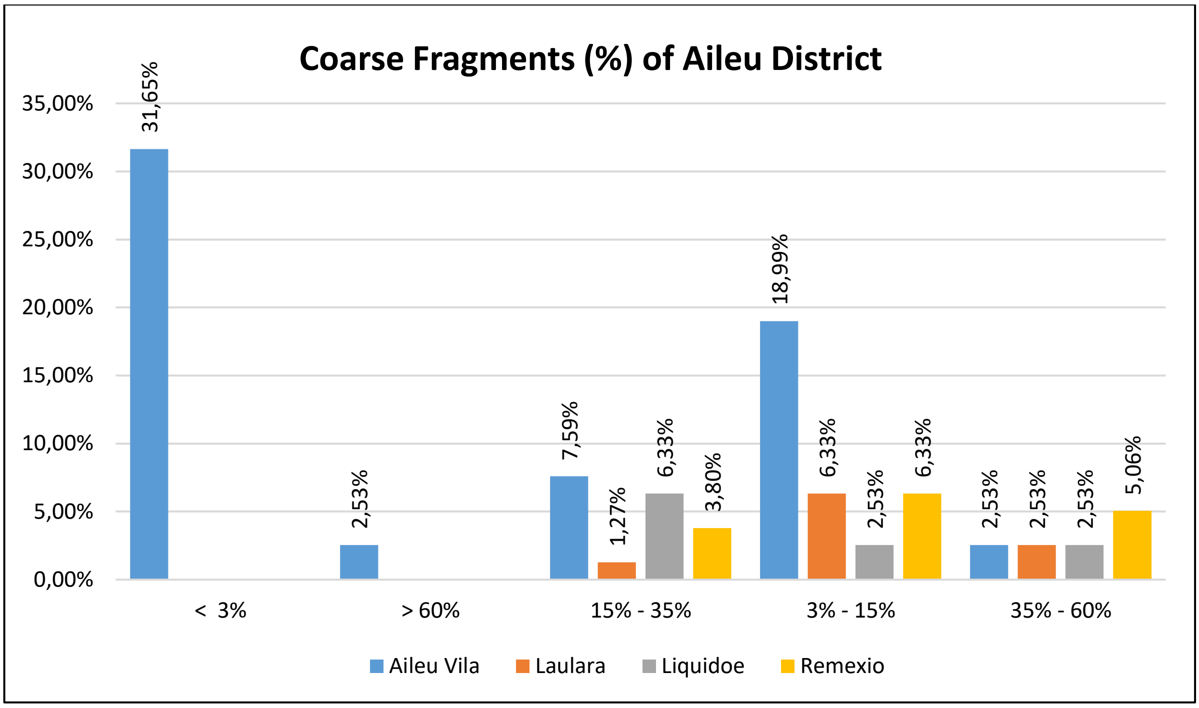


Figure 4.6 Coarse Fragments Data (%) of Aileu District

The 3-15% category has the largest percentage across the entire Aileu District. Aileu Vila Sub-District is dominant in this category, showing that some areas have slightly higher coarse fragment content, but still within manageable limits for agriculture. Next, the 15-35% category is dominated by Aileu Vila and Liquidoe Sub-Districts, while the 35-60% category is most dominant in Remexio Sub-District, indicating areas with coarser soil texture. The highest coarse fragment content, >60%, is found only in Aileu Vila Sub-District, suggesting that a small portion of the area may have limitations for agricultural use. The coarse fragment data for Aileu District is presented in **Figure 4.6.**

4.7 EFFECTIVE SOIL DEPTH

Effective soil depth is an important factor in determining land suitability for agricultural activities. This depth indicates how far plant roots can grow and absorb nutrients and water from the soil. Deeper soils allow plant roots to develop more optimally, enhancing water retention capacity and nutrient availability, as well as providing better physical stability for plants (Suriadi, 2016).

The analysis of effective soil depth percentages in Aileu District shows that the distribution of effective soil depth in agricultural land spans several depth categories. The 30–60 cm depth category is found only in Aileu Vila Sub-District and is one of the dominant categories in the district. Shallower soil depths may be caused by more steep topography, active erosion processes, or the presence of surface rock outcrops, which limit soil layer development (Supriadi *et al.*, 2018).

The 60–90 cm depth category is found only in two Sub-Districts, with Aileu Vila Sub-District having the largest proportion. Next, the 90–120 cm depth category is found across all Sub-Districts in Aileu District, with Remexio Sub-District being dominant, followed by Laulara Sub-District. Areas with flat topography and intensive weathering processes tend to have deeper and more fertile soils, while regions with steep slopes or high erosion typically have shallower soils (Ramadhan & Adji, 2020). The effective soil depth data for Aileu District is presented in **Figure 4.7.**

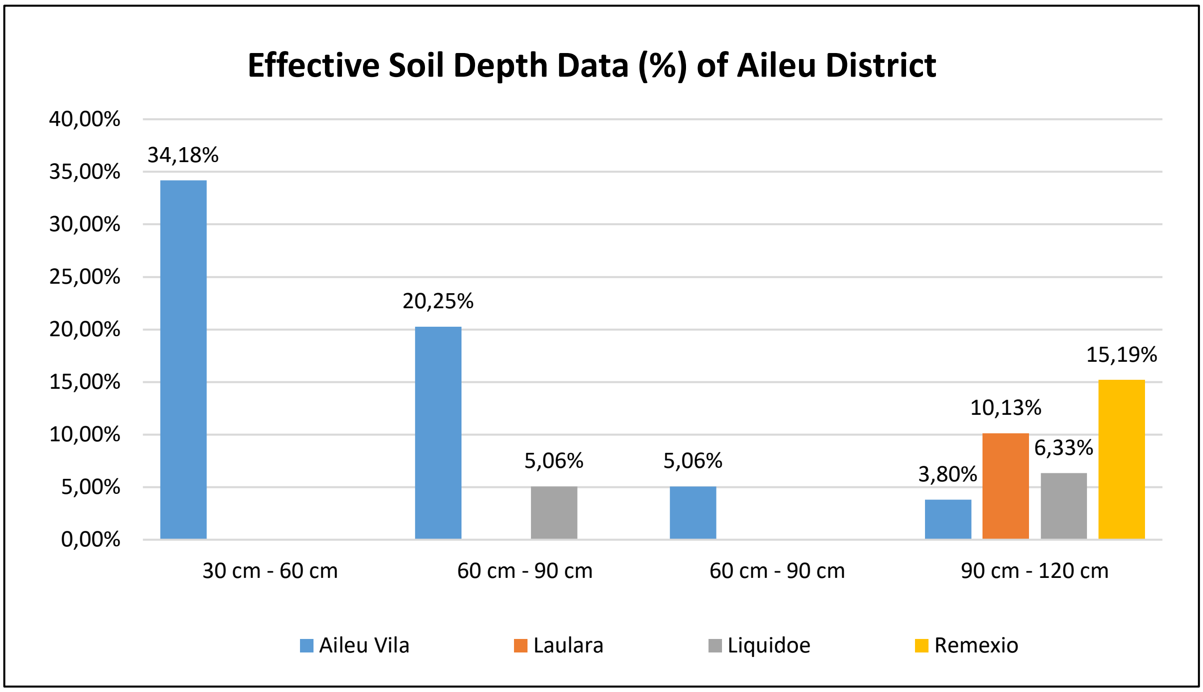


Figure 4.7 Effective Soil Depth (%) of Aileu District

4.8 SURFACE ROCKS

The condition of surface rocks is an important parameter in determining the potential and challenges of land management. The presence of surface rocks affects land suitability for agriculture, as high surface rock content can hinder soil cultivation activities and reduce the effective fertility of the soil. The distribution of surface rocks is influenced by geological factors and sedimentation processes, which are affected by tectonic conditions, parent rock weathering, and the level of erosion related to rainfall and topography (Sari *et al.*, 2024; Wahyudi *et al.*, 2020).

The analysis of surface rock percentage in Aileu District shows that most areas have low surface rock content. The category with the largest percentage is <5%, which dominates Aileu Vila Sub-District, indicating that most of the area has relatively rock-free soil surfaces, thus more supportive of agricultural activities and land use.

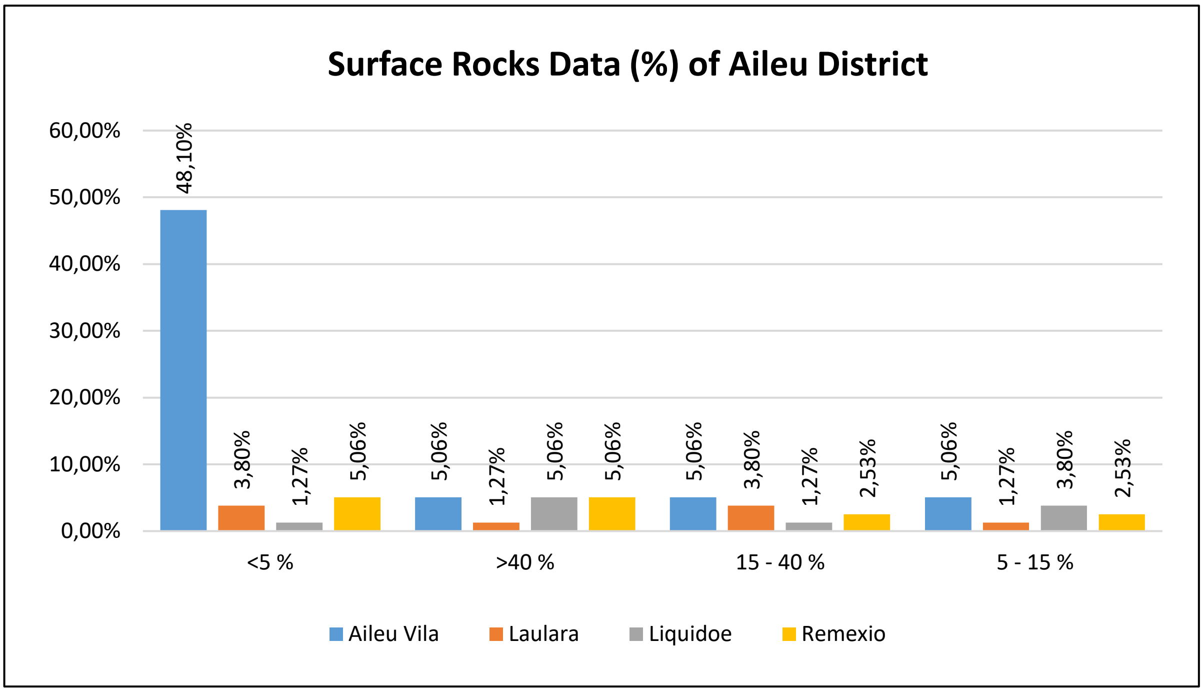


Figure 4.8 Surface Rocks Data (%) of Aileu District

The 5–15% and 15–40% categories dominate in Aileu Vila Sub-District, showing that a small portion of the area has higher surface rock content, but still within manageable limits for agricultural activities. The >40% category dominates in Aileu Vila, Liquidoe, and Remexio Sub-Districts, indicating that certain parts of the area have relatively high surface rock content. High surface rock content can hinder root penetration, reduce the soil's water retention capacity, and complicate land cultivation, negatively impacting agricultural productivity (Wahyudi *et al.*, 2020). The surface rock data for Aileu District is presented in **Figure 4.8.**

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 rates. The analysis of rock outcrop percentages in Aileu District shows that most areas have low levels of rock outcrops. The <5% category has the highest percentage and dominates Aileu Vila Sub-District, indicating that most areas have soil surfaces relatively free from rock outcrops, which greatly supports agricultural activities and infrastructure development. This condition results in thick, fertile soil layers that support plant growth and agricultural activities, as the soil is easier to cultivate and has a larger effective volume for root development (Supriadi *et al*., 2018; Suriadi, 2016). The rock outcrop data for Aileu District is presented in Figure 4.9.

The 5–15% category is dominant in Aileu Vila Sub-District, indicating that a small portion of the area has moderate rock exposure, but it is still manageable for various land uses. Next, the 15–25% category is dominant in Aileu Vila Sub-District, signaling that a considerable portion of the area has higher rock exposure. In the >25% category, areas with dominant rock outcrops are found, with the <5% category being dominant in Aileu Vila and Remexio Sub-Districts. Areas with high rock outcrop content are very vulnerable to land degradation, such as erosion and landslides, and have significant physical limitations for intensive agriculture due to shallow soil depth and limited availability of water and nutrients (Ramadhan & Adji, 2020).

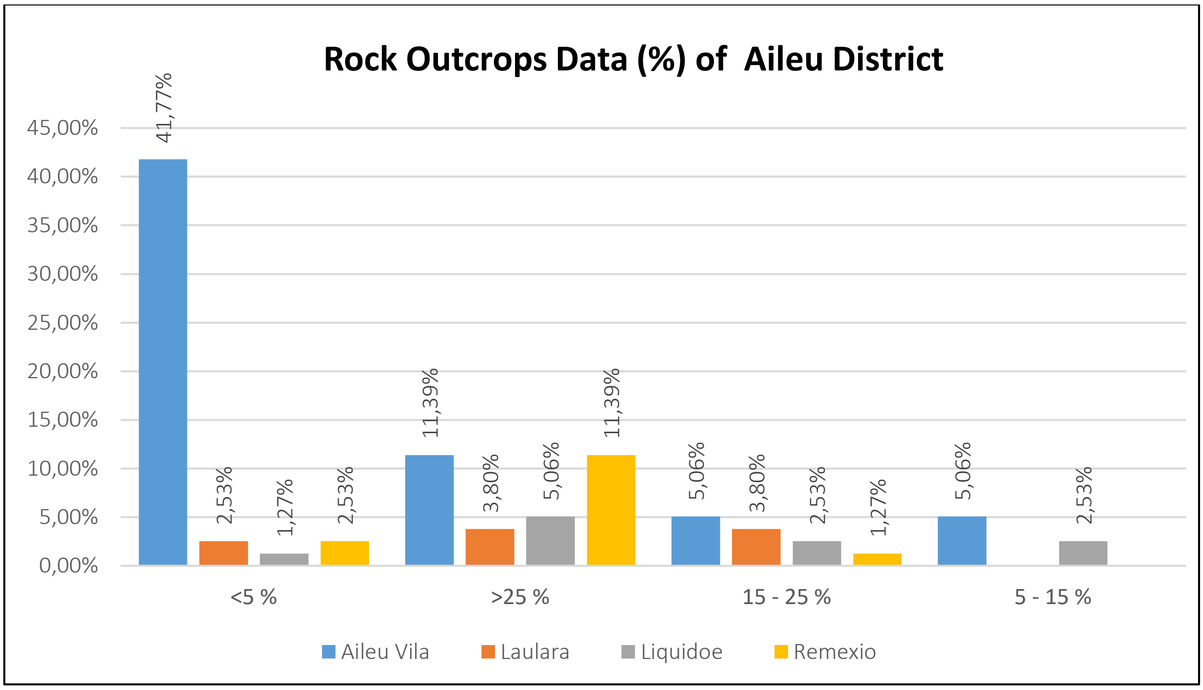


Figure 4.9 Rock Outcrops Data (%) of Aileu District

4.10 FLOOD HAZARD

Flooding is a natural disaster that often occurs due to several factors, such as high rainfall intensity, water flow exceeding the capacity of the soil or drainage system, causing water to inundate the land surface, settlements, and agricultural land. The worse the drainage in an area, the lower the soil's ability to absorb water.

The analysis of flood hazard percentages in Aileu District reveals that more than half of the district is dominated by areas with no flood hazard in each Sub-District, largely due to the predominance of well drained, as shown in **Figure 4.5.** Aileu Vila Sub-District has the largest percentage of areas with no flood hazard, followed by Laulara Sub-District. In the very low flood hazard category, Aileu Vila and Liquidoe Sub-Districts are dominant. The low flood hazard category is predominantly found in Aileu Vila Sub-District, followed by Laulara Sub-District. The very high and moderate flood hazard categories are found only in Aileu Vila Sub-District. In the high hazard category, flood risk is present in Aileu Vila and Liquidoe Sub-Districts. The flood hazard data for Aileu District is presented in **Figure 4.10**.

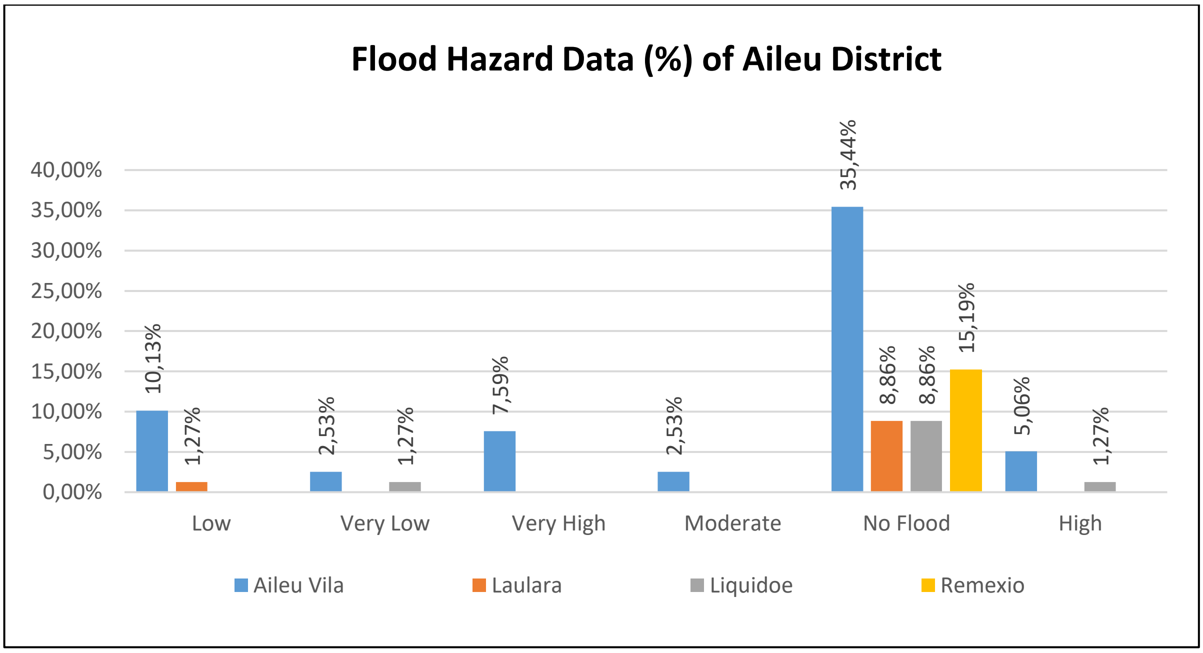


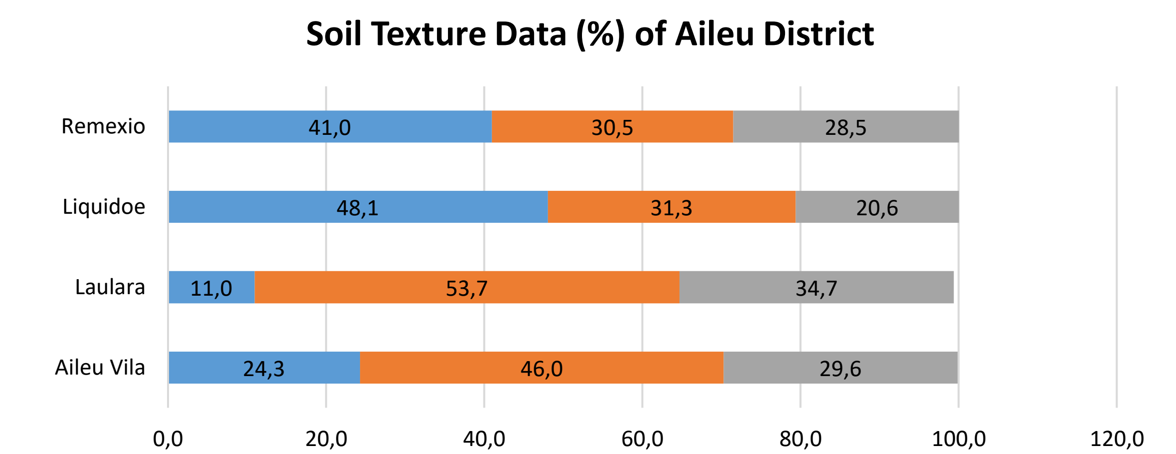
Figure 4.10 Flood Hazard Data of Aileu District

4.11 SOIL TEXTURE

Soil texture is a crucial factor influencing various physical and chemical processes in the soil, including water retention, drainage, erosion, and nutrient availability. Additionally, soil texture affects nutrient availability, which in turn impacts soil productivity and land management (Schaetzl & Anderson, 2005). Coarse-textured soils, such as sand, have large pores, allowing water to infiltrate quickly but not hold it for long, leading to rapid loss of soil moisture. In contrast, finer-textured soils retain organic matter better and are more effective in storing water, while coarse-textured soils improve soil aeration.

Laboratory analysis results show that soil texture in Aileu District is generally dominated by clay loam, with clay fractions at 28.2%, silt at 42.7%, and sand at 28.9%. At the sub-district level, soil texture variations are more specific. Aileu Vila Sub-District is dominated by clay texture, with clay at 24.3%, silt at 46.0%, and sand at 29.6%. Laulara Sub-District has silty clay texture with 11.0% clay, 53.7% silt, and 34.7% sand. Liquidoe Sub-District is dominated by clay texture with 48.1% clay, 31.3% silt, and 20.6% sand. Remexio Sub-District also shows a dominant clay texture, with 41.0% clay, 30.5% silt, and 28.5% sand **(Figure 4.11).**

According to Hardjowigeno (2003), soil texture is one of the most stable soil properties and does not change easily due to cultivation. Soil texture affects not only the physical properties of the soil but also plays a significant role in agricultural land productivity. Plants require water, air, and nutrients in optimal amounts and availability. Therefore, soil texture impacts water availability in the root zone. On the other hand, sandy soils have well drained but poor water and nutrient retention, leading to more frequent droughts and nutrient deficiencies.



	Aileu Vila	Laulara	Liquidoe	Remexio
Clay (%)	24,3	11,0	48,1	41,0
Silt (%)	46,0	53,7	31,3	30,5
Sand (%)	29,6	34,7	20,6	28,5

Figure 4.11 Soil Texture Data (%) of Aileu District

4.12 pH

Soil pH is a measure of the soil's acidity or alkalinity, expressed on a scale of 0 to 14, with a pH of 7 considered neutral. Values below 7 are acidic, while values above 7 are alkaline. If the soil has a high concentration of H+ ions, it is classified as acidic, whereas low H+ ion concentration indicates alkaline soil (Brady & Weil, 2002). Soil pH significantly affects the activity of microorganisms involved in organic matter decomposition and nitrogen fixation. Soil microorganisms are generally more active at a neutral to slightly acidic pH (around pH 6–7), which is considered ideal for the growth of most plants.

Soil pH in Aileu District is generally in the slightly acidic to mildly acidic range. The lowest pH value is recorded in Liquidoe Sub-District at 5.11, followed by Remexio Sub-District at 5.17, and Laulara Sub-District at 5.50. The highest pH is found in Aileu Vila Sub-District, with a value of 5.55, as shown in **Figure 5.1, Chapter V of this book.**

According to Hardjowigeno (2003), soil pH plays a critical role in determining soil chemical conditions, particularly the availability of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K). In highly acidic soils (pH <5.5), elements such as aluminum (Al) and iron (Fe) become highly soluble and toxic to plants, while phosphorus becomes unavailable due to binding with Al and Fe. Conversely, in highly alkaline soils (pH >7.5), micronutrients such as zinc (Zn), copper (Cu), and manganese (Mn) become unavailable to plants.

4.13 TOTAL NITROGEN

Total Nitrogen represents the total nitrogen content in the soil, both in organic and inorganic forms. The level of total nitrogen in the soil is heavily influenced by organic matter content, microorganism activity, climatic conditions, and soil type. According to Hardjowigeno (2003). Total Nitrogen includes nitrogen in organic compounds (such as amino acids and soil proteins) and inorganic compounds (such as ammonium and nitrate). However, most nitrogen in the soil exists in an organic form, which is not directly available to plants and must undergo mineralization by soil microorganisms before being converted into a form that plants can absorb.

Laboratory analysis results indicate that the total nitrogen in Aileu District soils is generally categorized as moderate. The lowest value is found in Liquidoe Sub-District at 0.34%, followed by Laulara and Remexio Sub-Districts with 0.37%.

The highest value is recorded in Aileu Vila Sub-District, with total nitrogen reaching 0.41% **(Figure 4.12).**

Soils with high organic matter content generally have higher total nitrogen. However, a high total nitrogen value does not necessarily mean that nitrogen is available in sufficient quantities for plants, as its availability depends on biochemical processes in the soil, such as ammonification and nitrification.

4.14 AVAILABLE PHOSPHORUS

Available Phosphorus refers to the form of phosphorus (P) in the soil that can be absorbed and directly utilized by plants. Available Phosphorus is also highly influenced by soil microorganism activity and organic matter content, which helps release phosphorus from organic compounds through the mineralization process. The main form of phosphorus (P) that plants can absorb is the orthophosphate ion, $H_2PO_4^-$ and HPO_4^{2-}, which are formed from phosphate minerals in the soil or from organic material mineralization. These phosphate ions depend heavily on soil pH: $H_2PO_4^-$ dominates at pH levels below 7.0, while HPO_4^{2-} is dominant at pH levels above 7.0 (Hakim *et al*., 1986; Engelstad, 1997).

Laboratory analysis results show that Available Phosphorus content in the soil in Aileu District varies across the sub-districts (**Figure 4.12**). Aileu Vila Sub-District has the highest Available Phosphorus content at 4.14 ppm, followed by Remexio at 3.75 ppm, Laulara at 3.73 ppm, and Liquidoe at 3.44 ppm.

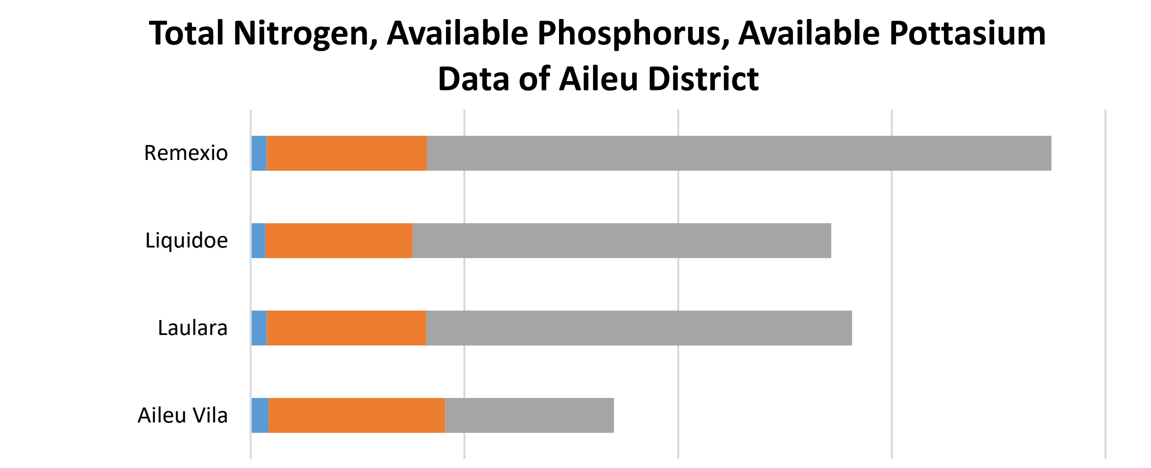
Soils with low Available Phosphorus content can inhibit plant growth, particularly in the early stages, as roots, which are still short, cannot explore the bound phosphorus in the soil. According to Hardjowigeno (2003), the total phosphorus content in the soil can reach hundreds to thousands of mg/kg, but only a small fraction is available in the form of soluble phosphate ions in the soil solution. Most phosphorus is in an insoluble form or tightly bound to iron (Fe), aluminum (Al), and calcium (Ca) ions, especially in soils with very low or very high pH.

4.15 AVAILABLE POTTASIUM

Available Pottasium refers to the form of potassium in the soil that can be directly absorbed by plants. Potassium is an essential macronutrient that plays a critical role in plant physiological processes. The form of potassium (K) that can be directly absorbed by plants is the potassium ion (K+) found in the soil solution or exchangeable potassium (K-dd). This form of potassium is the most active and easily absorbed by plant roots, although it is not always present in large quantities and is prone to leaching (Bubun *et al*., 2024). According to Hardjowigeno (2003), potassium in the soil exists in several fractions, including available potassium, exchangeable potassium, and non-available potassium. Of all the potassium in the soil, only a small fraction is available to plants.

The available potassium content in Aileu District is generally classified as very high. Remexio Sub-District shows the highest value at 14.61 me/100 g, followed by Laulara Sub-District at 9.96 me/100 g and Liquidoe Sub-District at 9.79 me/100 g. Meanwhile, the lowest value is recorded in Aileu Vila Sub-District, with available potassium content of 3.95 me/100 g (**Figure 4.12**).

Soils rich in organic matter and with a high clay fraction generally have a better ability to retain available pottasium. In contrast, sandy soils tend to be low in available pottasium because potassium is more easily leached. Available potassium plays an important role in the efficiency of water use by plants. Potassium acts as a physiological regulator, particularly in the opening and closing of stomata, transport of photosynthesis products, and strengthening of cell walls.



	Aileu Vila	Laulara	Liquidoe	Remexio
Total Nitrogen	0,41	0,37	0,34	0,37
Available phosphorus	4,14	3,73	3,44	3,75
Available Potassium	3,95	9,96	9,79	14,61

Figure 4.12 Total Nitrogen, Available Phosporus, Available Pottasium Data of Aileu District

4.16 ELECTRICAL CONDUCTIVITY (EC) / TOXICITY

Electrical conductivity (EC) or toxicity is a measure of the soil's ability to conduct electrical currents, which is generally related to the amount of dissolved salts in the soil solution. The higher the EC value, the more dissolved salts are present in the soil. According to Hanafiah (2005), EC values are important for determining whether a soil is saline (high salt content) or not, as high salinity can cause toxicity to plants. Plants growing in soils with high EC will have difficulty absorbing water because the osmotic pressure of the soil solution is higher than that of the plant roots.

The electrical conductivity (EC) content in Aileu District soils ranges from very low to low. The lowest value is recorded in Liquidoe Sub-District at 0.38 dS/m, increasing to 0.49 dS/m in Laulara, 0.51 dS/m in Remexio, and reaching the highest value in Aileu Vila at 0.58 dS/m, as presented in **Figure 5.1, Chapter V.**

Toxicity in soil can arise from the accumulation of salts, especially in dry climates or due to excessive irrigation without proper drainage, as well as from excessive levels of micronutrients that become toxic at high concentrations. Soil toxicity not only impacts land productivity but can also enter the food chain, posing risks to human health and the environment.

V. SOIL FERTILITY

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

5.1 CATION EXCHANGE CAPACITY (CEC)

Cation Exchange Capacity (CEC) describes the ability of the soil to retain and supply cations to plants. Soils with a high CEC are better able to store nutrients, supporting optimal plant growth. According to Mukhlis (2014), the CEC of soil depends on (1) soil texture, (2) soil mineral type, and (3) organic matter content. The higher the clay content or finer the texture, the greater the CEC of the soil.

Laboratory analysis results show that the CEC content in Aileu District ranges from low to moderate, reflecting the soil's limited ability to absorb and store nutrients essential for plant growth. The highest CEC value was recorded at Aileu Vila Sub-District, with a value of 19.67 me/100g, classified as moderate, indicating that the soil in this area is relatively more fertile than in other regions. In contrast, the lowest CEC value was found at Liquidoe Sub-District, with a value of 12.35 me/100g, which falls under the low category and indicates suboptimal soil conditions for supporting plant growth without specific management interventions. The other two regions, Laulara and Remexio Sub-District, also exhibited relatively low CEC values.

Soils with clay texture and high organic matter content tend to have higher CEC values due to the abundance of ion exchange sites available. While a high CEC is generally considered beneficial, in some cases, an excessively high CEC may indicate extreme base saturation. This condition leads to soil structure deterioration, poor drainage, and impaired root growth. Sandy soils or soils with low organic matter content typically exhibit low CEC values and, therefore, require specific management practices to improve their cation exchange capacity, as shown in **Figure 5.1.**

5.2 BASE SATURATION (BS)

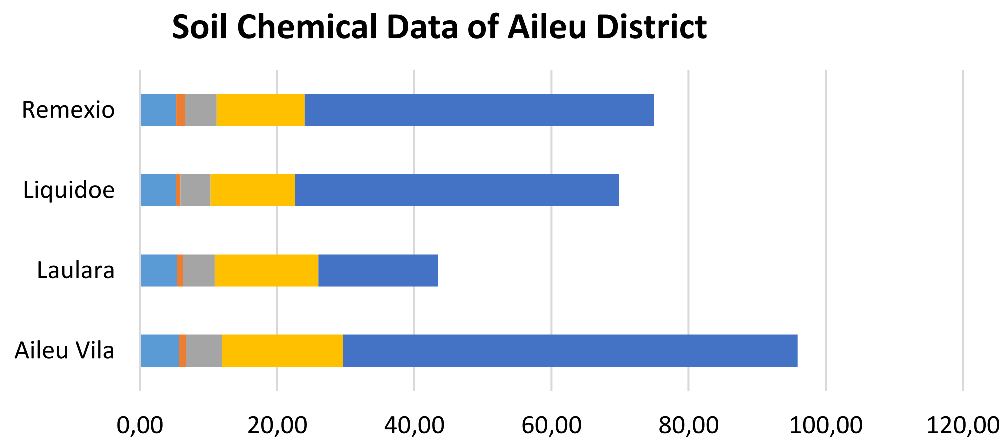
Base Saturation (BS) describes the percentage of base cations in the soil cation exchange complex relative to the cation exchange capacity. The higher the BS value, the greater the proportion of base cations available to plants, which affects soil fertility. According to Hardjowigeno (2003), base saturation is the ratio between the exchangeable base cations and the soil's cation exchange capacity, expressed as a percentage. High BS indicates that most of the cation exchange sites in the soil are occupied by plant-essential elements. Soils with high BS tend to have a neutral to slightly alkaline pH, which supports the optimal availability of macro and micronutrients.

Laboratory analysis results show that the base saturation (BS) content in Aileu District varies, ranging from very low to high categories. The highest base saturation value was found in Aileu Vila Sub-District, at 65.35%, classified as high, indicating that most of the soil colloids in this area are occupied by base elements such as calcium, magnesium, potassium, and sodium, making the soil more fertile and supporting plant growth. Remexio and Liquidoe Sub-District have moderate BS values, suggesting that the soil conditions are still reasonably good, though management is required to maintain nutrient balance. In contrast, Laulara Sub-District exhibited the lowest BS value at 28.92%, which falls into the very low category, indicating the dominance of acidic elements in the soil, which can hinder nutrient absorption by plants, as shown in **Figure 5.1.**

5.3 SOIL ORGANIC CARBON (SOC)

Soil Organic Carbon (SOC) refers to the carbon content derived from organic matter in the soil, including plant residues, roots, dead microorganisms, and decomposed organic materials. Adequate SOC content improves the physical, chemical, and biological properties of the soil. SOC is essential as it plays a role in improving soil structure, enhancing cation exchange capacity (CEC), retaining moisture, and providing energy for soil microorganisms. The highest SOC value was found in Remexio Sub-District, at 2.49%.

Soils with high SOC have darker colors, stable soil aggregates, and good capacity to absorb water and nutrients. In contrast, the lowest SOC content was found in Liquidoe Sub-District, at 1.17%, as shown in **Figure 5.1.** The low SOC content is attributed to the lack of organic material in the soil, particularly from sugarcane farmers who often burn crop residues. The scarcity of organic matter significantly affects soil fertility, as stated by Suarjana *et al*. (2019). Low SOC content is generally caused by intensive soil cultivation, minimal organic material input, soil erosion, crop residue burning, and high rainfall.



	Aileu Vila	Laulara	Liquidoe	Remexio
pH	5,67	5,38	5,27	5,31
Electrical Conductivity	1,10	0,90	0,64	1,23
Organic-Carbon (%)	5,15	4,63	4,38	4,65
Cation Echange Capaciyt	17,64	15,10	12,35	12,80
Base Saturation	66,32	17,46	47,23	50,95

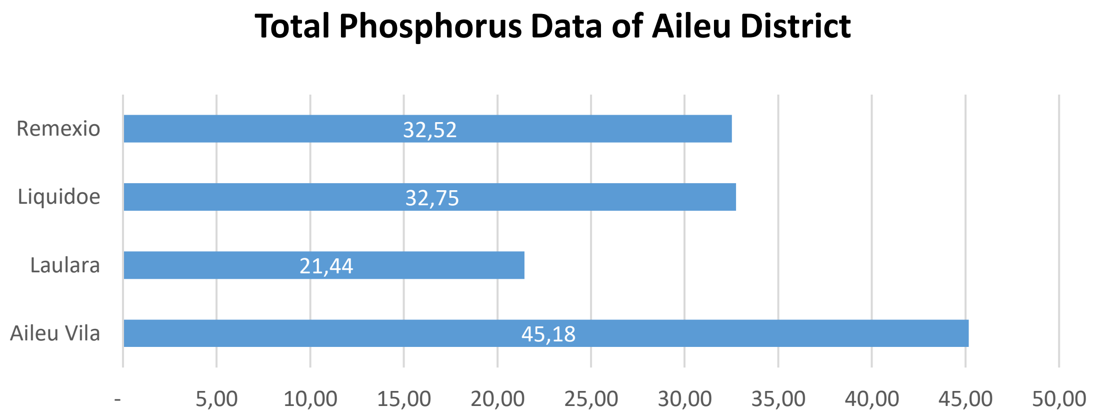
Figure 5.1 Soil Chemical Data of Aileu District

5.4 TOTAL PHOSPHORUS

Total Phosphorus includes both inorganic and organic phosphorus bound in soil particles and organic matter. The content of Total Phosphorus is important to determine because it provides a long-term phosphorus reserve for plants. According to Foth (1990), Total Phosphorus is the total amount of phosphorus in the soil, consisting of both available phosphorus for plants and phosphorus that is unavailable due to strong binding to soil minerals or organic matter. Phosphorus in the soil comes from various sources, including decomposed organic matter, soil minerals, and external inputs such as synthetic fertilizers (Herawati, 2015).

Based on laboratory analysis, the Total Phosphorus content in Aileu District falls into the moderate to high category, reflecting a relatively good phosphorus availability for plant growth in most of the area. The highest Total Phosphorus content was found in Aileu Vila Sub-District, at 45.18 mg/100g, which is classified as high and indicates that the soil in this area has good fertility potential, especially in supporting root development and flower or fruit formation in plants. Meanwhile, Liquidoe, Remexio, and Laulara have moderate Total Phosphorus contents, which are still adequate for plant needs, although ongoing monitoring and sustainable management are required. Among these three regions, Laulara Sub-District has the lowest Total Phosphorus value, at 21.44 mg/100g (**Figure 5.2**).

Adequate Total Phosphorus content in the soil indicates a potential phosphorus reserve for the long term. Total Phosphorus values in the moderate to high range suggest that the soil has sufficient phosphorus reserves to support plant growth over the medium to long term. Low Total Phosphorus can occur in sandy soils with low adsorption capacity, continuous phosphorus uptake by plants without replenishment, and low organic matter content. High Total Phosphorus values may result from excessive phosphate fertilizer use and poor drainage conditions.



	Aileu Vila	Laulara	Liquidoe	Remexio
Total	45,18	21,44	32,75	32,52

Figure 5.2 Total Phosphorus Data of Aileu District

5.5 TOTAL POTASSIUM

Total Potassium refers to the total amount of potassium present in the soil, both in available and unavailable forms for plants. According to Foth (1990), total potassium reflects the entire potassium content in the soil, but only a small fraction of it is directly available to plants. Therefore, even if Total Potassium is high, it does not always mean the soil is fertile if the available potassium fraction is low. Total Potassium levels in the soil depend significantly on the soil type and parent material. Soils derived from potassium-rich rocks, such as granite, generally have high total potassium. Soils with moderate to high total potassium have sufficient potassium reserves for medium to long-term crop cultivation, especially when managed properly to optimize its availability.

Laboratory analysis results show that the total potassium content in Aileu District varies, ranging from low to high, reflecting differences in potassium nutrient availability across each Sub-District. The highest Total Potassium value was found in Remexio Sub-District, at 47.10 mg/100g, classified as high, indicating that the soil in this area has good potential to support plant physiological functions such as protein formation, stomatal regulation, and environmental stress resistance. Laulara and Liquidoe Sub-District have moderate total potassium content, which is sufficient to support plant growth but requires ongoing nutrient management to prevent potassium depletion. In contrast, Aileu Vila Sub-District recorded the lowest Total Potassium content at 17.29 mg/100g, classified as low, indicating that the soil in this area has limitations in providing enough potassium for plants, requiring corrective actions such as appropriate potassium fertilization.

Low Total Potassium in the soil can be caused by advanced weathering, which leads to the loss of primary minerals, sandy soils that are poor in clay minerals, and excessive land exploitation without balanced nutrient replenishment. According to Herawati (2015), potassium ions are highly mobile and easily leached from the soil because potassium is not strongly retained by the soil colloid surface. While high Total Potassium is generally beneficial, if not balanced with other nutrients or if potassium dominance is too high, it can disrupt the absorption of other nutrients.

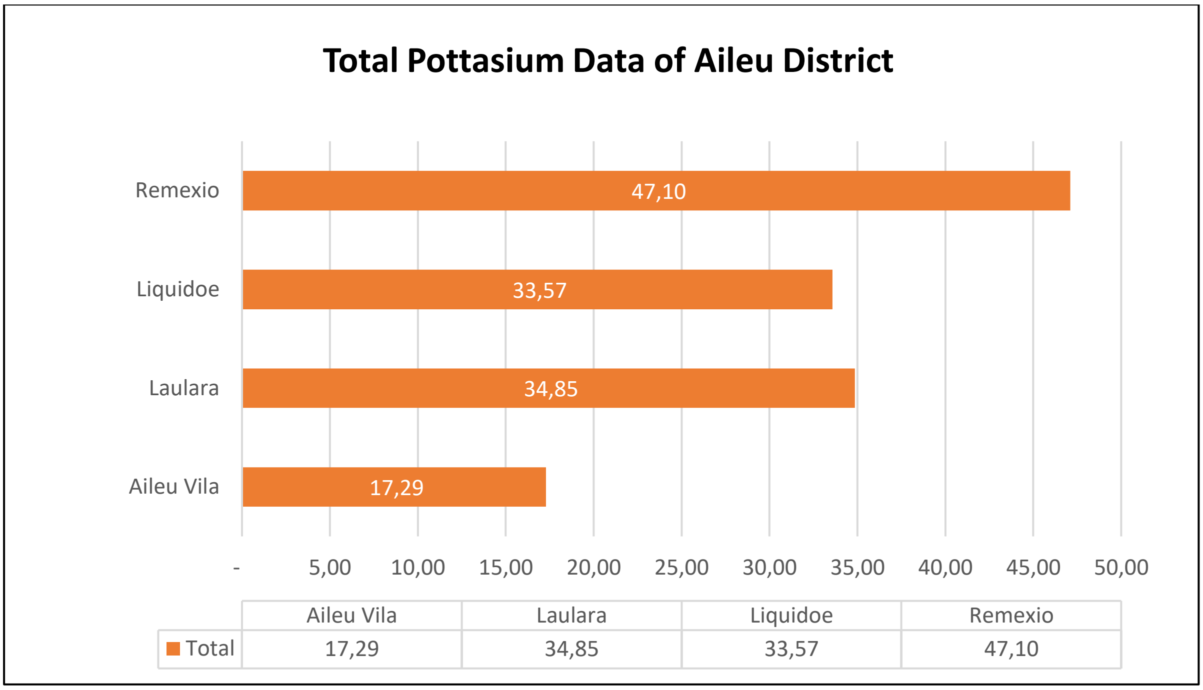


Figure 5.3 Total Potassium Data of Aileu District

5.6 TOTAL ZINC

Zn-Total in the soil refers to the total zinc (Zn) content stored in the soil, including all Zn, both available to plants and bound in mineral or organic forms in the soil. Zinc available to plants is typically only a small fraction of the total Zn, and it is highly influenced by soil pH, organic matter content, soil texture, and microbial activity. A good Total Zinc in the soil must not only be sufficiently high in total amount but also have an adequate level of available Zn to be effectively absorbed by plants.

Based on laboratory analysis results, the total zinc content in Aileu District varies, with the highest value recorded in Aileu Vila Sub-District at 87.21 ppm. This content indicates that the soil in Aileu Vila has good potential to provide the essential micronutrient zinc for plants, particularly in processes like enzyme formation, protein synthesis, and the growth of new tissues. In contrast, the lowest Zn-Total value was found in Laulara Sub-District at 60.67 ppm **(Figure 5.4).** Although this value is still within the range that can support plant growth, its lower level compared to other regions suggests that more attention is needed for micronutrient fertilization, especially in lands used for intensive agriculture.

Very low Zn availability is found in soils with high organic matter content because Zn-humus complexes are formed (Riwandi *et al.*, 2016). Excessively high Total Zinc content may be related to contamination or excessive fertilizer use.

Too low Total Zinc can lead to deficiencies and reduced agricultural yields, while excessively high values may pose a risk of toxicity.

5.7 AVAILABLE ZINC

Available Zinc refers to the fraction of zinc in the soil that is in soluble or exchangeable forms, making it directly available for uptake by plant roots. This micronutrient plays a crucial role in various plant metabolic processes, such as growth hormone (auxin) formation, protein synthesis, and enzymatic activity. Zn-Available in the soil can be low even if Total Zinc is high. This is because Zn bound to clay minerals or organic matter is difficult to dissolve and not available to plants.

Based on laboratory analysis results, the available zinc content in Aileu District was highest in Aileu Vila Sub-District, with a value of 1.36 ppm, reflecting the availability of the micronutrient zinc in a form that can be directly absorbed by plants. This content indicates that the soil in this area has good potential to support the physiological processes of plants that require zinc, such as growth hormone synthesis, cell division, and seed production. In contrast, the lowest Available Zinc content was found in Laulara Sub-District at 0.33 ppm **(Figure 5.4).** This relatively low value can indicate a risk of zinc deficiency in plants if proper nutrient management is not applied.

High Zn levels can reduce the amount of phosphorus in the soil due to the formation of Zn-P complexes in the soil solution (Barber, 1995). Some of the main causes include high soil pH, high phosphorus content in the soil, and light soil texture Available Zinc levels in the soil can be high under conditions of excessive Zn fertilization, particularly over the long term, in environments contaminated with heavy metals, or in extremely acidic soils, which increases the dissolution of metals, including zinc.

5.7 TOTAL SULFUR

Sulfur is a secondary macronutrient that is essential for plant growth because it plays a key role in amino acid formation. Sulfur in the soil exists in two main forms: organic sulfur and inorganic sulfur, with most of it being in the organic form. The total sulfur content refers to the total amount of sulfur in all these forms (Brady & Weil, 2008).

Based on laboratory analysis results, the total sulfur content in Aileu District varies, with the highest value recorded in Remexio Sub-District at 317.69

ppm. This figure indicates that the soil in Remexio has a relatively high sulfur content, which plays an important role in protein formation, enzyme activity, and enhancing the efficiency of other nutrients for plant use. On the other hand, the lowest total sulfur value was found in Liquidoe Sub-District, at 160.60 ppm **(Figure 5.4).** Although this value does not necessarily indicate a direct deficiency, the lower value compared to other regions suggests the need for monitoring and sustainable sulfur management, especially in intensively farmed lands.

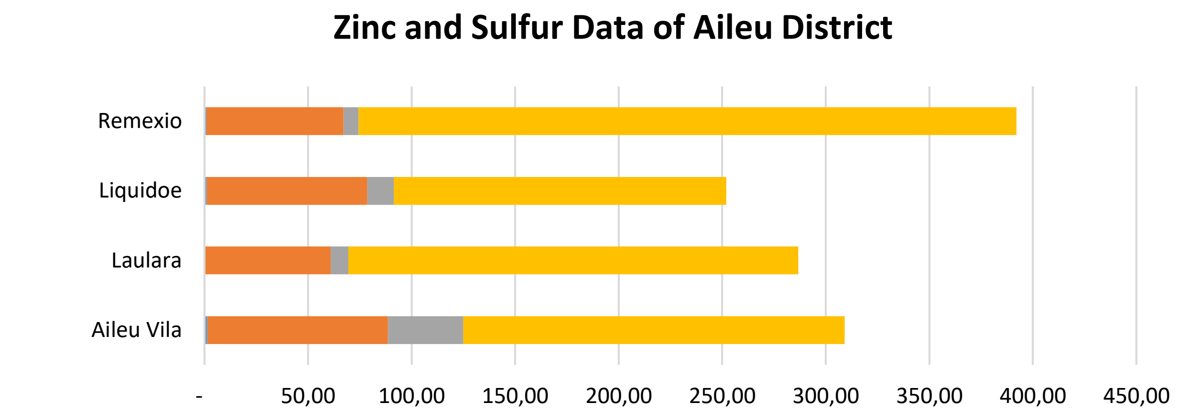
Several factors contributing to low total sulfur content in the soil include low organic matter content, and continuous use of chemical fertilizers without adding organic matter, which can cause nutrient depletion, including sulfur. High S-Total can occur under conditions of high organic matter accumulation, especially in peat soils or soils with poor drainage systems. At high levels, sulfur can cause problems in plants, such as interfering with the absorption of other nutrients or causing soil acidity if excessive sulfate forms are present.

5.8 AVAILABLE SULFUR

Available Sulfur in the soil refers to the portion of total sulfur that has been mineralized from organic matter and is ready for uptake by plants. This content is crucial because it directly indicates soil fertility related to sulfur availability. High Available Sulfur levels are influenced by high organic matter content. Organic matter undergoes decomposition and produces organic compounds such as organic sulfur, which then mineralizes into inorganic forms (SO_4^{2-}) that are available to plants (Widijanto *et al*., 2011).

Based on laboratory analysis results, the available sulfur content in Aileu District shows the highest value recorded in Aileu Vila Sub-District at 36.33 ppm, indicating that the soil in this area has a relatively high availability of sulfur in a form that can be directly absorbed by plants **(Figure 5.4).** Adequate sulfur availability is vital to support plant metabolic processes, particularly in amino acid synthesis, enzyme activity, and vitamin production. In contrast, the lowest Available Sulfur content was found in Remexio Sub-District at 7.32 ppm, which is considered low and could potentially limit plant growth if not balanced with proper nutrient management. Although Remexio had the highest S-Total value previously, the low Available Sulfur value indicates that not all sulfur in the soil is in a form that can be utilized by plants.

High Available Sulfur levels can occur under conditions of excessive sulfur fertilization without proper soil analysis. Low Available Sulfur content in the soil may be caused by low organic matter content, which means there is a limited source of sulfur from organic materials. Limited use of sulfur fertilizers and steep slopes, ranging from moderate to very steep, also contribute to the unavailability of sulfur for plants.



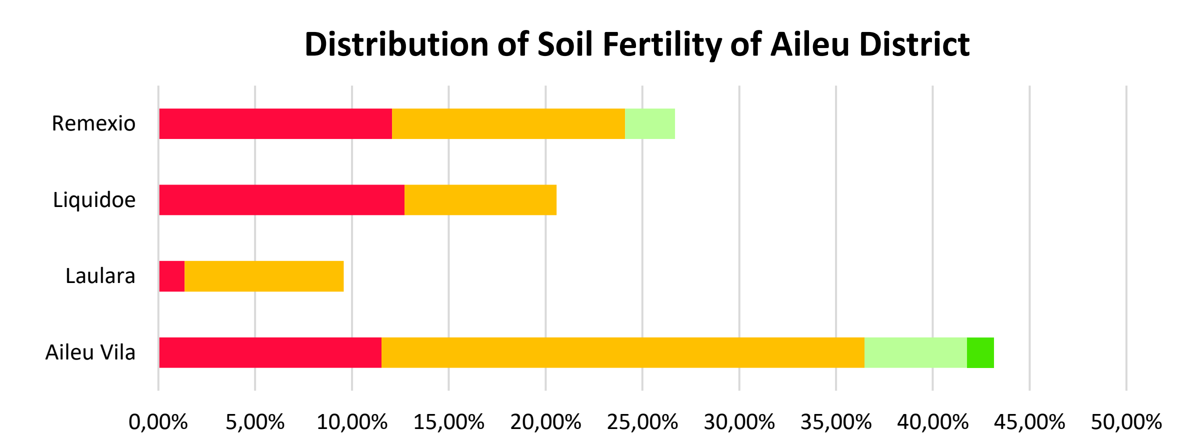
	Aileu Vila	Laulara	Liquidoe	Remexio
Available Zinc	1,36	0,33	1,07	0,89
Total Zinc	87,21	60,67	77,52	66,27
Available Sulfur	36,33	8,40	12,79	7,32
Total Sulfur	184,23	217,33	160,60	317,69

Figure 5.4 Graph of Zn and S Data in Aileu District

5.9 SOIL FERTILITY STATUS

Based on the soil fertility status analysis in Aileu District **(Figure 5.5),** approximately 53.05% or 389.58 km² consists of land with low fertility levels across the total area. Additionally, 276.56 km² (37.66%) falls into the very low category, indicating limited nutrient availability and the likely low productivity of the land without fertilization or rehabilitation interventions. Meanwhile, only 7.89% of the area, or 57.91 km², has moderate fertility levels, and only a small portion, 1.40% or 10.29 km², falls into the high fertility category. This condition reflects that, in general, Aileu District requires special attention in land resource management to support the sustainability of the agricultural sector and local food security.

The spatial distribution of soil fertility status across each sub-district shows varying results **(Figure 5.6).** Aileu Vila Sub-District is the area with the predominant low soil fertility, covering 183.23 km², which accounts for 24.95% of the total area of Aileu District. Next, Laulara Sub-District also has predominantly low soil fertility, covering 60.35 km² or 8.22%. In contrast, Liquidoe Sub-District and Remexio Sub-District show dominance of very low soil fertility, with areas of 93.38 km² (12.72%) and 88.64 km² (12.07%), respectively.



	Aileu Vila	Laulara	Liquidoe	Remexio
Very Low	11,52%	1,35%	12,72%	12,07%
Low	24,95%	8,22%	7,86%	12,03%
Moderate	5,30%	0,00%	0,00%	2,59%
High	1,40%	0,00%	0,00%	0,00%

Figure 5.5 Distribution of Soil Fertility Status Graphic of Aileu District

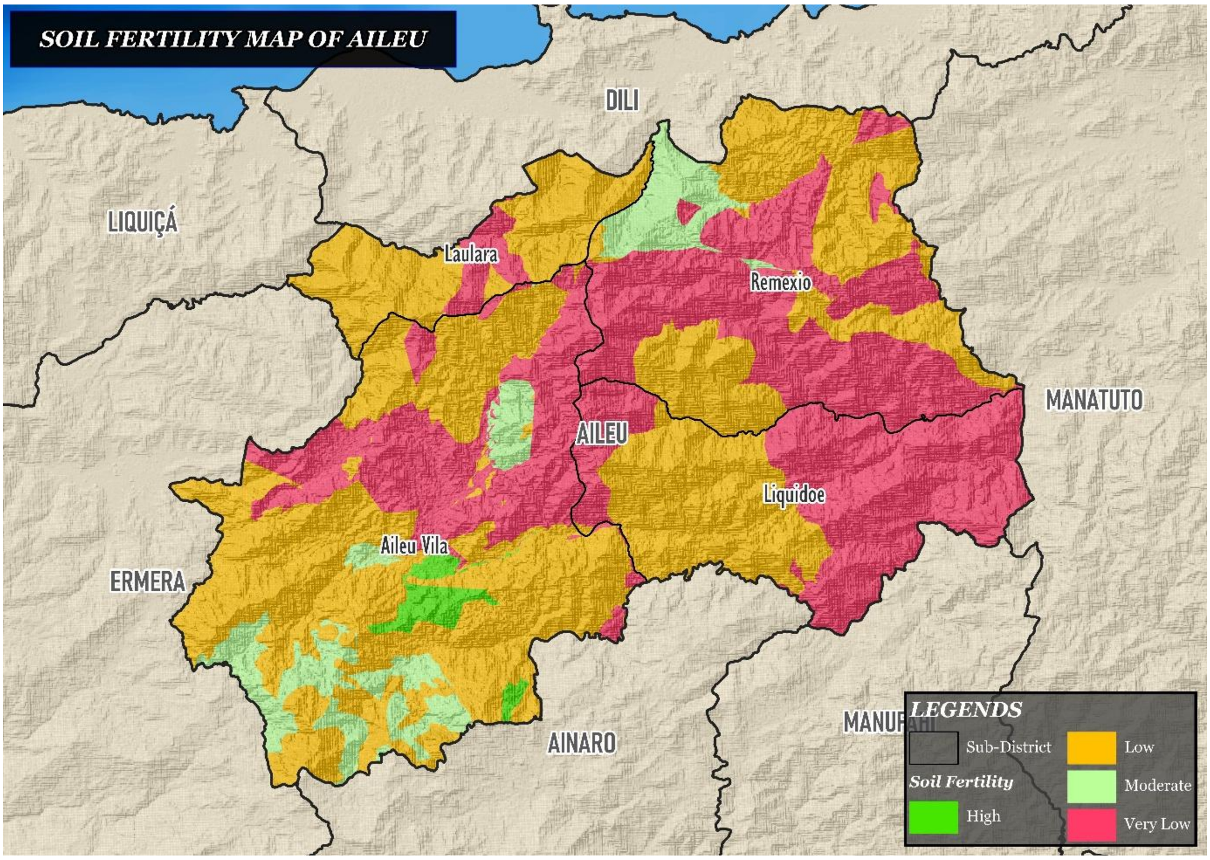


Figure 5.6 Distribution of Soil Fertility Status Map of Aileu District

5.10 FIELD PROBLEM SOLUTIONS

The death of orange trees in Aileu District is closely related to the low soil fertility caused by the acidic nature of the soil. Soil pH values range from 5.11 to 5.55, indicating a high level of acidity. This condition is due to the low cation exchange capacity (CEC), base saturation (BS), and soil organic carbon (SOC), which synergistically degrade soil quality and limit the availability of essential nutrients for plants. As a result, macro-nutrients such as calcium, magnesium, potassium, and phosphorus are easily leached, while acidic ions such as hydrogen and aluminum dominate the soil surface, further intensifying acidity and lowering pH more drastically.

In low pH conditions, phosphorus is bound by aluminum and iron to form insoluble compounds, making it unavailable for absorption by plant roots. Soluble aluminum ions are toxic and damage fine root tissues, inhibiting water and nutrient uptake. This damage to the root system triggers physiological symptoms such as yellowing leaves (chlorosis), stunted growth, branch dieback, and ultimately plant death. The low organic carbon content worsens soil structure, reduces water retention, and inhibits microbial activity. Consequently, the decomposition of organic matter and the release of nutrients such as nitrogen and sulfur are slowed. Micronutrients like zinc (Zn), although present in total, become unavailable because they are bound in insoluble forms, causing small, pale leaves and growth disturbances.

To address these issues, an integrated technical approach is required. Liming can be used to neutralize acidity and increase base saturation. The addition of organic materials, such as compost or manure, can improve soil structure, enhance CEC, and support microbial activity. Balanced fertilization with macro- and micronutrients, as well as the use of bio-fertilizers and biochar, can improve nutrient availability. Proper drainage management and the selection of orange varieties tolerant to acidic soils are also essential to support optimal growth. With proper and sustainable management, land in Aileu District still has the potential to support productive orange cultivation. Field observations have been conducted, as shown in Figure 5.7.

Figure 5.7 Observation on Agricultural Land (Orange Trees) in Faturasa Village
(Source: Researcher's Documentation, 2025)

VI. EROSION AND CONSERVATION

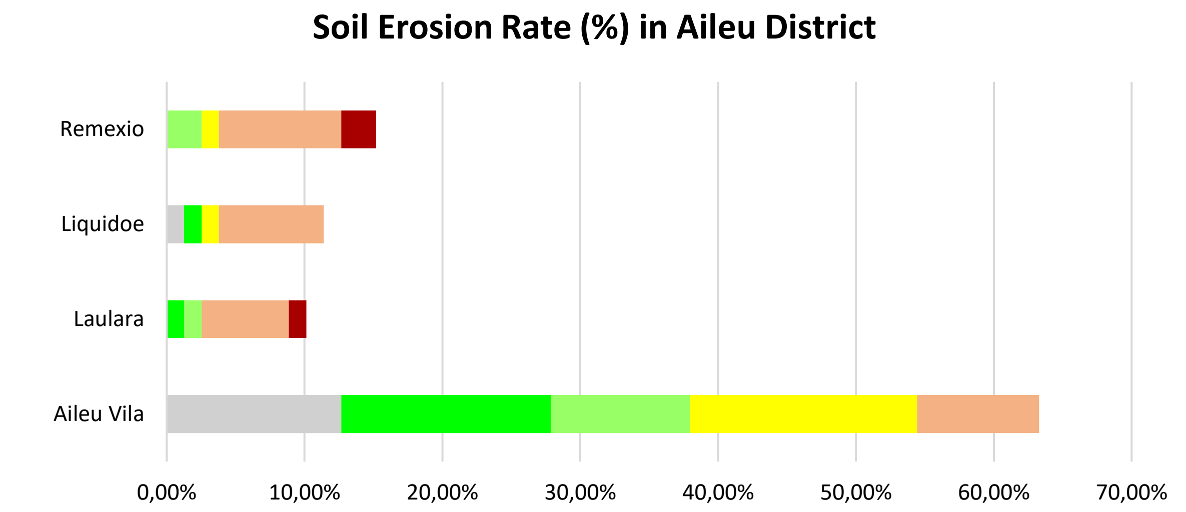
6.1 SOIL EROSION

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

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

Aileu District exhibits soil erosion ranging from very light to very severe. The Remexio Sub-District has a very severe erosion category, primarily due to its dominance of steep slopes, as discussed in **Chapter 2 of this book.** Steep slopes increase the kinetic energy of rainwater flowing downhill, thus enhancing the water's ability to transport soil particles (Tarigan *et al*., 2012). Additionally, this area is dominated by Inceptisols, as shown in **Chapter 2 of this book**, which are particularly prone to erosion due to their structure, which is easily eroded by water, and their clay-dominated texture, which has low water absorption capacity. According to Arsyad (2010), heavy erosion occurs when soil loss exceeds the tolerance threshold, preventing the soil from naturally recovering. The soil in this area, which is often managed without adequate conservation techniques, requires special attention to reduce damage from rapid surface water flow.

In contrast, areas like Aileu Vila experience very light erosion, as this area is relatively flat. Flat land is generally more stable, but soil loss can increase rapidly when the slope rises to 2-5%. At a slope gradient of 10%, erosion will increase eightfold, and at a slope gradient of 15%, soil erosion will increase even further (Anthony, 2001). The soil erosion data for Aileu District is presented in **Figure 6.1**. The distribution map of soil erosion levels in Aileu District is presented in **Figure 6.2**.



	Aileu Vila	Laulara	Liquidoe	Remexio
No erosion	12,66%	0,00%	1,27%	0,00%
Very Light	15,19%	1,27%	1,27%	0,00%
Light	10,13%	1,27%	0,00%	2,53%
Moderate	16,46%	0,00%	1,27%	1,27%
Heavy	8,86%	6,33%	7,59%	8,86%
Very Heavy	0,00%	1,27%	0,00%	2,53%

Figure 6.1 Soil Erosion Levels of Aileu District

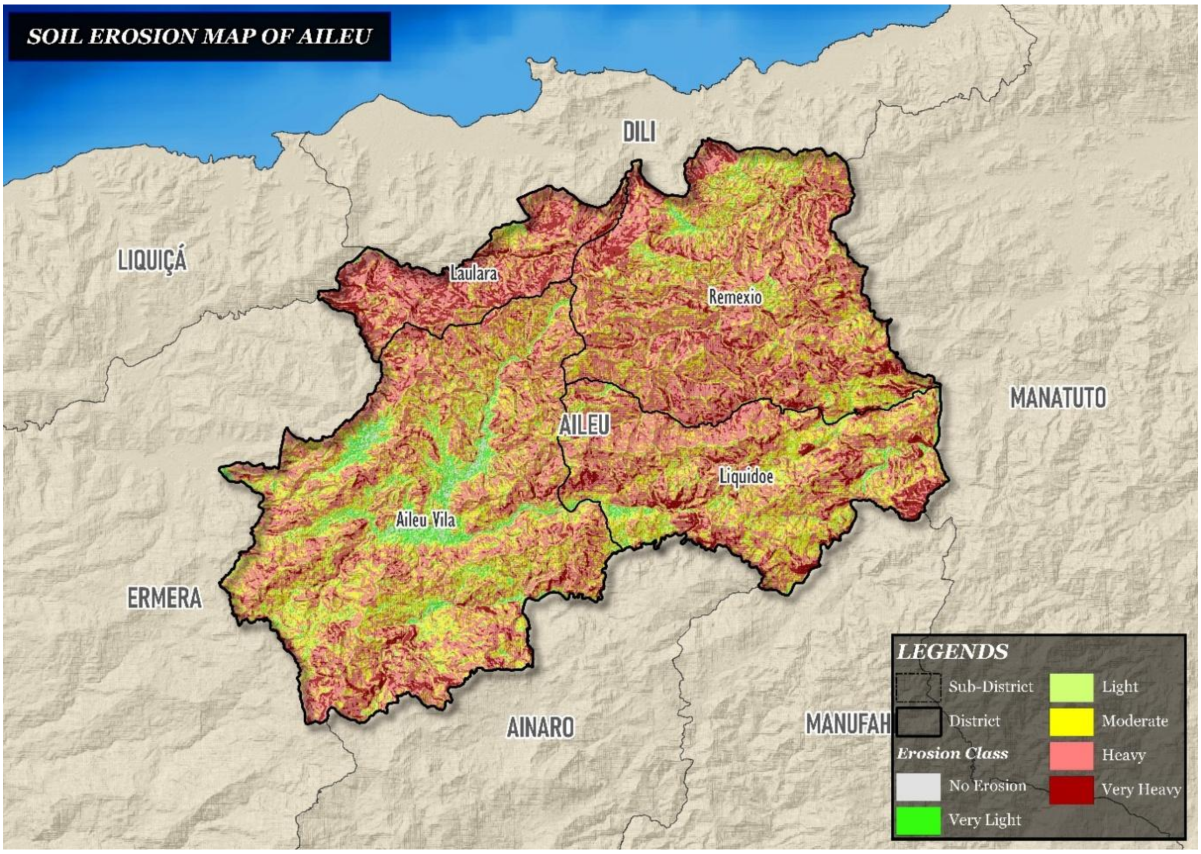


Figure 6.2 Soil Erosion Map of Aileu District

6.2 SOIL AND WATER CONSERVATION

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

Conservation in Aileu District is based on slope gradients, ranging from very light erosion to heavy erosion. The slopes in Aileu District are particularly prone to erosion in areas with gradients ranging from 15% to >45%. Based on the slope gradient criteria in Aileu District, the regions of Sub-District Aileu Vila, Laulara, Liquidoe, and Remexio range from flat to very steep (0–45%). Slope gradients of 0-8%, 8-15%, 15-25%, and 25-45% are distributed throughout the Sub-Districts, with the largest area found in Sub-District Aileu Vila. In areas with a slope gradient of 15-25%, terracing is recommended for planting food crops, cash crops, fruit horticulture, plantations, and industries. Areas with slopes greater than 45% are most prevalent in Sub-District Remexio, covering 3,170 ha or 4.30%, which means that land with such a steep gradient can only support perennial crops or be used for agroforestry. The slope gradient class data for Aileu District is presented in **Table 6.1,** and the slope gradient map for Aileu District is presented in **Figure 6.3.**

Table 6.1 Slope Gradient Data of Aileu District

Sub-Districts	Slope Gradient (%)	Potential Class	Area (ha)	Area (%)
Aileu Vila	>45	Agroforestry	2,564	3,48
Aileu Vila	0-8	Highly Potential	2,419	3,28
Aileu Vila	15-25	Moderately Potential	8,118	11,02
Aileu Vila	25-45	Agroforestry	14,821	20,11
Aileu Vila	8-15	Potential	3,449	4,68
Laulara	>45	Agroforestry	1,989	2,70
Laulara	0-8	Highly Potential	71	0,10
Laulara	15-25	Moderately Potential	663	0,90
Laulara	25-45	Agroforestry	3,166	4,30
Laulara	8-15	Potential	179	0,24
Liquidoe	>45	Agroforestry	1,938	2,63
Liquidoe	0-8	Highly Potential	588	0,80
Liquidoe	15-25	Moderately Potential	3,842	5,21
Liquidoe	25-45	Agroforestry	7,392	10,03
Liquidoe	8-15	Potential	1,347	1,83
Remexio	>45	Agroforestry	3,170	4,30
Remexio	0-8	Highly Potential	579	0,79
Remexio	15-25	Moderately Potential	4,520	6,13
Remexio	25-45	Agroforestry	11,389	15,45
Remexio	8-15	Potential	1,492	2,03

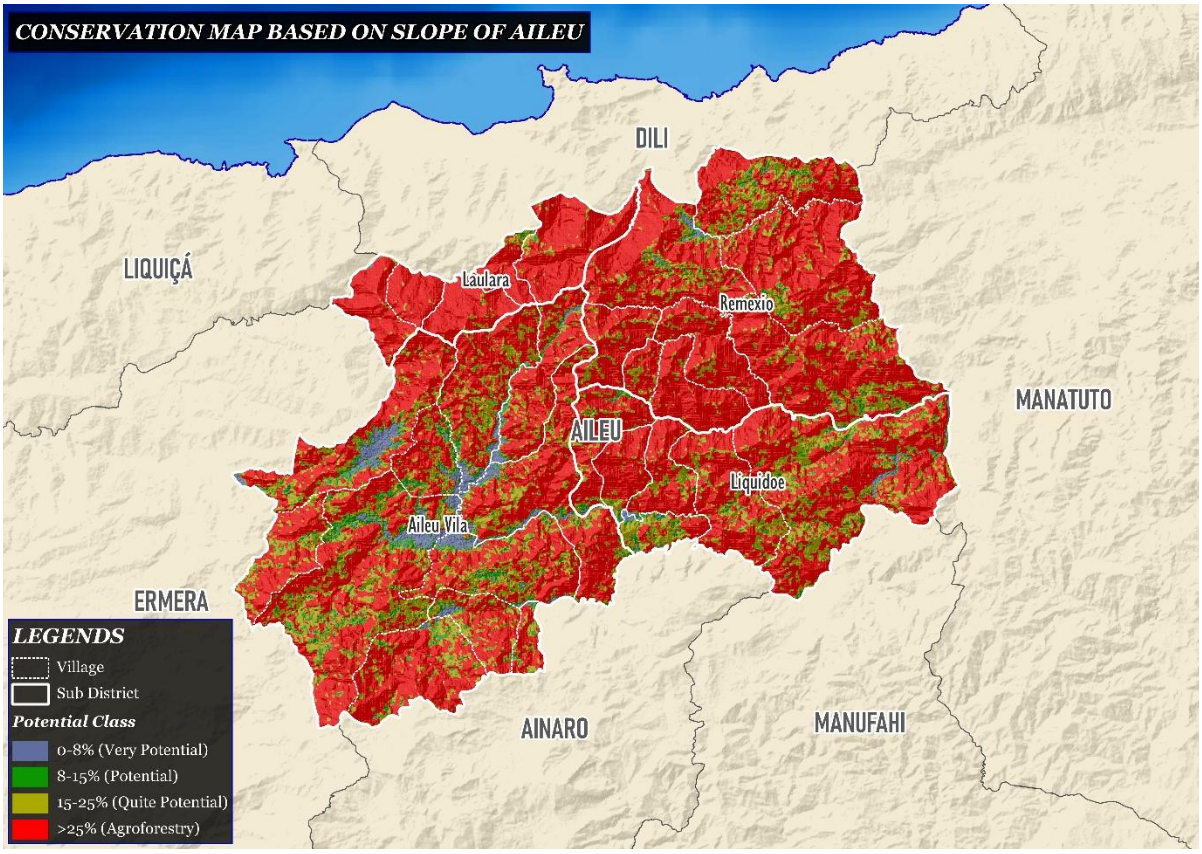


Figure 6.3 Conservation Map Based on Slope Gradient of Aileu District

Land with flat slopes (0-8%) covering 3,657.47 ha (4.96%) is highly suitable for the development of food crops, cash crops, horticulture, and other plants. Land with slopes of 8-15% covering 4,974.53 ha (8.78%) requires soil conservation efforts, such as terracing, to make the land productive and prevent erosion. Meanwhile, land with slopes of 15-25% covering 12,621.89 ha (23.26%) is considered moderately suitable, and areas with slopes greater than 25% cover 32,474.11 ha (63%). Overall, land that is highly suitable for agriculture in Aileu District is less than land used for agroforestry. Land with slopes greater than 45% can be utilized for perennial crops (such as trees like banyan, mahogany, *lenggung*, teak, gamal, *lamtoro*, mahogany, and others). If steep slopes are terraced, the planting area becomes very narrow, the soil is prone to erosion, and landslides may occur during rainfall.

Agroforestry is one of the conservation efforts in the form of a cropping system, which integrates forestry, agriculture, fisheries, and livestock into a unified farming effort to optimize land use. This system allows for efficient and optimal land use (Sanudin & Priambodo, 2013). 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 to support animal husbandry.
3. Agrosilvopastoral: The cultivation of trees, food crops, pasture, and livestock on the same land. This system aims to optimize the land's production function but requires intensive management at the subsystem level.
4. Home Garden System: This system is characterized by the intensive cultivation of perennial and seasonal crops, generally including vegetables, cereals, fruit trees, grasses, and animal husbandry.
5. Other Systems: These include the cultivation of multipurpose trees, beekeeping, and aquaculture, all of which can be utilized for both agricultural and non-agricultural purposes. The agroforestry conservation model is presented in **Figure 6.4.**

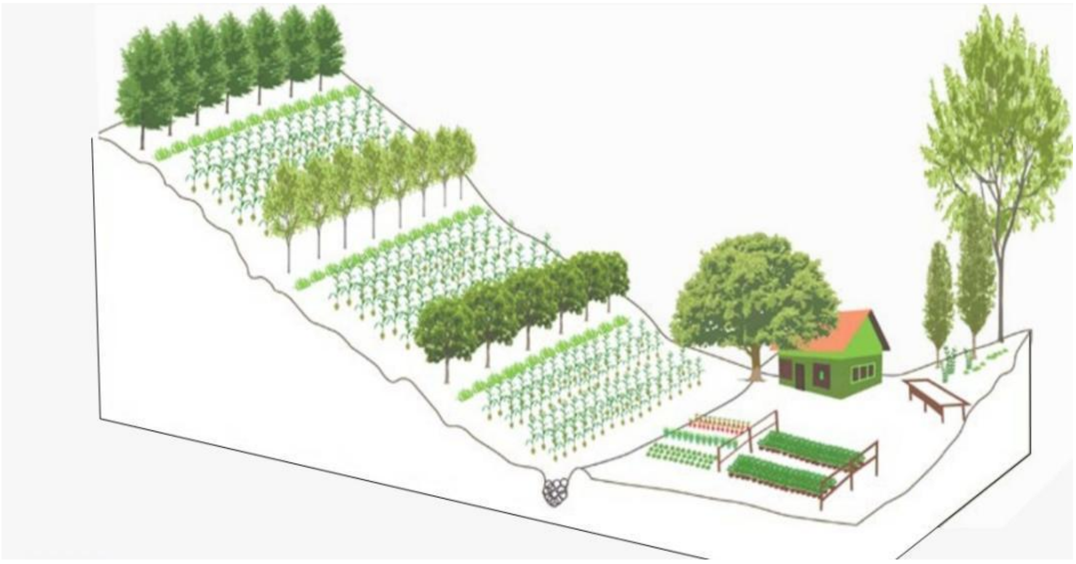


Figure 6.4 Agroforestry Conservation Model
(Source: La *et al*., 2016)

A. The Importance of the Agroforestry Concept

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

Agroforestry offers several benefits, including:

1. Improved Food Security and Nutritional Enrichment

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

2. Resilient Livelihoods

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

3. Climate Change Mitigation and Adaptation

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

4. Environmental Protection

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

5. Poverty Alleviation

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

B. Agroforestry and Agro-Ecology in Aileu District

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

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

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

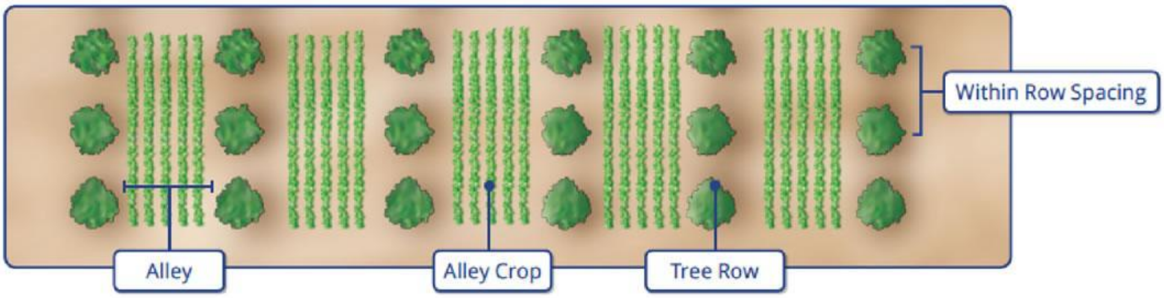


Figure 6.5 Alley Cropping Planting System Concept
(Source: USDA Alley Cropping)

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

Figure 6.6 Hedge Planting Concept
(Source: Flickr Hedgebrow)

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

Figure 6.7 Random Planting System Concept
(Source: PPID Ministry of Environment and Forestry)

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

be implemented at altitudes of 500 to 1500 meters with an average annual rainfall of 1500 to 3000 mm.

Cogné & Lescuyer (2024) combined agro-ecological and socio-technical data to identify agroforestry systems (AFS) in Aileu District, including home gardens combining perennial crops, spices, and small livestock; integration of crops and barren land to develop food crops and trees with specific spacing; planting of perennial crops (papaya, banana, chili, etc.) combined with timber trees (palms); forest plants typically near water sources; and silvopastoral systems combining trees, shrubs, and grazing livestock on the same land.

Aileu District has three agro-ecological zones (AEZ) based on agroclimatic zones. These zones have biophysical parameters such as land elevation, average rainfall, and soil types, which are essential in selecting appropriate crops and agroforestry models to apply in Aileu. Data on agro-ecological zones and main crops are presented in **Table 6.2.** The agroclimatic zone map of Aileu is presented in **Figure 6.8.**

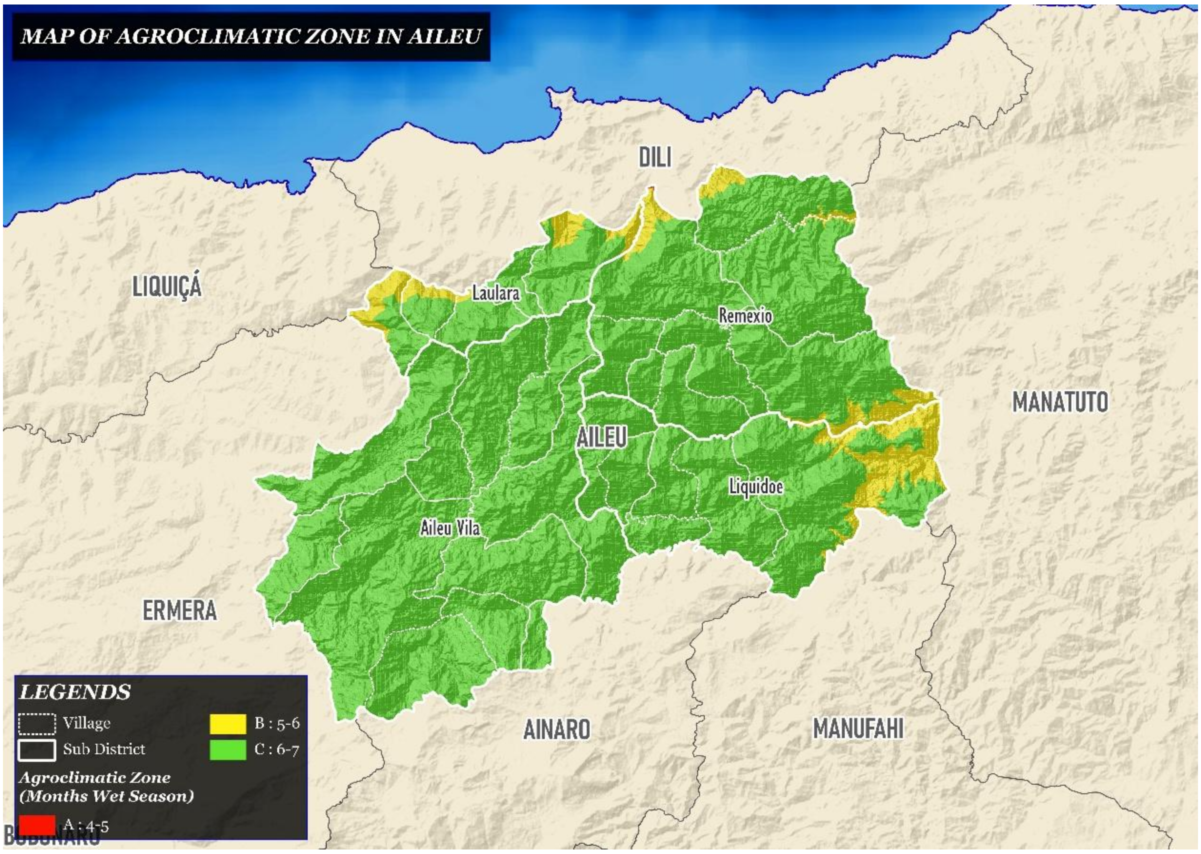


Figure 6.8 Agroclimatic Zone Map of Aileu District

Table 6.2 Agro-Ecological Zones Data and Main Crop Types

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

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

1. Zone A

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

2. Zone B

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

3. Zone C

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

C. Conservation Techniques in Aileu 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.

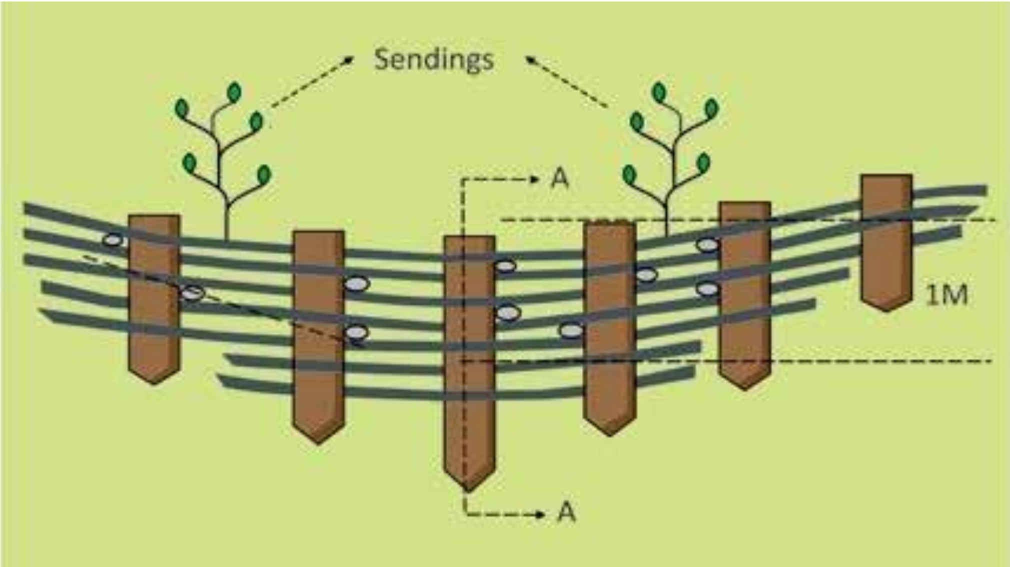


Figure 6.9 Brushwood Check Dam
(Source: Godinho *et al*., 2023)

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.**

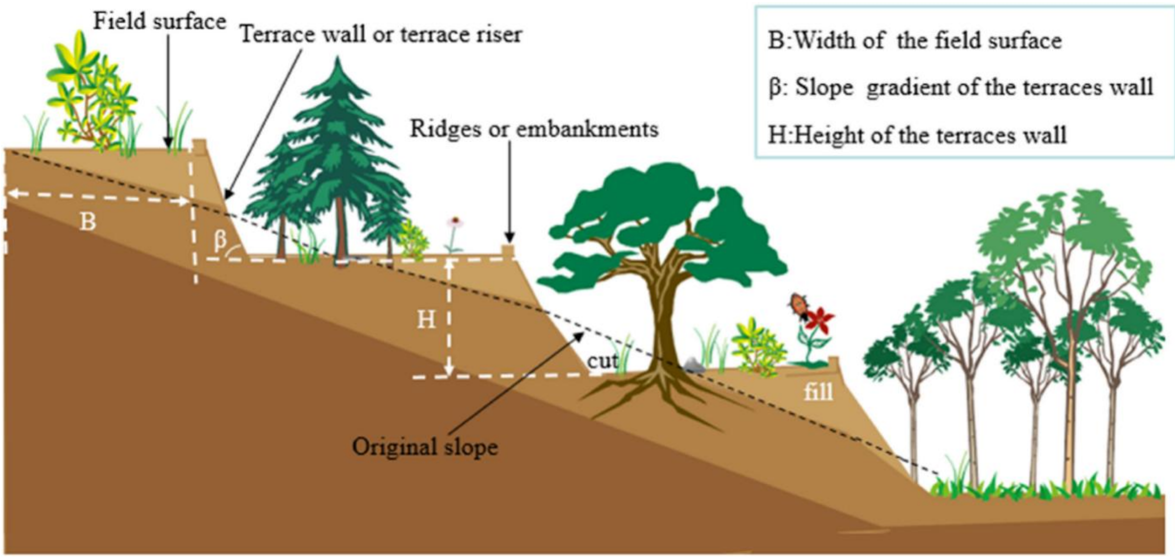
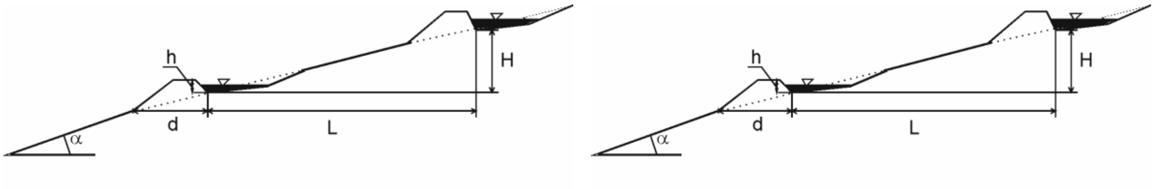


Figure 6.12 Terracing Conservation Concept
(Source: Deng *et al*., 2021)

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.**

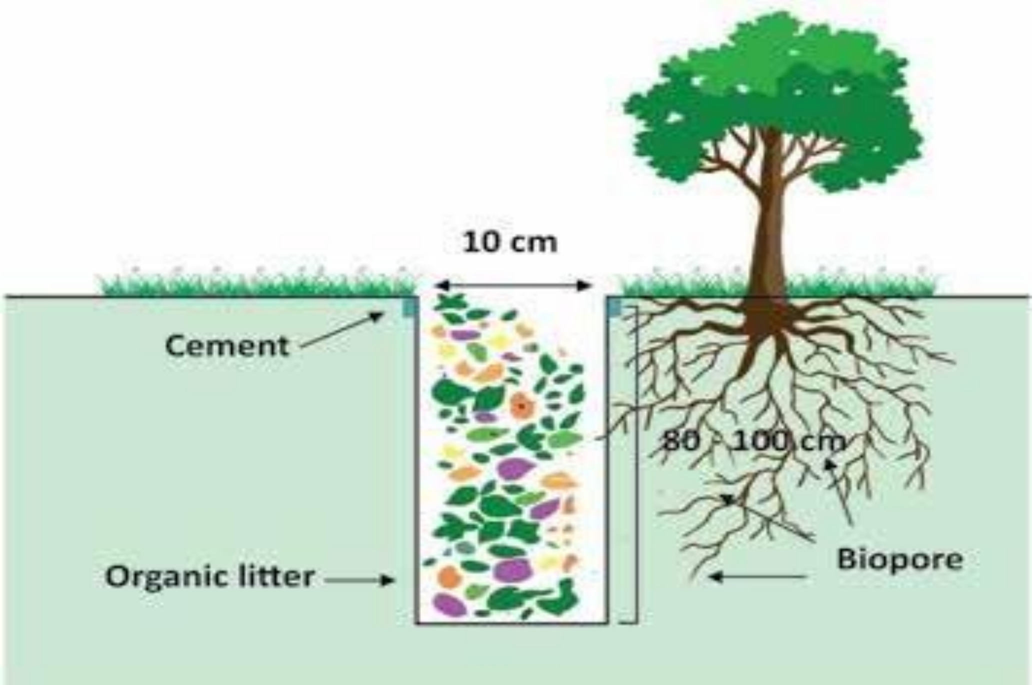


Figure 6.15 Biopore Infiltration Holes
(Source: Godinho *et al*., 2023)

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.**

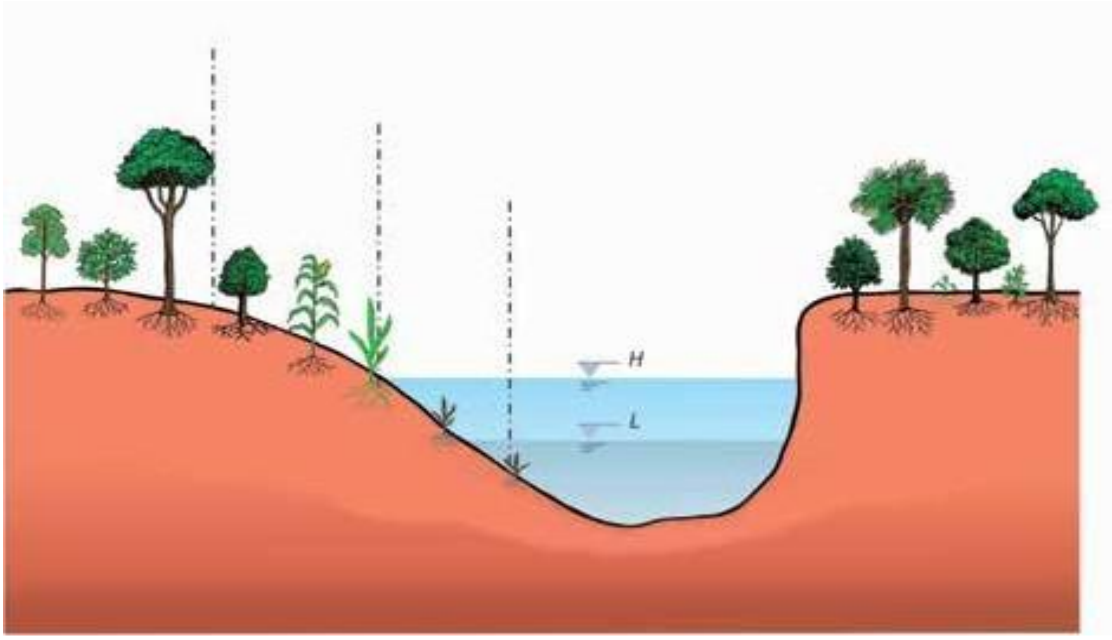


Figure 6.16 Riverbank Protection with Various Layers of Trees, Shrubs, and Grasses (Source: Godinho *et al*., 2023)

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.**

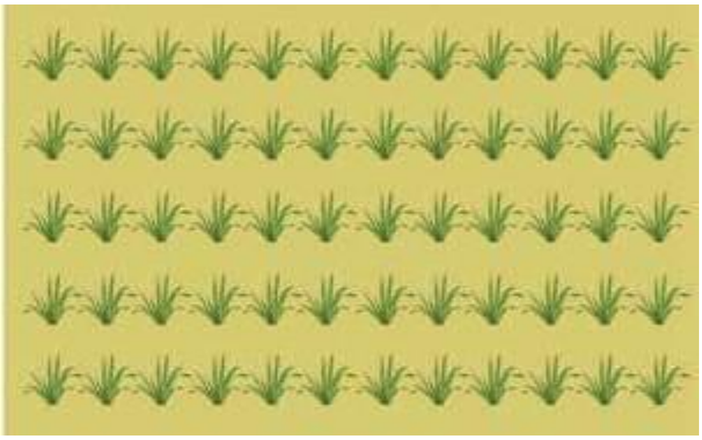


Figure 6.17 Horizontal Grass Planting
(Source: Godinho *et al*., 2023)

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.**

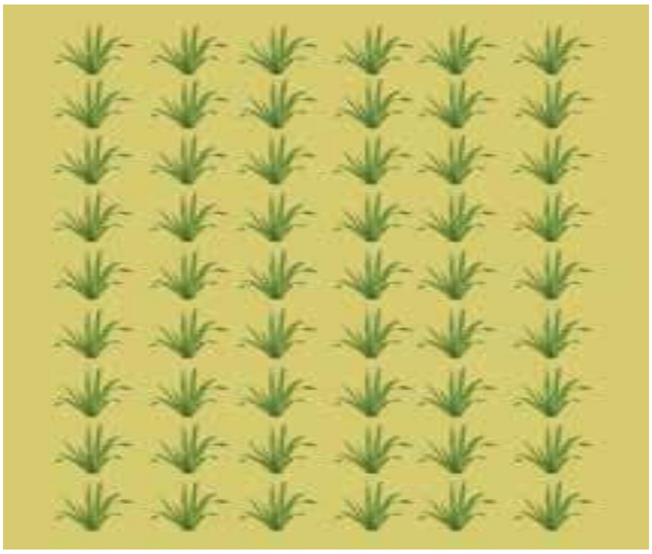


Figure 6.18 Vertical Grass Planting
(Source: Godinho *et al*., 2023)

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.**

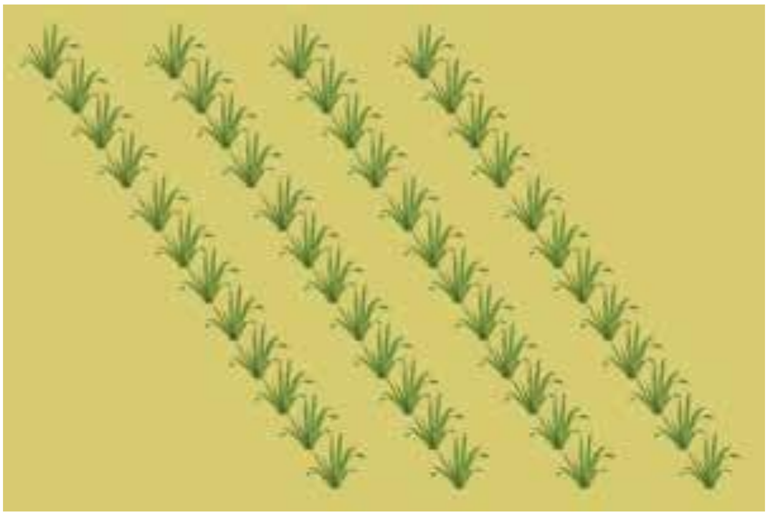


Figure 6.19 Diagonal Grass Planting
(Source: Godinho *et al.*, 2023)

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.**

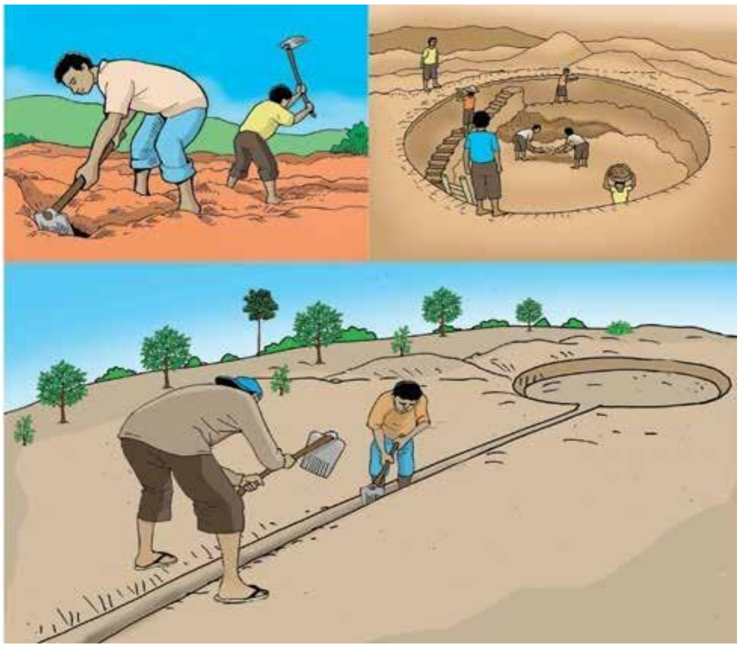


Figure 6.20 Rainwater Reservoir Construction
(Source: Godinho *et al*., 2023)

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.**

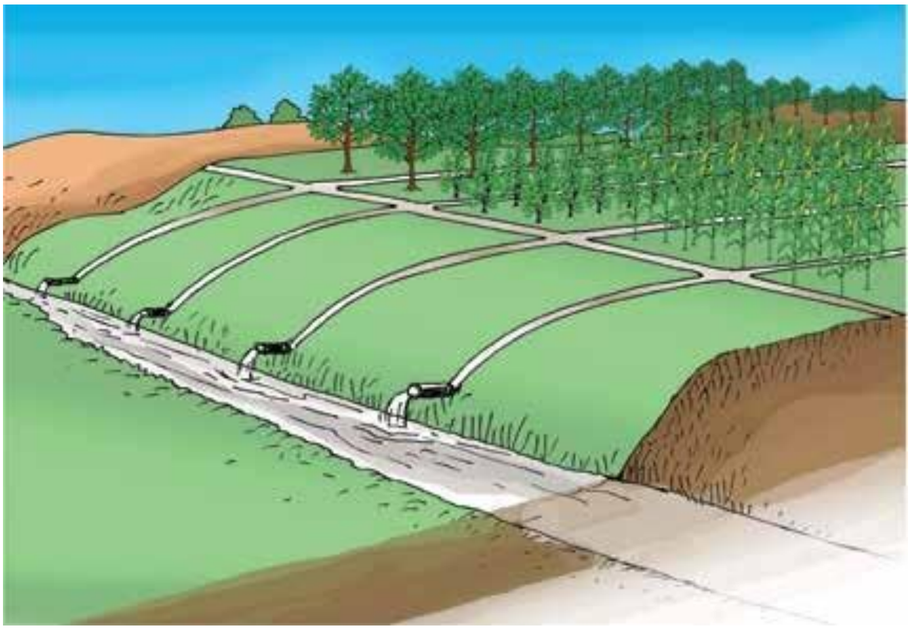


Figure 6.21 Drainage Channel
(Source: Godinho *et al*., 2023)

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.**

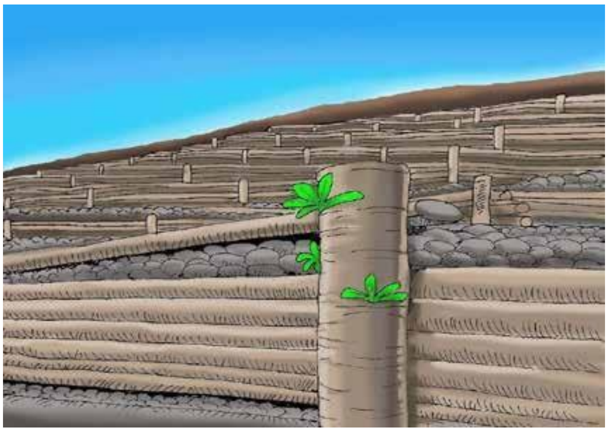


Figure 6.22 *Wattle Fence*

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 suitable for a specific intended use. For example, land may be evaluated as highly suitable for rice paddies, moderately suitable for coffee crops, or marginally suitable for orange trees. Land suitability can be assessed based on two conditions: the current condition and the condition after improvements.

7.1 AGRICULTURAL LAND SUITABILITY

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

Potential land suitability refers to the land's suitability after improvements have been made. For example, land that is marginally suitable (S3) in its actual state due to nutrient deficiencies can change to moderately suitable (S2) or even highly suitable (S1) after land improvements, such as fertilization, are carried out. Potential land suitability is assessed by making improvements to the land qualities that are limiting factors, thereby increasing the suitability class. With technology, lands that naturally have low suitability classes (actual suitability) can be upgraded to higher suitability classes (potential suitability) through improvements. However, not all land qualities or characteristics can be improved with current technology, and high levels of management may be required to improve them.

In land use planning, the main focus is on potential land suitability, as this assessment provides an overview of the land's maximum potential for various uses after improvements. Thus, potential land suitability helps in planning effective and sustainable land use and determining the necessary improvement steps to achieve optimal results.

7.2 LAND SUITABILITY CLASSIFICATION STRUCTURE

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

Table 7.1 Land Suitability Classification (FAO, 1976)

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

Orders and classes are generally used in land survey mapping, subclasses in semi-detailed land mapping, and units for detailed land mapping. Orders are also used in land mapping at a coarse scale (exploratory):

Land Suitability Order

The suitability order describes the general suitability of land, meaning whether a land area is suitable or not for a specific land use purpose. At the order level of suitability, land is classified into suitable (S) and not suitable (N).

Suitable Order (S)

Land in this order is land that can be used for a long period for a designated use with a high level of satisfaction after input is provided, with little or no risk of resource damage.

Not Suitable Order (N)

Land in this order has various difficulties or obstacles, either physically (e.g., very steep slopes, rocky terrain) or economically (i.e., input-output imbalance, which prevents the land from being used for the intended purpose).

Land Suitability Class

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

Highly Suitable Class (S1)

Land in this class has no significant limiting factors or only minor limitations that do not reduce productivity significantly, allowing for sustainable land use.

Moderately Suitable Class (S2)

Land in this class has somewhat severe limitations, requiring specific management practices. These limitations reduce productivity or profit and increase the necessary inputs.

Marginally Suitable Class (S3)

Land in this class has severe limitations that require intensive management to maintain. These heavy limitations may decrease productivity and profit, requiring additional inputs to achieve the desired output.

Not Suitable Class (N1)

Land in this class has extremely severe limitations that are difficult to overcome, preventing its sustainable use in the long term.

Permanently Not Suitable Class N2:

Land in this class has permanent limitations that prevent any possibility of sustainable land use in the long term.

7.3 LAND SUITABILITY EVALUATION RESULTS

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

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

Subsequently, the obtained data is analyzed based on the actual growth requirements of each plant type, as well as potential suitability after various land improvement efforts, such as fertilization, organic matter addition, or the application of soil conservation techniques. This process provides comprehensive information to determine commodity development priorities, identify limiting factors, and design relevant technical solutions.

This scientific approach serves as the foundation for land suitability evaluation in Aileu District. The results of this analysis provide strategic guidance to maximize land productivity while maintaining the sustainability of natural resources in each area. In **Table 7.2,** the land suitability assessment results place several plant commodities in the same column, indicating that these plants share similar growth requirements and limiting factors. Commodities placed in the same column require similar environmental conditions to grow optimally and face relatively the same constraints in the cultivation process. Plants placed in different columns have distinct growth requirements and limiting factors, and therefore require management approaches tailored to the specific needs of each plant commodity.

A. Land Suitability Evaluation for Aileu Vila Sub-District

Aileu Vila Sub-District has the potential for the development of various agricultural commodities such as food crops (soybeans, peanut, sweet potato, etc.), vegetable horticulture (e.g., shallots, chili, and broccoli), fruit horticulture (e.g., mango, soursop, and pineapple), and flower horticulture (e.g., roses, asters, sunflowers). In addition, spices and medicinal plants such as aromatic ginger and vetiver root can be developed. Industrial commodities, such as robusta coffee and sugarcane, can be developed, while grazing areas with leguminous plants and livestock feed such as elephant grass and setaria in Aileu Vila Sub-District can be enhanced with inputs to improve soil fertility.

The main constraints in agricultural development in Aileu Vila Sub-District are the long dry season, soil texture, rainfall intensity, slope gradient, erosion rates, drainage, flood potential, and soil depth. These factors can be addressed through technical solutions such as optimizing irrigation systems, constructing drainage channels, adding organic matter, and applying soil conservation techniques like terracing with supporting plants and ground cover. However, there are also permanent limiting factors, such as temperature, surface rocks, and rock outcrops, which cannot be improved. Despite these constraints, land management can still be carried out through methods such as clearing surface rocks and creating planting holes between rock outcrops, which can support the efficiency and productivity of cultivation.

This region has good potential for supporting sustainable agriculture. Meanwhile, cashew and cotton are not recommended for cultivation due to the permanent temperature constraints that cannot be corrected. Other plants that can be developed in Aileu Vila Sub-District are listed in **Table 7.5.**

B. Land Suitability Evaluation for Laulara Sub-District

Laulara Sub-District has the potential for the development of various agricultural commodities such as dryland food crops, vegetable horticulture (e.g., shallots, chili, and eggplant), fruit horticulture (e.g., oranges, mango, and soursop), and flower horticulture (e.g., roses, asters, sunflowers). Additionally, spices and medicinal plants such as cardamom and vetiver root can be developed. Industrial commodities such as robusta coffee and sugarcane can be developed, while grazing areas with leguminous plants and livestock feed such as elephant grass and setaria in Laulara Sub-District can be enhanced with inputs to improve soil fertility.

The main constraints in agricultural development in Laulara Sub-District are the long dry season, soil texture, rainfall intensity, slope gradient, erosion rates, drainage, flood potential, and soil depth. These factors can be addressed through technical solutions such as optimizing irrigation systems, constructing drainage channels, adding organic matter, and applying soil conservation techniques like terracing with supporting plants and ground cover. However, there are also permanent limiting factors, such as temperature, surface rocks, and rock outcrops, which cannot be improved. Despite these constraints, land management can still be carried out through methods such as clearing surface rocks and creating planting holes between rock outcrops, which can support the efficiency and productivity of cultivation.

This region has good potential for supporting sustainable agriculture. Meanwhile, cashew and cotton are not recommended for cultivation due to the permanent temperature constraints that cannot be corrected. Other plants that can be developed in Laulara Sub-District are listed in **Table 7.5.**

C. Land Suitability Evaluation for Liquidoe Sub-District

Liquidoe Sub-District has the potential for the development of food crops such as soybeans, Peanut, and sweet potatoes. Vegetable and fruit horticulture crops such as shallots, chili, bell peppers, guava, soursop, and breadfruit can also be developed. Flower crops such as roses, asters, and sunflowers can be grown, as well as spices and medicinal plants such as lemongrass, vanilla, and candlenut. Industrial crops such as robusta coffee and sugarcane have moderate suitability (S2), while grazing and livestock feed areas such as elephant grass and leguminous plants have marginal suitability (S3). Other plants that can be developed in Liquidoe Sub-District are listed in **Table 7.5.**

The land suitability is influenced by several limiting factors, including slope gradient, rainfall intensity, drainage, soil depth, dry season, coarse material, flood potential, and erosion rates. These factors can be addressed through technical solutions such as optimizing irrigation systems, constructing drainage channels, and applying soil conservation techniques like terracing with supporting plants and ground cover. However, there are also permanent limiting factors, such as temperature, surface rocks, and rock outcrops, which cannot be improved. Despite these constraints, land management can still be carried out through methods such as clearing surface rocks and creating planting holes between rock outcrops, which can support the efficiency and productivity of cultivation.

This area has potential for sustainable agriculture. However, crops such as taro, cashew, and cotton cannot be developed in this area due to the permanent temperature limitations that cannot be corrected.

D. Land Suitability Evaluation for Remexio Sub-District

Remexio Sub-District has the potential for the development of food crops such as soybeans, Peanut, and sweet potatoes. Vegetable and fruit horticulture crops such as shallots, chili, bell peppers, guava, soursop, and breadfruit can also be developed. Flower crops such as roses, asters, and sunflowers can be grown, as well as spices and medicinal plants such as lemongrass, vanilla, and candlenut. Industrial crops such as robusta coffee and sugarcane have moderate suitability (S2), while grazing and livestock feed areas such as elephant grass and leguminous plants have marginal suitability (S3). Other plants that can be developed in Remexio Sub-District are listed in **Table 7.5.**

The land suitability is influenced by several limiting factors, including slope gradient, rainfall intensity, drainage, soil depth, dry season, coarse material, flood potential, and erosion rates. These factors can be addressed through technical solutions such as optimizing irrigation systems, constructing drainage channels, and applying soil conservation techniques like terracing with supporting plants and ground cover. However, there are also permanent limiting factors, such as temperature, surface rocks, and rock outcrops, which cannot be improved.

Despite these constraints, land management can still be carried out through methods such as clearing surface rocks and creating planting holes between rock outcrops, which can support the efficiency and productivity of cultivation.

This area has potential for sustainable agriculture. However, crops such as taro, cashew, and cotton cannot be developed in this area due to the permanent temperature limitations that cannot be corrected.

Table 7.2 Land Suitability Evaluation Analysis Matrix in Aileu District

Commodities	Sub-District	Limiting Factors	Potential Land Suitability / Land Improvement Efforts
		FOOD COMMODITES	
Irrigated Rice	• Aileu Vila	**S3:** Temperature, Available-P **S2:** N-total, Available-K	**S3:** Temperature
Rainfed Rice	• Aileu Vila	**S3:** Temperature, Slope, Available-P **S2:** N-total, Available-K, Erosion, Flood	**S3:** Temperature
Dryland Food Commodities			
Corn	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Erosion, Slope **S3:** Rainfall, Available-P, Available-K, Coarse Fragments, Rock outcrops **S2:** N-total, Surface rocks	**S3:** Rock outcrops **S2:** Erosion, Slope, Coarse Fragments, Surface rocks
Mung bean Cowpea	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Rainfall, Available-P, Available-K, Erosion, Rock outcrops **S2:** Drainage, N-total, Surface rocks	**S3:** Rock outcrops **S2:** Slope, Surface rocks
Upland Rice Sorghum Cassava	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Rainfall, Slope **S3:** Temperature, Coarse Fragments, Available-P, Erosion, Rock outcrops **S2:** N-total, Available-K, Surface rocks	**S3:** Temperature, Rock outcrops **S2:** Rainfall, Slope, Coarse Fragments, Surface rocks
Wheat	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Rainfall, Slope **S3:** Coarse Fragments, Available-P, Available-K, Erosion, Rock outcrops **S2:** Drainage, N-total, Surface rocks	**S3:** Rock outcrops **S2:** Rainfall, Coarse Fragments, Slope, Surface rocks

Soybean Peanut	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Rainfall, Slope **S3:** Avalaible-P dan Available-K, Erosion, Rock outcrops **S2:** Temperature, N-total, Surface rocks	**S3:** Rock outcrops **S2:** Temperature, Rainfall, Slope, Surface rocks
Sweet Potato	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Dry month, Coarse Fragments, Erosion, Rock outcrops **S2:** Temperature, Rainfall, Effective Depth, N-Total, Available-P, Available-K, Surface rocks	**S3:** Rock outcrops **S2:** Temperature, Dry month, Coarse Fragments, Slope, Surface rocks
Taro	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Temperature, Slope **S3:** Erosion, Rock outcrops **S2:** Drainage, Surface rocks	**N:** Temperature **S3:** Rock outcrops **S2:** Slope, Surface rocks
VEGETABLE HORTICULTURAL COMMODITIES			
Potato	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Temperature, Rock outcrops, Erosion **S2:** Drainage, Effective Depth, Flood, Surface rocks, Texture, N, P, K, CEC, BS	**S3:** Temperature **S2:** Slope, Rock outcrops, Erosion, Surface rocks, Texture
Carrot	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Temperature, Rock outcrops, Effective Depth, Erosion **S2:** Drainage, Rainfall, Flood, Surface rocks, Texture, pH, N-Total, Available-P, Available-K, CEC, BS	**S3:** Temperature **S2:** Slope, Rock outcrops, Effective Depth, Surface rocks, Texture
Shallot	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Rock outcrops, Erosion **S2:** Drainage, Effective Depth, Flood, Texture, pH, N-Total, Available-P, Available-K, CEC, BS	**S2:** Slope, Rock outcrops, Effective Depth, Texture
Garlic	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Rainfall, Slope **S3:** Temperature, Rock outcrops, Erosion **S2:** Drainage, Effective Depth, Flood, Surface rocks, pH, N-Total, Available-P, Available-K, CEC, BS	**S3:** Temperature **S2:** Slope, Rock outcrops, Effective Depth, Surface rocks

Chili	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope, Rainfall **S3:** Rock outcrops, Effective Depth, Erosion **S2:** Drainage, Flood, Surface rocks, pH, N-Total, Available-P, Available-K, CEC, BS	**S2:** Slope, Rock outcrops, Effective Depth, Surface rocks
Bell Pepper **Green Bean** **Broccoli**	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Rock outcrops, Effective Depth, Erosion **S2:** Drainage, Flood, Surface rocks, pH, N-Total, Available-P, Available-K, CEC, BS	**S2:** Slope, Rock outcrops, Effective Depth, Surface rocks
Caisim	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Rock outcrops, Erosion **S2:** Temperature, Drainage, Rainfall, Flood, Surface rocks, Texture, pH, N-Total, Available-P, Available-K, CEC, BS	**S2:** Slope, Rock outcrops, Temperature, Surface rocks, Texture
Snow Pea	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Effective Depth, Rock outcrops, Erosion **S2:** Temperature, Drainage, Flood, Surface rocks, pH, N-Total, Available-P, Available-K CEC, BS	**S2:** Slope, Effective Depth, Rock outcrops, Temperature, Surface rocks
Cucumber	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Rainfall, Effective Depth, Rock outcrops, Erosion **S2:** Temperature, Drainage, Flood, Surface rocks, N-Total, Available-P, Available-K, CEC, BS	**S2:** Slope, Effective Depth, Rock outcrops, Temperature, Surface rocks
Eggplant **Bitter melon** **Vegetable Tomato**	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Rainfall, Effective Depth, Rock outcrops, Flood, Erosion **S2:** Drainage, Surface rocks, pH N-Total, Available-P, Available-K, CEC, BS	**S2:** Slope, Effective Depth, Rock outcrops, Surface rocks
Cabbage **Long bean**	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Effective Depth, Rock outcrops, Erosion **S2:** Drainage, Flood, Surface rocks, Texture, pH, N-Total, Available-P, Available-K, CEC, BS	**S2:** Slope, Effective Depth, Rock outcrops, Surface rocks, Texture

FRUIT HORTICULTURAL COMMODITIES			
Guava **Soursop** **Breadfruit** **Longan**	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Erosion, N-total, Available-P **S2:** Rainfall, Effective Depth, Rock outcrops, Surface rocks, Available-K	**S2:** Slope, Effective Depth, Rock outcrops, Surface rocks
Watermelon **Melon**	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Erosion, Slope **S3:** Rainfall, Rock outcrops, N-total, Available-P **S2:** Temperature, Surface rocks, Available-K, Texture	**S2:** Texture, Erosion, Slope, Temperature, Rock outcrops, Surface rocks
Banana	• Aileu Vila • Laulara • Liquidoe • Remexio	**S3:** Dry month, Erosion, Slope, N-total, Available-P **S2:** Temperature, Drainage, Rock outcrops, Surface rocks, Available-K, Texture	**S2:** Texture, Dry month, Temperature, Rock outcrops, Surface rocks
Papaya	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Erosion, Rainfall, N-total, Available-P **S2:** Temperature, Rock outcrops, Surface rocks, Available-K	**S2:** Slope, Temperature, Rock outcrops, Surface rocks
Orange	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Erosion, N-total, Available-P **S2:** Effective Depth, Rock outcrops, Surface rocks, Available-K, Texture	**S2:** Texture, Slope, Rock outcrops, Surface rocks
Rambutan	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Rainfall, Erosion, N-total, Available-P **S2:** Temperature, Effective Depth, Rock outcrops, Surface rocks, Available-K	**S2:** Slope, Temperature, Rock outcrops, Surface rocks
Avocado	• Aileu Vila • Laulara • Liquidoe • Remexio	**S3:** Rainfall, Erosion, Slope, N-total, Available-P **S2:** Temperature, Effective Depth, Rock outcrops, Surface rocks, Available-K	**S2:** Temperature, Rock outcrops, Surface rocks
Mango	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Rainfall, Erosion, N-total, Available-P **S2:** Effective Depth, Rock outcrops, Surface rocks, Available-K	**S2:** Slope, Rock outcrops, Surface rocks

Jackfruit	• Aileu Vila • Laulara • Liquidoe • Remexio	**S3:** Erosion, Slope, N-total, Available-P **S2:** Temperature, Rainfall, Effective Depth, Rock outcrops, Surface rocks, Available-K	**S2:** Temperature, Rock outcrops, Surface rocks
Snake Fruit	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Erosion, N-total, Available-P **S2:** Temperature, Rainfall, Rock outcrops, Surface rocks, Available-K, pH	**S2:** Slope, Temperature, Rock outcrops, Surface rocks
Durian	• Aileu Vila • Laulara • Liquidoe • Remexio	**S3:** Temperature, Rainfall, Erosion, Slope, Rock outcrops, N-total, Available-P **S2:** Effective Depth, Surface rocks, Available-K	**S2:** Temperature, Rock outcrops, Surface rocks
Custard Apple	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Erosion, Rock outcrops, N-total, Available-P **S2:** Rainfall, Effective Depth, Available-K	**S2:** Slope, Rock outcrops, Surface rocks
Pineapple	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Rainfall, Erosion, Rock outcrops, N-total, Available-P **S2:** Surface rocks, Available-K	**S2:** Slope, Rock outcrops, Surface rocks
Strawberry	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Erosion, Slope **S3:** Rock outcrops, N-total, Available-P **S2:** Temperature, Rainfall, Surface rocks, Available-K	**S2:** Erosion, Slope, Temperature, Rock outcrops, Surface rocks
Grape	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Erosion, Rock outcrops, N-total, Available-P **S2:** Temperature, Rainfall, Effective Depth, Surface rocks, Available-K	**S2:** Slope, Temperature, Rock outcrops, Surface rocks
Passion Fruit	• Aileu Vila • Laulara • Liquidoe • Remexio	**S3:** Erosion, Slope, Rock outcrops, N-total, Available-P **S2:** Temperature, Rainfall, Effective Depth, Surface rocks, Available-K	**S2:** Temperature, Rock outcrops, Surface rocks
FLOWER HORTICULTURAL COMMODITIES			
Rose Aster Sunflower	• Aileu Vila • Laulara • Liquidoe	**N:** Erosion, Slope	**S2:** Erosion hazard, Slope, Effective Depth, Rock outcrops, Surface rocks

	• Remexio	**S3:** Effective Depth, Rock outcrops, Surface rocks, N-total, Available-P, Available-K **S2:** Drainage, Rainfall	
SPICE AND MEDICINAL COMMODITIES			
Ginger	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Rainfall, Dry month, Slope **S3:** Temperature, Erosion, Surface rocks, Rock outcrops **S2:** Effective Depth, N-Total, Available-P, Available-K, Texture	**S3:** Dry month **S2:** Rainfall, Slope, Surface rocks, Rock outcrops, Effective Depth
Vetiver Root	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Erosion, Flood Hazard, Rock outcrops **S3:** Drainage, Rainfall **S2:** Temperature, Surface rocks, N-Total, Available-P, Available-K, Texture	**S3:** Rock outcrops **S2:** Erosion, Flood hazard, Surface rocks
Lemongrass	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Erosion, Rock outcrops, Flood **S3:** Drainage, Rainfall, Slope **S2:** Temperature, Effective Depth, Surface rocks, Texture	**S3:** Rock outcrops, **S2:** Temperature, Erosion, Flood, Effective Depth, Surface rocks
Vanilla	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry month, Erosion, Flood **S3:** Rainfall, Slope, Rock outcrops **S2:** Temperature, Drainage, Effective Depth, Surface rocks, N-Total, Available-P, Available-K, Texture	**S3:** Dry month **S2:** Temperature, Erosion, Flood, Rock outcrops, Effective Depth, Surface rocks
Candlenut	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry month, Erosion, Rock outcrops, Flood **S3:** Drainage, Slope, Rock outcrops **S2:** Temperature, Rainfall, N-Total, Available-P, Available-K, Effective Depth, Surface rocks, Texture	**S3:** Dry month **S2:** Temperature, Erosion, Effective Depth, Surface rocks, Rock outcrops, Flood
Cinnamon	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry month, Slope **S3:** Drainage, Erosion, Slope, Surface rocks, Rock outcrops, Flood **S2:** Temperature, Rainfall, Effective Depth, N-Total, Available-P, Available-K, Texture	**S3:** Dry month **S2:** Temperature, Slope, Effective Depth, Surface rocks, Rock outcrops

Nutmeg	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Rainfall, Dry month, Flood S3: Erosion, Slope, Surface rocks, Rock outcrops S2: Temperature, Drainage, Effective Depth, Texture	S3: Dry month S2: Temperature, Rainfall, Effective Depth, Surface rocks, Rock outcrops, Flood
Pepper	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Dry month, Slope, Flood S3: Erosion, Rock outcrops S2: Temperature, Drainage, Rainfall, Surface rocks, N-Total, Available-P, Available-K, Texture	S3: Dry month S2: Temperature, Slope, Rock outcrops, Flood, Surface rocks
Jathropa	• Aileu Vila • Laulara • Liquidoe • Remexio	S3: Erosion, Slope, Surface rocks, Rock outcrops S2: Temperature, Drainage, Rainfall, Effective Depth	S2: Temperature, Effective DepthSurface rocks, Rock outcrops
Aromatic Ginger	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Rainfall, Slope, Flood S3: Erosion, Surface rocks, Rock outcrops S2: Temperature, Rainfall, Effective Depth, N-Total, Available-P, Available-K	S2: Temperature, Rainfall, Slope, Surface rocks, Rock outcrops, Flood
Turmeric	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Slope, Flood S3: Erosion, Rock outcrops, Surface rocks S2: Temperature, Rainfall, Effective Depth	S2: Temperature, Slope, Effective Depth, Rock outcrops, Surface rocks, Flood
Galangal	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Slope, Flood S3: Temperature, Drainage, Erosion, Effective Depth, Surface rocks, Rock outcrops S2: Rainfall	S2: Temperature, Effective Depth, Surface rocks, Rock outcrops Flood
Cardamom	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Rainfall, Slope, Flood S3: Drainage, Erosion, Effective Depth, Surface rocks, Rock outcrops	S2: Rainfall, Slope, Effective Depth, Surface rocks, Rock outcrops Flood
Sesame	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Rainfall, Dry month S3: Erosion, Effective Depth, Surface rocks, Rock outcrops, N-Total, Available-P, Available-K	S3: Dry month S2: Rainfall, Effective Depth, Surface rocks, Rock outcrops
INDUSTRIAL COMMODITIES			
Rubber	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Dry month, Flood S3: Temperature, Rainfall, Slope, Erosion, Rock outcrops, N-total, Available-P, Available-K	S3: Dry month, Temperature S2: Flood, Rock outcrops, Surface rocks

		S2: Effective Depth, Drainage, Surface rocks	
Coconut	• Aileu Vila • Laulara • Liquidoe • Remexio	**S3:** Temperature, Slope, Erosion, Rock outcrops, N-total, Available-P, Available-K **S2:** Effective Depth, Rainfall, Dry month, Flood, Surface rocks	**S3:** Temperature **S2:** Rock outcrops, Surface rocks
Oil Palm	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Dry month **S3:** Temperature, Erosion, Rock outcrops, N-total, Available-P, Available-K **S2:** Surface rocks, Effective Depth, Slope, SOC, BS	**S3:** Dry month, Temperature **S2:** Rock outcrops, Surface rocks, Effective Depth
Arabica Coffee	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Dry month **S3:** Rainfall, Erosion, Slope, Rock outcrops, N-total, Available-P **S2:** Temperature, Effective Depth, Surface rocks	**S3:** Dry month **S2:** Rock outcrops, Effective Depth, Surface rocks, Temperature
Robusta Coffee	• Aileu Vila • Laulara • Liquidoe • Remexio	**S3:** Rainfall, Dry month, Erosion, Slope, Rock outcrops **S2:** Effective Depth, Surface rocks, N-total, Available-P	**S2:** Rock outcrops, Effective Depth, Surface rocks
Cocoa **Clove** **Tea**	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Dry month **S3:** Rainfall, Erosion, Slope, Rock outcrops **S2:** Temperature, Effective Depth, Surface rocks, N-total, Available-P, SOC	**S3:** Dry month, Rock outcrops **S2:** Surface rocks, Temperature
Tobacco	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Dry month, Erosion **S3:** Rainfall, Slope, Rock outcrops, Texture **S2:** Temperature, Surface rocks, N-total, Available-P, SOC	**S3:** Dry month **S2:** Rock outcrops, Temperature, Surface Rocks
Sugarcane	• Aileu Vila • Laulara • Liquidoe • Remexio	N: Erosion, Slope **S3:** Temperature, Rainfall, Rock outcrops **S2:** Surface rocks	**S2:** Rock outcrops, Surface rocks
Cashew	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Temperature **S3:** Dry month, Erosion, Slope, Rock outcrops **S2:** Rainfall, Effective Depth, Surface rocks	**N:** Temperature **S2:** Dry month, Rock outcrops, Effective Depth, Surface rocks

Melinjo	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry month **S3:** Erosion, Slope, Rock outcrops **S2:** Temperature, Surface rocks	**S3:** Dry month **S2:** Rock outcrops, Surface rocks, Temperature
Cotton	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Temperature **S3:** Rainfall, Erosion, Slope, Rock outcrops **S2:** Surface rocks	**N:** Temperature **S2:** Rock outcrops, Surface rocks
Kapok	• Aileu Vila • Laulara • Liquidoe • Remexio	**S3:** Temperature, Rainfall, Erosion, Slope, Rock outcrops **S2:** Effective Depth, Surface rocks	**S3:** Temperature **S2:** Rock outcrops, Effective Depth, Surface rocks
Quinine	• Aileu Vila • Laulara • Liquidoe • Remexio	**S3:** Erosion, Slope, Rock outcrops **S2:** Temperature, Effective Depth, Surface rocks	**S2:** Rock outcrops, Effective Depth, Surface rocks
GRAZING AREAS AND LIVESTOCK FEED			
Livestock Feed Group: Elephant Grass Setaria	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Slope **S3:** Rock outcrops, Erosion **S2:** Surface rocks, Rainfall, N-total, Available-P, Available-K	**S3:** Rock outcrops **S2:** Slope, Surface rocks
Legumes	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Erosion, Slope **S3:** Rock outcrops **S2:** Surface rocks, Rainfall, N-total, Available-P, Available-K	**S3:** Rock outcrops **S2:** Erosion, Slope, Surface rocks
Grazing	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry month, Slope **S3:** Rock outcrops, Erosion **S2:** Surface rocks, N-total, Available-P, Available-K	**S3:** Dry month **S2:** Slope, Surface rocks, Rock outcrops

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

7.4 LAND IMPROVEMENT EFFORTS

Improvement efforts for each limiting factor are crucial for enhancing productivity and sustainability in the agricultural sector. Various constraints, such as shallow effective soil depth, poor drainage, erosion risks, and surface rocks, require appropriate solutions to maximize land potential. On the other hand, some soil chemical parameters, such as Soil Organic Carbon (SOC) and nutrient content (N, P, K), are relatively low in the current state, requiring land improvement efforts to elevate them into potential land for agricultural commodity development.

Recommendations for land improvement efforts for each limiting factor, as the basis for implementing potential land suitability enhancement for agricultural commodities, livestock feed, and grazing, are presented in **Table 7.3.** The level of improvement from actual land quality to potential quality, according to management level, is presented in **Table 7.4,** which is then used as a guideline for transforming actual land suitability into potential suitability.

Table 7.3 Recommendations for Improvement Measures for Each Limiting Factor

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

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

Descriptions:

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

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

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

Descriptions:

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

7.5 LAND USE GUIDELINES

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

The selection of recommended plant commodities is carried out carefully, based on technical criteria outlined in the land suitability evaluation. This assessment involves various key limiting factors, including water availability, root capacity, nutrient retention and availability, erosion and flood risks, and ease of land preparation. Each of these factors is analyzed in terms of its potential for improvement, through mechanical, chemical, or biological approaches.

It should be emphasized that although the evaluation results indicate that certain commodities fall within the highly suitable (S1), this does not mean that the crops will automatically grow and develop optimally solely based on the physical land conditions. These recommendations assume that all land management actions are optimally performed, including balanced fertilization according to the specific needs of the crops, appropriate agronomic management, proper irrigation management, climate-appropriate planting patterns, and the soil and water conservation techniques.

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

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

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

NO	DISTRICT	SUB-DISTRICT	FOOD CROPS	DRYLAND AGRICULTURE (PLANTATIONS & HORTICULTURE)	FORESTRY	LIVESTOCK FEED & GRAZING AREAS
1	Aileu	Aileu Vila	WETLAND FOOD CROPS **S3:** Irrigated Rice DRYLAND FOOD CROPS **S2:** Soybean, Peanut, Sweet Potato **S3:** Rainfed Rice, Corn, Mung Bean, Cowpea, Upland Rice, Sorghum, Cassava, Wheat	INDUSTRY **S3:** Rubber, Coconut, Oil Palm, Arabica Coffee, Cocoa, Clove, Tea, Tobacco, Melinjo, Kapok **S2:** Robusta Coffee, Sugarcane, Quinine FRUITS **S2:** Banana, Papaya, Orange, Rambutan, Avocado, Mango, Guava, Durian, Watermelon, Melon, Jackfruit, Soursop, Cherimoya, Breadfruit, Snake Fruit, Pineapple, Longan, Strawberry, Grape, Passionfruit VEGETABLES **S2:** Shallots, Chili, Bell Pepper, Green Bean, Broccoli, Caisim, Snow pea, Cucumber, Eggplant, Bitter Melon, Vegetable Tomato, Cabbage, Long Bean **S3:** Potato, Carrot, Garlic FLOWERS **S2:** Rose, Sunflower, Aster SPICES & MEDICINAL PLANTS **S2:** Jathropa, Aromatic Ginger, Turmeric, Galangal, Cardamom **S3:** Ginger, Vetiver Root, Lemongrass, Vanilla, Candlenut, Cinnamaon, Nutmeg, Pepper, Sesame	**S3:** Agathis, Sengon, Leucaena, Acacia, Eucalyptus, Sandalwood **S2:** Teak, Mahogany, Altingia, Gelam, Pine	**S3:** Elephant Grass, Setaria, Leguminous Plants, Grazing

2	Aileu	Laulara	DRYLAND FOOD CROPS **S2:** Soybean, Groundnut, Sweet Potato **S3:** Rainfed Rice, Corn, Mung Bean, Cowpea, Upland Rice, Sorghum, Cassava, Wheat	INDUSTRY **S3:** Rubber, Coconut, Oil Palm, Arabica Coffee, Cocoa, Clove, Tea, Tobacco, Melinjo, Kapok **S2:** Robusta Coffee, Sugarcane, Quinine FRUITS **S2:** Banana, Papaya, Orange, Rambutan, Avocado, Mango, Guava, Durian, Watermelon, Melon, Jackfruit, Soursop, Cherimoya, Breadfruit, Snake Fruit, Pineapple, Longan, Strawberry, Grape, Passionfruit VEGETABLES **S2:** Shallots, Chili, Bell Pepper, Green Bean, Broccoli, Caisim, Snow pea, Cucumber, Eggplant, Bitter Melon, Vegetable Tomato, Cabbage, Long Bean **S3:** Potato, Carrot, Garlic FLOWERS **S2:** Rose, Sunflower, Aster SPICES & MEDICINAL PLANTS **S2:** Jathropa, Aromatic Ginger, Turmeric, Galangal, Cardamom **S3:** Ginger, Vetiver Root, Lemongrass, Vanilla, Candlenut, Cinnamaon, Nutmeg, Pepper, Sesame	**S3:** Agathis, Sengon, Leucaena, Acacia, Eucalyptus, Sandalwood **S2:** Teak, Mahogany, Altingia, Gelam, Pine	**S3:** Elephant Grass, Setaria, Leguminous Plants, Grazing

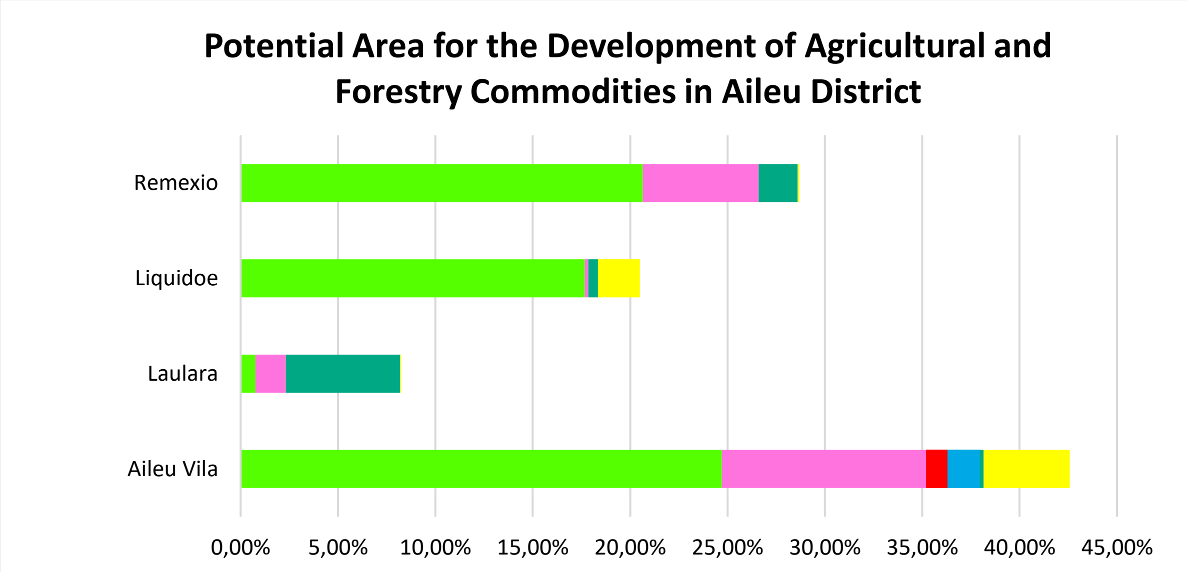
3	Aileu	Liquidoe	**DRYLAND FOOD CROPS** **S2:** Soybean, Groundnut, Sweet Potato **S3:** Rainfed Rice, Corn, Mung Bean, Cowpea, Upland Rice, Sorghum, Cassava, Wheat	**INDUSTRY** **S3:** Rubber, Coconut, Oil Palm, Arabica Coffee, Cocoa, Clove, Tea, Tobacco, Melinjo, Kapok **S2:** Robusta Coffee, Sugarcane, Quinine **FRUITS** **S2:** Banana, Papaya, Orange, Rambutan, Avocado, Mango, Guava, Durian, Watermelon, Melon, Jackfruit, Soursop, Cherimoya, Breadfruit, Snake Fruit, Pineapple, Longan, Strawberry, Grape, Passionfruit **VEGETABLES** **S2:** Shallots, Chili, Bell Pepper, Green Bean, Broccoli, Caisim, Snow pea, Cucumber, Eggplant, Bitter Melon, Vegetable Tomato, Cabbage, Long Bean **S3:** Potato, Carrot, Garlic **FLOWERS** **S2:** Rose, Sunflower, Aster **SPICES & MEDICINAL PLANTS** **S2:** Jathropa, Aromatic Ginger, Turmeric, Galangal, Cardamom **S3:** Ginger, Vetiver Root, Lemongrass, Vanilla, Candlenut, Cinnamaon, Nutmeg, Pepper, Sesame	**S3:** Agathis, Sengon, Leucaena, Acacia, Eucalyptus, Sandalwood **S2:** Teak, Mahogany, Altingia, Gelam, Pine	**S3:** Elephant Grass, Setaria, Leguminous Plants, Grazing

4	Aileu	Remexio	DRYLAND FOOD CROPS **S2:** Soybean, Groundnut, Sweet Potato **S3:** Rainfed Rice, Corn, Mung Bean, Cowpea, Upland Rice, Sorghum, Cassava, Wheat	INDUSTRY **S3:** Rubber, Coconut, Oil Palm, Arabica Coffee, Cocoa, Clove, Tea, Tobacco, Melinjo, Kapok **S2:** Robusta Coffee, Sugarcane, Cinchona FRUITS **S2:** Banana, Papaya, Orange, Rambutan, Avocado, Mango, Guava, Durian, Watermelon, Melon, Jackfruit, Soursop, Cherimoya, Breadfruit, Salak, Pineapple, Longan, Strawberry, Grape, Passionfruit VEGETABLES **S2:** Shallots, Chili, Bell Pepper, Green Beans, Broccoli, Mustard, Peas, Cucumber, Eggplant, Bitter Melon, Vegetable Tomato, Cabbage, Long Beans **S3:** Potato, Carrot, Garlic FLOWERS **S2:** Rose, Sunflower, Aster SPICES & MEDICINAL PLANTS **S2:** Castor, Aromatic ginger, Turmeric, Galangal, Cardamom **S3:** Ginger, Vetiver, Lemongrass, Vanilla, Candlenut, Dryland Cinnamon, Nutmeg, Pepper, Sesame	**S3:** Agathis, Sengon, Leucaena, Acacia, Eucalyptus, Sandalwood **S2:** Teak, Mahogany, Altingia, Gelam, Pine	**S3:** Rumput gajah, Setaria, Leguminosa **S3:** Penggembalaan

7.6 AGRICULTURAL POTENTIAL DEVELOPMENT ZONING

The research results show that Aileu District has significant land resource potential to support the development of the agriculture, forestry, and livestock sectors. To maximize this potential, a comprehensive scientific land suitability evaluation was conducted, which included field observations, laboratory tests on soil samples, and matching plant growth requirements with the region's agroclimatic map. The evaluation results produced a systematic, science-based zoning approach to identify the potential for developing various strategic commodities. This zoning reflects the diverse potential land uses to sustainably support the agriculture, forestry, and livestock sectors, contributing to food security, environmental protection, and the improvement of community welfare.

Aileu District's development potential is divided into several main categories: agroforestry covering 470.36 km² (63.79%), dryland agriculture 134.02 km² (18.18%), protected forests 63.29 km² (8.58%), rainfed rice fields 61.40 km² (8.33%), irrigated rice fields 12.07 km² (1.64%), and grazing areas 8.25 km² (1.12%). With structured and sustainable management efforts, the significant potential of this area can be optimized through synergies between the government, policymakers, and local communities, ensuring the benefits are felt by all parties. The area that can be developed is presented in **Figure 7.1**, and **Figure 7.2** illustrates the spatial distribution of the development percentages by sub-district in Aileu District.



	Aileu Vila	Laulara	Liquidoe	Remexio
Agroforestry	24,70%	0,77%	17,68%	20,65%
Dryland Farming	10,49%	1,56%	0,18%	5,95%
Grazing Area	1,12%	0,00%	0,00%	0,00%
Irrigated Rice Fields	1,64%	0,00%	0,00%	0,00%
Protected Forest	0,21%	5,87%	0,50%	2,01%
Rainfed Rice Fields	4,42%	0,04%	2,15%	0,08%

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

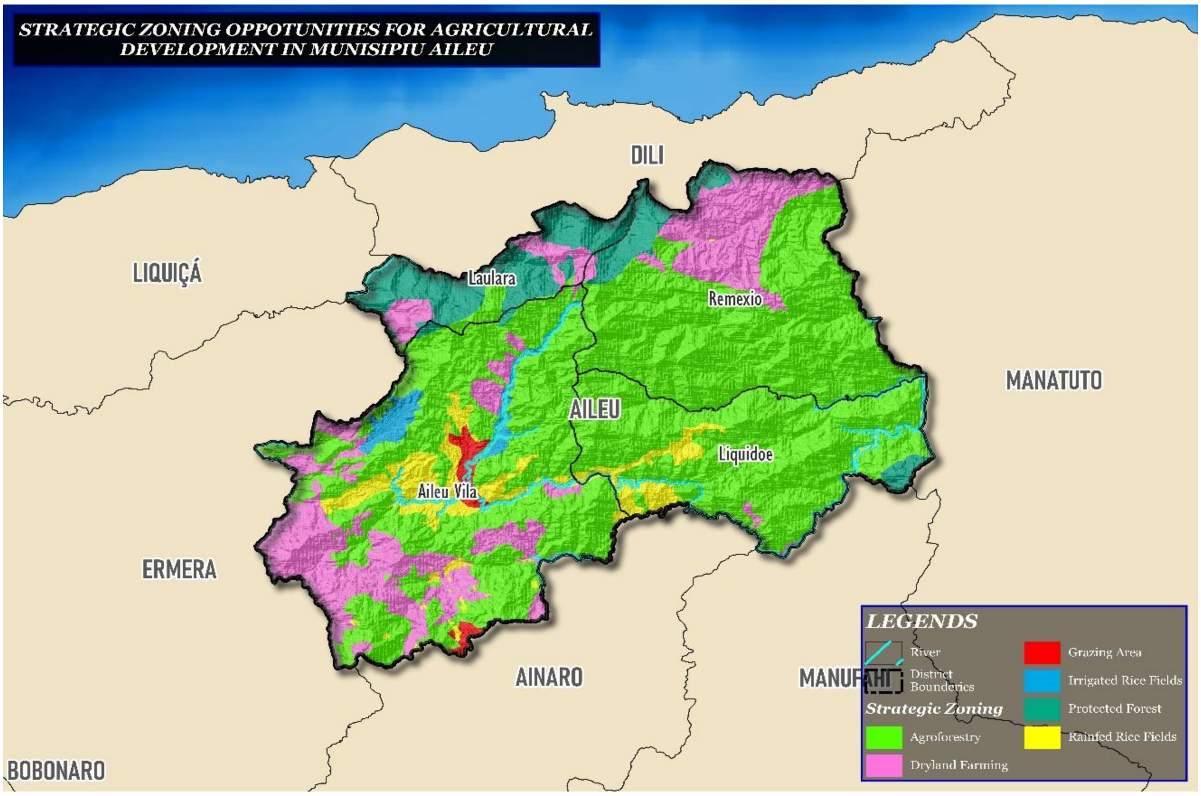


Figure 7.2 Spatial Distribution of Agricultural and Forestry Commodity Development in Aileu District

A. Dryland Agriculture

Dryland agriculture in Aileu District covers an area of 134.02 km², or approximately 18.18% of the total land area, distributed across all sub-districts with the largest proportion in Aileu Vila (10.49%), followed by Remexio (5.95%), Laulara (1.56%), and Liquidoe (0.18%). This area is characterized by land slopes ranging from 0% to over 45% and elevations from 100 to 1500 meters above sea level, with the dominant soil type being Inceptisols—young soils with underdeveloped horizons but sufficiently fertile for conservative agriculture. Therefore, conservation techniques such as terracing, cover crops, and contour planting are highly recommended to maintain land stability and long-term productivity.

Climatically, this region falls within a monomodal rainfall zone, with a single peak rainy season per year. Based on agroclimatic classification, Aileu is categorized in zones B and C, with a dry period lasting five to six months. These conditions require adaptive water management strategies, such as rainwater harvesting and the selection of drought-tolerant crop varieties. The commodities developed in this area are diverse, including food crops such as cassava, sweet potato, and peanut; vegetables such as chili, snow pea, eggplant, and tomato; tropical fruits like banana, orange, rambutan, jackfruit, avocado, papaya, mango, and snakefruit; as well as horticultural flowers and industrial crops like robusta coffee and spices. This crop diversification not only strengthens local food security but also opens up economic opportunities through the development of sustainable agricultural value chains.

B. Rainfed Rice Fields

The rainfed rice zone in Aileu District covers an area of 49.32 km², or approximately 6.69% of the total area. This zone is located on land with slopes ranging from 0% to 25% and elevations between 800 and 1200 meters above sea level, which are considered moderately flat to slightly sloping and suitable for rice cultivation with relatively low erosion risk. The dominant soil types include Entisols, Inceptisols, and Mollisols. This generally supports rice cultivation, especially on lands with good drainage and low erosion risk. However, the main challenge for rainfed agriculture in this area is limited water resources.

This region also falls within a monomodal rainfall zone, with one peak rainy season per year and a dry period lasting five to six months. The rainfall pattern directly affects the planting cycle and productivity of rainfed rice fields, making water management crucial for maintaining yields. The rainfed rice fields are distributed across four sub-districts: Aileu Vila (4.42%), Liquidoe (2.15%), Remexio (0.08%), and Laulara (0.04%). This distribution reflects variations in biophysical suitability, access to water sources, and land utilization intensity.

To address these challenges, recommended management strategies include the construction of reservoirs as an alternative water source, the use of drought-resistant rice varieties, and the application of efficient water management techniques. Additionally, location-specific nutrient management should be implemented to overcome the low availability of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), which often limit rainfed agricultural systems. An integrated approach combining water conservation, balanced fertilization, and the use of adaptive varieties can improve productivity and the long-term sustainability of rainfed rice systems.

C. Irrigated Rice Fields

Aileu District has an irrigated rice area of 12.07 km², or 1.64% of the total land area, which is located only in Aileu Vila Sub-District. This land is situated on slopes ranging from 5% to 25% and at elevations of 800 to 1200 meters above sea level. Edaphically, this area is dominated by Entisols, Inceptisols, and Mollisols. The climate in this region is monomodal, with one peak rainy season per year and a dry period lasting five to six months. This rainfall pattern affects the planting cycle and irrigation needs, making a consistent irrigation system a critical factor in maintaining rice productivity, particularly during sensitive growth stages such as panicle formation and grain filling.

This area faces challenges such as steeper topography, limited surface water sources, and a lack of permanent irrigation infrastructure. However, there is potential for intensifying rice production through the optimization of the existing irrigation network, the creation of terraces, and the application of balanced fertilization. Adaptive strategies include strengthening integrated farming systems, water conservation, and the use of water-efficient irrigation technologies such as drip or simple gravity systems. These approaches will not only support the sustainability of rice production but also improve local food security amid biophysical and climatic limitations.

D. Grazing Areas

The grazing area in Aileu District covers 8.25 km², or 1.12% of the total land area, located on flat to slightly sloping land with a gradient of 0% to 5% and elevations ranging from 100 to 900 meters above sea level. Although morphologically suitable for grazing activities, uncontrolled livestock trampling may lead to soil compaction, increased surface runoff, and accelerated erosion, particularly in fragile geological substrates. Land management is directed toward rotational grazing systems adjusted to the vegetation's carrying capacity and the land's soil capacity.

To ensure sustainable feed availability, this zone includes a forage bank consisting of elephant grass (*Pennisetum purpureum*), planted along the contours to serve as a biomass source and slope stabilizer. The silvopastoral system is enhanced by planting leguminous trees such as *Gliricidia sepium* and *Leucaena leucocephala*, which contribute to the supply of fodder, improve soil structure, and support land conservation efforts.

The integration of livestock and crops in this zone offers dual benefits, including improved food security through the provision of animal protein and the use of manure to support agricultural productivity. This approach also enhances the efficiency of integrated farming systems and supports local nutrient cycles.

VIII. FORESTRY POTENTIAL

8.1 LAND SUITABILITY EVALUATION RESULTS

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

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

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

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

In **Table 8.1,** the results of the land suitability Evaluation group several plant commodities in the same column, indicating that these plants share similar growth requirements and limiting factors. Plants listed in different columns have distinct growth requirements and limiting factors, requiring management approaches tailored to the specific needs of each plant commodity.

A. Land Suitability Evaluation for Aileu Vila Sub-District

Aileu Vila Sub-District has the potential for forestry commodity development with varying land suitability levels, ranging from class S2 (moderately suitable) to S3 (marginally suitable). Gelam trees fall into the moderately suitable (S2) category, making it one of the most recommended species for cultivation. Meanwhile, other species such as sandalwood, teak, mahogany, agathis, Eucalyptus, and pine are considered marginally suitable (S3), meaning they can still be developed with the proper management approach.

This suitability is influenced by several biophysical and climatic limiting factors, including the length of the dry season, less supportive soil texture, steep slope gradients, high erosion rates, and limited soil depth. Additionally, there are permanent constraints that cannot be improved, such as unsuitable temperatures for optimal growth of certain plants and the presence of surface rocks and outcrops that hinder root activity and land preparation. Nevertheless, this area still holds significant potential for forestry development, especially if suitable species are selected and proper land conservation techniques are applied. **Table 8.1** lists alternative species that also have potential for development, and **Table 7.5** provides recommendations for forestry development in Aileu Vila Sub-District as part of a strategy for land use diversification and sustainable optimization.

B. Land Suitability Evaluation for Laulara Sub-District

Laulara Sub-District has the potential for forestry commodity development with varying land suitability levels, ranging from class S2 (moderately suitable) to S3 (marginally suitable). Gelam trees fall into the moderately suitable (S2) category, making it one of the most recommended species for cultivation. Other species such as sandalwood, teak, mahogany, altingia, sengon, Leucaena, Eucalyptus, and pine are considered marginally suitable (S3), meaning they can still be developed with the proper management approach.

This suitability is influenced by several biophysical and climatic limiting factors, including the length of the dry season, less supportive soil texture, steep slope gradients, high erosion rates, and limited soil depth. Additionally, there are permanent constraints that cannot be improved, such as unsuitable temperatures for optimal growth of certain plants and the presence of surface rocks and outcrops that hinder root activity and land preparation. Nevertheless, this area still holds significant potential for forestry development, especially if suitable species are selected and proper land conservation techniques are applied. **Table 8.1** lists alternative species that also have potential for development, and **Table 7.5** provides recommendations for forestry development in Laulara Sub-District as part of a strategy for land use diversification and sustainable optimization.

C. Land Suitability Evaluation for Liquidoe Sub-District

Liquidoe Sub-District has the potential for forestry commodity development with varying land suitability levels, ranging from class S2 (moderately suitable) to S3 (marginally suitable). Gelam trees fall into the moderately suitable (S2) category, making it one of the most recommended species for cultivation. Other species such as sandalwood, teak, mahogany, sengon, Leucaena, Eucalyptus, and pine are considered marginally suitable (S3), meaning they can still be developed with the proper management approach.

This suitability is influenced by several biophysical and climatic limiting factors, including the length of the dry season, less supportive soil texture, steep slope gradients, high erosion rates, and limited soil depth. Additionally, there are permanent constraints that cannot be improved, such as unsuitable temperatures for optimal growth of certain plants and the presence of surface rocks and outcrops that hinder root activity and land preparation. Nevertheless, this area still holds significant potential for forestry development, especially if suitable species are selected and proper land conservation techniques are applied. **Table 8.1** lists alternative species that also have potential for development, and **Table 7.5** provides recommendations for forestry development in Liquidoe Sub-District as part of a strategy for land use diversification and sustainable optimization.

D. Land Suitability Evaluation for Remexio Sub-District

Remexio Sub-District has the potential for forestry commodity development with varying land suitability levels, ranging from class S2 (moderately suitable) to S3 (marginally suitable). Gelam trees fall into the moderately suitable (S2) category, making it one of the most recommended species for cultivation. Other species such as sandalwood, teak, mahogany, agathis, altingia, Leucaena, Eucalyptus, and pine are considered marginally suitable (S3), meaning they can still be developed with the proper management approach.

This suitability is influenced by several biophysical and climatic limiting factors, including the length of the dry season, less supportive soil texture, steep slope gradients, high erosion rates, and limited soil depth. Additionally, there are permanent constraints that cannot be improved, such as unsuitable temperatures for optimal growth of certain plants and the presence of surface rocks and outcrops that hinder root activity and land preparation. Nevertheless, this area still holds significant potential for forestry development, especially if suitable species are selected and proper land conservation techniques are applied. **Table 8.1** lists alternative species that also have potential for development, and **Table 7.5** provides recommendations for forestry development in Remexio Sub-District as part of a strategy for land use diversification and sustainable optimization.

Table 8.1 Land Suitability Evaluation Analysis Matrix in Aileu District

Commodity	Sub-District	Limiting Factors	Potential Suitability / Land Improvement Effort
Teak	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry Month **S3:** Effective Depth, Rock outcrops, Erosion, Slope, Total Nitrogen, Available Phosphorus, Available Pottasium **S2:** Temperature, Surface Rocks	**S3:** Dry Month **S2:** Temperature, Effective Depth, Rock outcrops, Surface Rocks
Mahogany	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry Month **S3:** Erosion, Effective Depth, Slope, Rock outcrops, Total Nitrogen, Available Phosphorus, Available Pottasium **S2:** Temperature, Batuan Pemukaan, Texture	**S3:** Dry Month **S2:** Temperature, Effective Depth, Rock outcrops, Surface Rocks, Texture
Agathis	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry Month **S3:** Erosion, Effective Depth, Slope, Rock outcrops, Total Nitrogen, Available Phosphorus, Available Pottasium **S2:** Surface Rocks, Texture	**S3:** Dry Month **S2:** Effective Depth, Rock outcrops, Surface Rocks, Texture
Altingia	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry Month **S3:** Erosion, Effective Depth, Slope, Rock outcrops, Total Nitrogen, Available Phosphorus, Available Pottasium **S2:** Temperature, Surface Rocks, Texture	**S3:** Dry Month **S2:** Temperature, Effective Depth, Rock outcrops, Surface Rocks, Texture
Sengon	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry Month **S3:** Erosion, Effective Depth, Slope, Rock outcrops, Total Nitrogen, Available Phosphorus, Available Pottasium **S2:** Surface Rocks	**S3:** Dry Month **S2:** Effective Depth, Rock outcrops, Surface Rocks
Leucaena Acacia	• Aileu Vila • Laulara • Liquidoe	**N:** Dry Month **S3:** Erosion, Slope, Rock outcrops, pH, Total	**S3:** Dry Month **S2:** Rock outcrops, Effective Depth, Surface Rocks

	• Remexio	Nitrogen, Available Phosphorus, Available Pottasium **S2:** Effective Depth, Surface Rocks	
Eucalyptus	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry Month **S3:** Erosion, Slope, Rock outcrops, Total Nitrogen, Available Phosphorus, Available Pottasium **S2:** Effective Depth, Surface Rocks, Texture	**S3:** Dry Month **S2:** Rock outcrops, Effective Depth, Surface Rocks, Texture
Gelam	• Aileu Vila • Laulara • Liquidoe • Remexio	**S3:** Rock outcrops, Total Nitrogen, Available Phosphorus, Available Pottasium **S2:** Effective Depth, Surface Rocks, pH	**S2:** Rock outcrops, Effective Depth, Surface Rocks
Pine	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Dry Month **S3:** Erosion, Slope, Rock outcrops, Total Nitrogen, Available Phosphorus, Available Pottasium **S2:** Temperature, Effective Depth, Surface Rocks, Texture	**S3:** Dry Month **S2:** Temperature, Rock outcrops, Effective Depth, Surface Rocks, Texture
Sandalwood	• Aileu Vila • Laulara • Liquidoe • Remexio	**N:** Rock outcrops **S3:** Erosion, Surface Rocks, pH, Total Nitrogen, Available Phosphorus, Available Pottasium **S2:** Coarse Fragments, Slope, C-Organik	**S3:** Rock outcrops **S2:** Surface Rocks, Coarse Fragments

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

8.2 LAND IMPROVEMENT EFFORTS

The productivity and sustainability of agriculture in Aileu District highly depend on addressing land limiting factors in an appropriate and integrated manner. The primary physical constraints include limited soil depth, high erosion risks, and the presence of surface rocks and rock outcrops that cannot be rehabilitated. Shallow soil depth limits root development and water retention capacity, while erosion accelerates the loss of the nutrient-rich topsoil layer. The spread of surface rocks and rock outcrops causes fragmentation of planting spaces, hinders land preparation, and reduces cultivation efficiency.

In addition to physical constraints, the soil's chemical aspects show significant limitations. The organic carbon content is low, leading to weak soil structure and microbial activity. Key nutrients such as nitrogen, phosphorus, and potassium are also at insufficient levels to support plant vegetative growth. Therefore, improving soil fertility through the addition of organic matter and balanced fertilization is a strategic step to enhance production capacity and support the cultivation of forestry commodities adapted to marginal conditions.

Although most constraints are permanent, land management can still be carried out through adaptive technical approaches based on local biophysical characteristics. Strategies that can be applied include erosion control, clearing of surface rocks, creating planting holes between outcrops, and selecting plant species that are tolerant to high temperatures and shallow soils. This integrated approach allows for the sustainable optimization of land functions, supports vegetation rehabilitation, and strengthens the ecological functions of the area, such as runoff control, increased water infiltration, and biodiversity conservation. Thus, marginal land in Aileu District still holds strategic value for conservation-based forestry development and adaptation.

8.3 FORESTRY CROP DEVELOPMENT ZONING

The zoning for forestry crop development in Aileu District reflects a systematic effort to manage forest resources sustainably. Aileu District has biophysical characteristics that support the development of agroforestry and protected forest zones, with both zones covering 72.37% of the total area. This area is located on slopes with gradients ranging from 5-45% and elevations between 800-1500 meters above sea level, and is predominantly covered by Inceptisols, which have moderate fertility and are suitable for conservative farming systems. The climate in this region is monomodal, characterized by a single peak rainy season each year, which directly impacts planting patterns and production cycles. According to agroclimatic classification, Aileu falls within zones B and C, with a dry season lasting five to six months, requiring adaptive strategies for water management and plant selection.

A. Agroforestry

The agroforestry system in Aileu District has been widely implemented, covering 470,357 ha or 63.79% of the total area. The highest distribution is found in Aileu Vila Sub-District (24.70%), followed by Remexio (20.65%), Liquidoe (17.68%), and Laulara (0.77%) **(Figure 7.1 in Chapter VII).** This distribution reflects differences in biophysical conditions, accessibility, and land use intensity. This system serves as an integrated approach that combines production, conservation, and socio-economic empowerment.

One of the leading commodities developed in the agroforestry system in this region is coffee, which is generally cultivated using a multistrata approach. In this system, coffee is planted under the canopy of hardwood trees that provide natural shade. This planting pattern provides significant ecological benefits, including reducing erosion rates through the root system of shade trees, maintaining soil moisture, and increasing organic matter content through leaf litter accumulation. The complex vegetation structure also creates stable habitats and supports biodiversity conservation, including local flora and fauna species that rely on forest cover.

Economically, coffee holds a high market value both domestically and internationally, especially if cultivated sustainably. Environmentally friendly practices enhance the competitiveness of the product through opportunities for premium prices in the global market. Socially, coffee agroforestry development encourages job creation, strengthens farmers' institutions, and enhances community capacity in farm management. Active community involvement in land management also strengthens collective awareness of the importance of forest and natural resource conservation. Thus, the coffee agroforestry system not only functions as a production tool but also as an instrument for conservation and socio-economic empowerment that is relevant and sustainable.

Land suitability evaluation shows that this region is moderately suitable for coffee cultivation, especially for the robusta variety. Biophysical conditions such as elevation, average temperature, soil texture, and water availability fall within the optimal range for robusta coffee growth, though technical management is still needed to enhance sustainable productivity. In contrast, land suitability for arabica coffee is marginal, as the agroclimatic characteristics of the region do not fully meet the ideal requirements for this variety, such as low temperatures and stable high humidity **(Table 7.2 in Chapter VII).**

Thus, coffee development in this region is better focused on the robusta variety, which is more adaptable to local conditions. However, if arabica coffee is to be cultivated, additional technical interventions are required, such as selecting cooler microclimate locations, using tolerant varieties, and implementing proper shading and soil conservation systems. This approach aims to minimize the risk of cultivation failure and optimize land potential sustainably.

Figure 8.1 Application of Agroforestry System and Coffee Development in Aileu District (Source: Researcher's Documentation 2025)

B. Protected Forest

Aileu District has a potential zoning area for protected forest of 63,292 ha, or approximately 8.58% of the total administrative area. The largest area is found in Laulara Sub-District (5.87%), followed by Remexio (2.01%), Liquidoe (0.50%), and Aileu Vila (0.21%) **(Figure 7.1 in Chapter VII).** This zoning serves as a conservation area supporting the protection of river basins (DAS), maintaining landscape stability, and providing natural habitats for local biodiversity. The ecological role of this area is especially important in regions with high environmental pressures and biophysical conditions vulnerable to degradation.

One of the officially designated conservation areas is the Francisco Xavier do Amaral Botanical Garden, covering 27.26 ha. This area serves as a multifunctional protective space supporting ecosystem preservation, conservation of endemic species, and providing space for environmental education and research. With supportive biophysical characteristics, this botanical garden has great potential to be developed as an integrated conservation model combining ecological, scientific, and social aspects. Its presence also strengthens ecosystem resilience and raises community awareness about the importance of environmental conservation.

The topography of Aileu, dominated by steep slopes and high erosion rates, demands strict and sustainable conservation management. Required technical interventions include planting contour strips to reduce surface runoff, using cover vegetation to strengthen soil structure and increase infiltration, and building living fences as natural barriers against water runoff. With proper management, the protected forest areas in Aileu can serve as ecological fortresses supporting adaptation to climate change, landscape restoration, and the development of conservation-based ecotourism. This approach provides ecological, social, and economic benefits simultaneously for local communities.

8.4 POTENTIAL FOR SANDALWOOD DEVELOPMENT

Sandalwood (*Santalum album L.*) is a high-value tree species with ecological, economic, and cultural functions. The essential oil extracted from its wood is widely used in the perfume, cosmetic, and pharmaceutical industries, and it holds symbolic value in the traditions of Asian societies, including Timor-Leste. Additionally, sandalwood is utilized as a raw material for crafts, carvings, and high-value art products, making it a commodity with broad and sustainable market appeal.

The land suitability evaluation results indicate that the potential for sandalwood development in Aileu District falls into the S3 (marginally suitable) category. This means that the land is still suitable for sandalwood cultivation, but there are biophysical constraints that require technical interventions. Recommended efforts include selecting appropriate planting locations, maintaining host trees to support growth, and applying adaptive silvicultural techniques. With proper management based on conservation practices, these constraints do not pose an obstacle to making sandalwood a flagship commodity for the region.

As part of the national strategy, the Government of Timor-Leste has implemented a sandalwood tree inventory program to strengthen sustainable resource management and ensure investment certainty. This program aims to document the quantity, 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, sandalwood development in Aileu holds significant prospects. If managed sustainably, sandalwood can not only become a source of income for local communities but also a symbol of cultural identity and successful conservation of local natural resources.

IX. LIVESTOCK POTENTIAL

9.1 INTRODUCTION

Timor-Leste is a country largely characterized by mountainous regions and highlands. Administratively, Timor-Leste is divided into 14 District: Ainaro, Aileu, Ataúro, Bobonaro, Baucau, Covalima, Dili, Ermera, Lautém, Liquiçá, Manufahi, Manatuto, Região Administrativa Especial Oe-Cusse Ambeno (RAEOA), and Viqueque. The country experiences two seasons: the dry season, from June to November, and the rainy season, from December to May. The predominant hilly topography, along with its proximity to the Australian continent, results in Timor-Leste being affected by the dry east monsoon winds, causing drought in certain areas. Additionally, the low annual rainfall impacts vegetation growth throughout the country.

The hilly topography and low rainfall not only affect vegetation growth and agricultural activities but also limit the availability of forage for the livestock sector. The development of the livestock sector heavily depends on the land's resource potential, proper land use, and its management methods. These factors are crucial in providing animal feed, which generally consists of grasses and legumes.

Forage for livestock can come from both natural sources and cultivated crops, including from grazing lands (Priyanto, 2016). Optimal use of livestock land is determined by both anthropogenic factors and the bio-physical conditions of the land. Therefore, the application of various technological innovations and institutional efforts is needed to ensure the effective and optimal use of land resources (Suryana and Rahman, 2006).

In general, the livestock sector in Timor-Leste faces several challenges. One of the main causes is the traditional and extensive management system, which results in suboptimal production outcomes. A lack of awareness, knowledge, and mastery of technology among farmers is another major obstacle, especially in fulfilling the needs of livestock feed, both in terms of variety and quality. Livestock is generally kept as household savings, which can be sold when needed for emergencies. Additionally, some people still use livestock as draft animals in traditional land cultivation.

The success of livestock farming depends on three key factors: breeding, feed, and management (Aman *et al*., 2019). These three factors form an interconnected system: if one of them is neglected or receives insufficient attention, managing the other factors, no matter how well, will not yield optimal results. Livestock productivity, especially in ruminants, is highly dependent on effective feed management, in terms of both quantity and quality, as well as its sustainable availability (Rokhayati and Evadewi, 2023). According to Winarni and Sukaesih (2015), feed plays a crucial role in supporting livestock development because it directly impacts production, productivity, and animal health. The quality of livestock forage is influenced by the variety of forage, genotype, harvest maturity, season, and management practices applied (Adesogan *et al*., 2015).

One of the initial steps that can be undertaken to develop the livestock sector in Timor-Leste is optimizing land use for the sustainable provision of livestock feed. To maximize land use, there needs to be alignment between the land characteristics and the types of livestock forage to be cultivated. Therefore, land suitability evaluation becomes an essential approach in assessing the potential and carrying capacity of land resources (Harahap *et al*., 2019). This evaluation not only assesses land potential but also determines its suitability for various uses based on the level of management applied (Nugroho *et al*., 2014). Land suitability evaluation requires environmental data and soil quality of a region. This assessment is conducted by identifying various land characteristics, such as topography, climate, soil conditions and quality, and other physical environmental properties (Iswan *et al*., 2019). Through this evaluation process, information about the bio-physical land resources, including climate and soil, is obtained, enabling the determination of land suitability classes and identifying limiting factors that need to be improved (Jawang *et al*., 2018).

9.2 RESEARCH METHODS

The research was conducted using survey methods and descriptive analysis methods in selected research areas (purposive), specifically the KTS (*Karau Timor Susubeen*) center and the recommended livestock land. The types of data collected include both quantitative and qualitative data sourced from primary and secondary data. Primary data consists of interview data covering livestock production and socio-economic aspects, as well as bio-physical land observations and soil characteristics for forage land suitability. The bio-physical and soil properties were further analyzed according to laboratory standards. Secondary data used include the Timor-Leste Agricultural Census 2019 data.

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

A. Research Procedure

1. Observing Livestock Production and Socio-Economic Aspects

Observations were carried out using interview techniques with the following parameters:

1) Livestock types
2) Livestock population
3) Land area
4) Husbandry/pen management system
5) Feed and nutrition management system
6) Water sources
7) Breeding system
8) Livestock health management system
9) Livestock products
10) Marketing
11) Infrastructure
12) Livestock owner characteristics
13) Customs/traditions

2. Forage Land Suitability

The research procedure has been outlined in **Chapter III (Research Methods).**

9.3 GENERAL OVERVIEW

A. Global Existing Conditions

The livestock sector plays an important role in supporting the livelihoods of many households in Aileu District. The distribution of households involved in livestock farming shows significant variation across each sub-district. Aileu Vila has the largest number of households engaged in livestock farming, with 47 households (66.20%). On the other hand, Liquidoe has the fewest households involved in livestock farming, with only 4 households (5.63%).

Nevertheless, their contributions remain significant in meeting local needs and preserving livestock farming traditions that have become an integral part of the community's life. With these differences, each sub-district contributes to the sustainability of the livestock sector in Aileu. The number of agricultural households involved in livestock farming is presented in **Figure 9.1.**

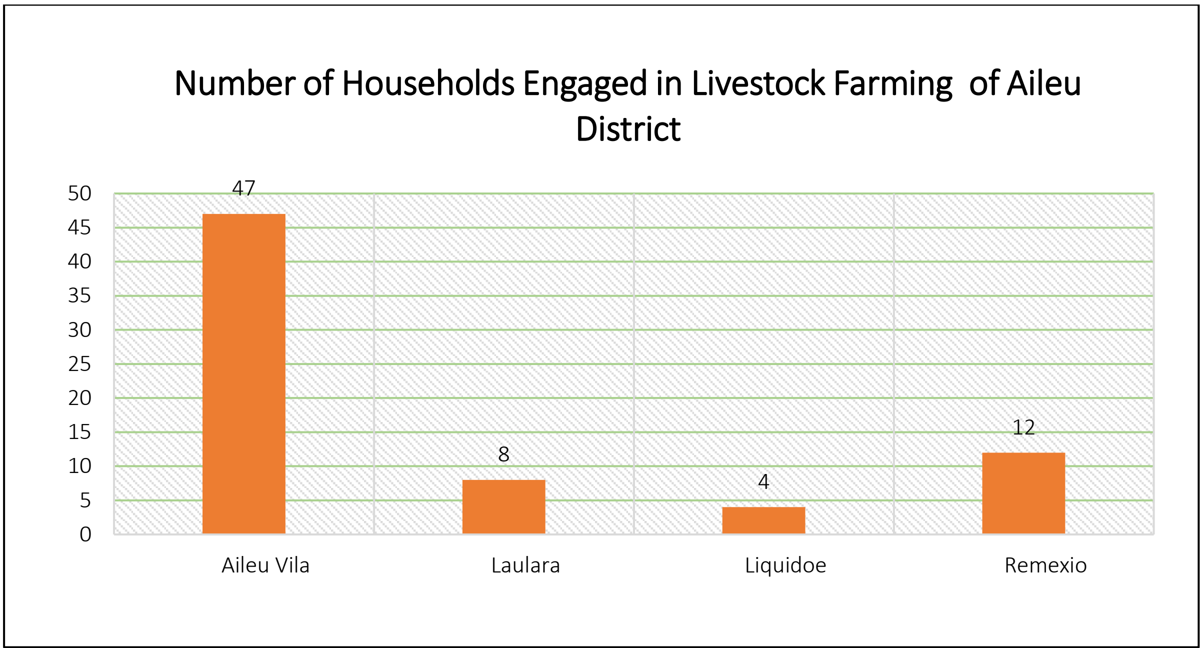


Figure 9.1 Number of Households Engaged in Livestock Farming (Source: Timor-Leste Agriculture Census, 2019)

Figures 9.2 and Figure 9.3 show that cattle farming is the dominant type of livestock farming in Aileu District. Aileu Vila has the highest number of cattle farmers, with 1,613 households (52.13%) and a total cattle population of 4,296.

In contrast, Laulara has the smallest number of cattle farmers, with 329 households (10.63%) and a population of 746 cattle.

The most commonly raised large livestock species, horses, are primarily kept in Aileu Vila, with 680 households (59.08%) and a population of 1,111 horses. Conversely, the lowest number of horse farmers is found in Laulara, with only 19 households (1.65%) and 23 horses.

For buffalo farming, Aileu Vila also dominates with 680 households (59.08%) and 803 buffalo. The smallest number of buffalo farmers is found in Laulara, with 52 households (6.75%) and a total of 80 buffaloes. No households in any of the sub-districts keep dairy cattle.

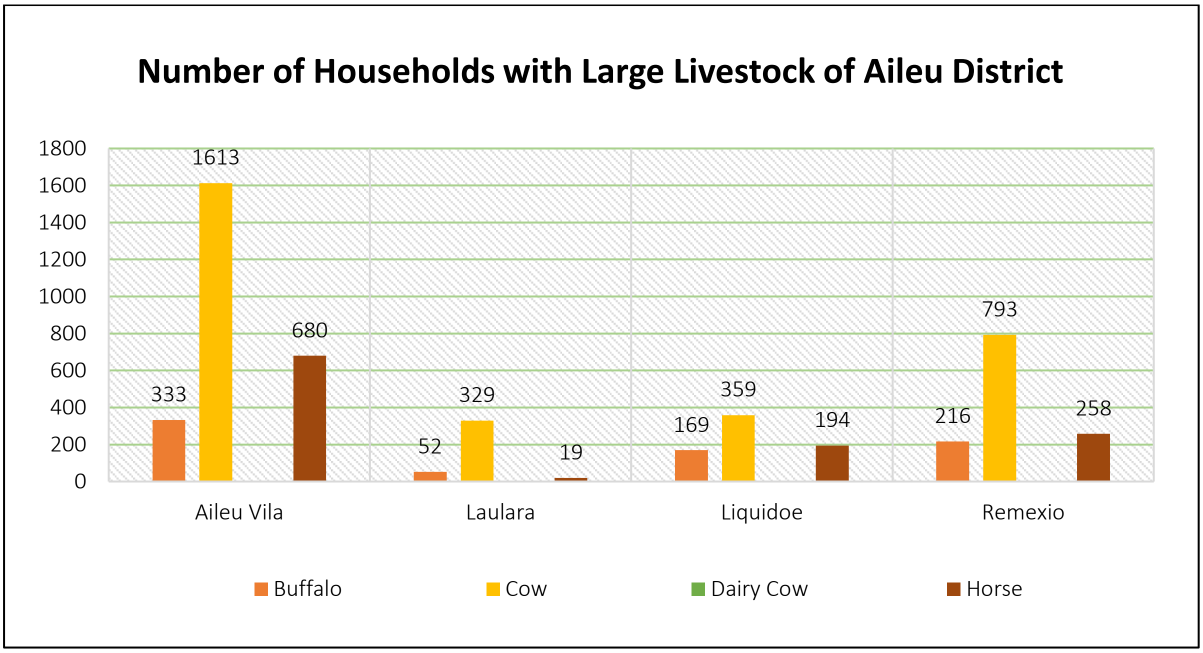


Figure 9.2 Number of Households with Large Livestock
(Source: Timor-Leste Agriculture Census, 2019)

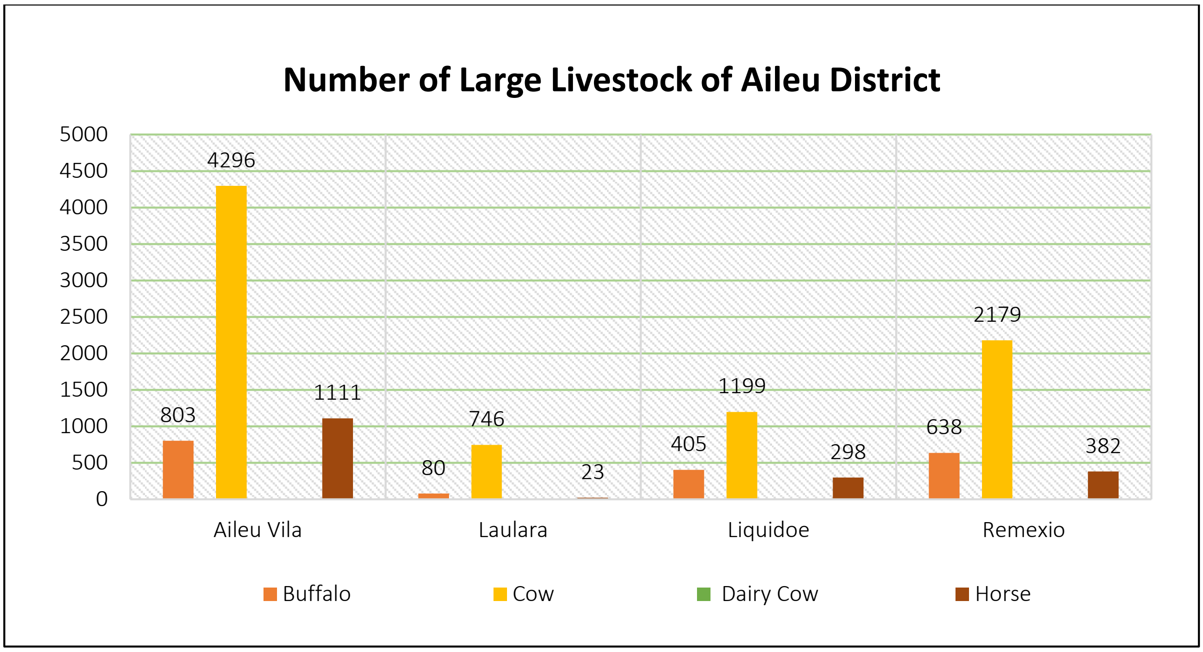


Figure 9.3 Number of Large Livestock
(Source: Timor-Leste Agriculture Census, 2019)

In Aileu District, pigs are the most commonly raised livestock. Aileu Vila has the highest number of pig farmers, with 2,741 households and a population of 6,530 pigs. In contrast, Liquidoe has the fewest pig farmers, with 816 households and 2,136 pigs **(Figure 9.4 and Figure 9.5).**

The number of households keeping goats shows more variation. Remexio has the largest number of goat farmers, with 878 households and a total population of 2,415 goats, while Laulara has the smallest number of goat farmers, with 362 households and a total of 833 goats. In addition to goats, sheep are also raised, although in smaller numbers. Aileu Vila has 96 households raising sheep, while Laulara has the smallest number, with only 5 households.

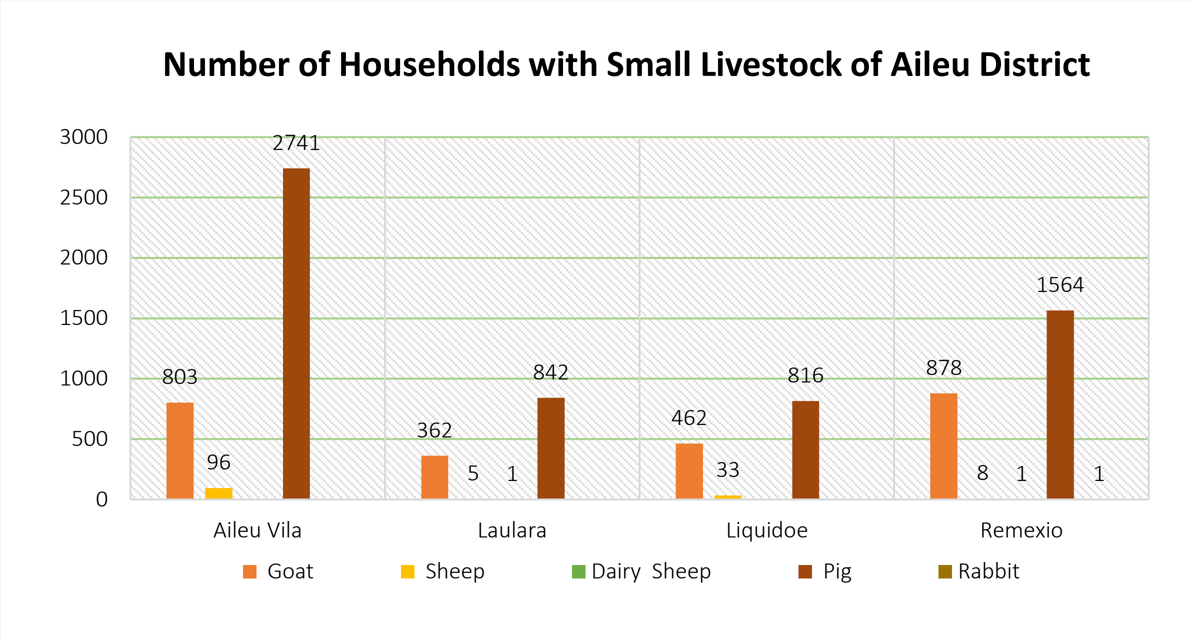


Figure 9.4 Number of Households with Small Livestock
(Source: Timor-Leste Agriculture Census, 2019)

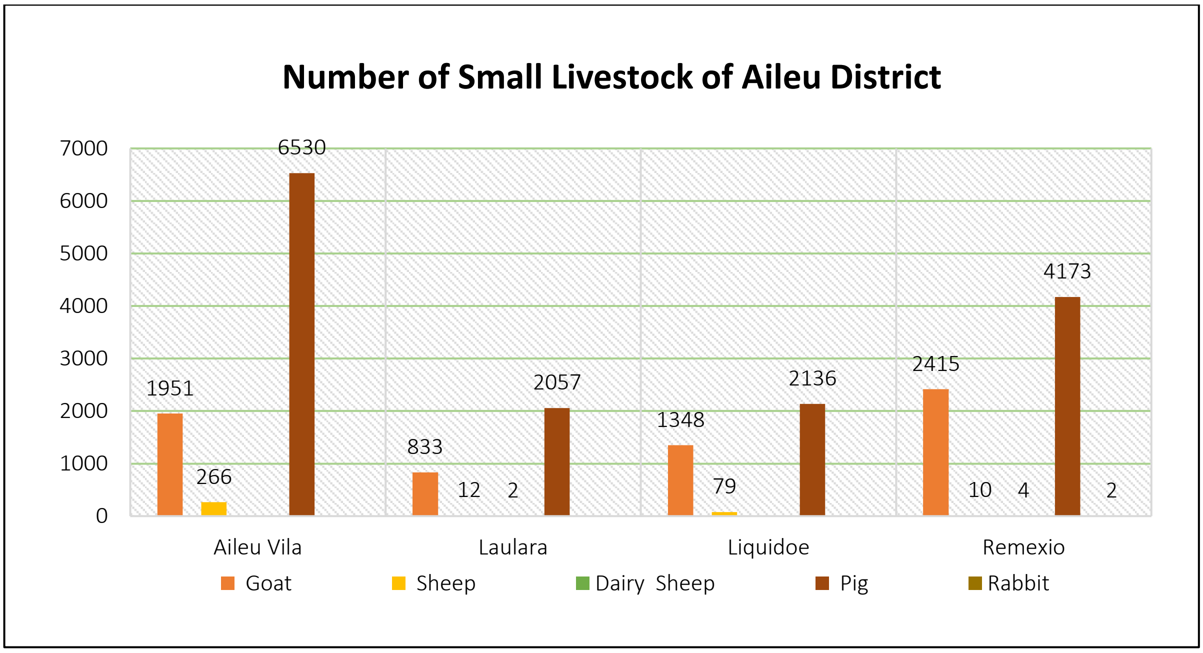


Figure 9.5 Number of Small Livestock
(Source: Timor-Leste Agriculture Census, 2019)

The number of households keeping poultry in Aileu District shows significant differences between sub-districts, with chickens being the most commonly raised poultry (**Figure 9.6**). Aileu Vila has the highest number of poultry farmers, with 19,304 households, or about 44.47%, keeping a total of 14,357 chickens. In contrast, Liquidoe has the fewest poultry farmers, with only 775 households (13.94%) raising 4,408 chickens (**Figure 9.6 and Figure 9.7**).

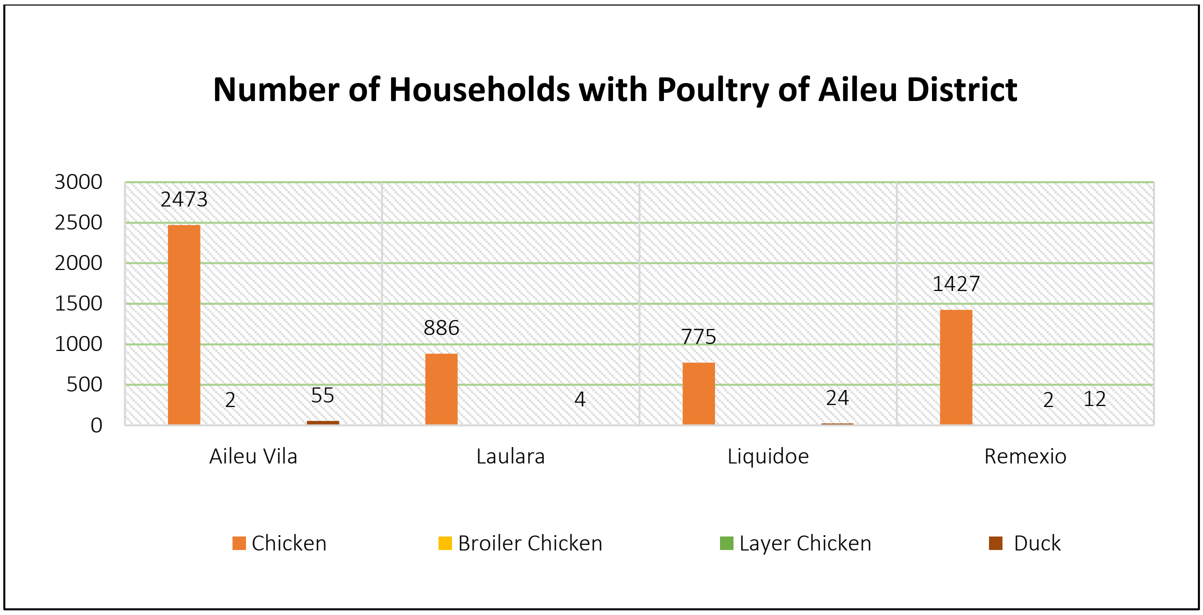


Figure 9.6 Number of Households with Poultry
(Source: Timor-Leste Agriculture Census, 2019)

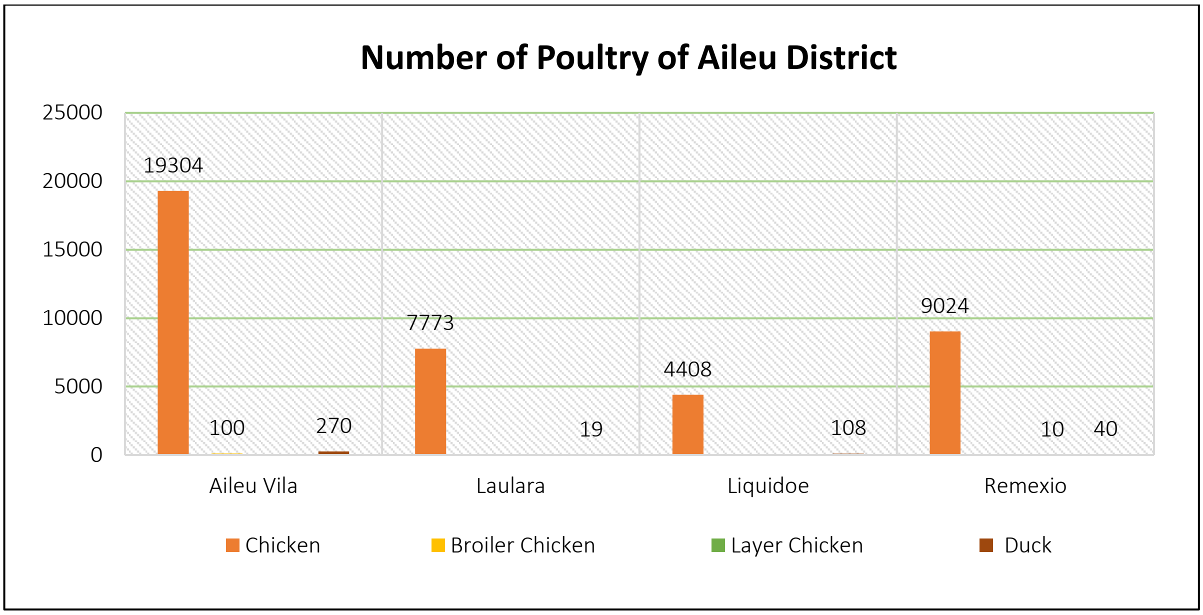


Figure 9.7 Number of Poultry
(Source: Timor-Leste Agriculture Census, 2019)

Grazing land potential is one of the important assets that can serve as a primary feed source, particularly for animals such as cattle, goats, and sheep, which require high-quality grass to support growth and production in a sustainable livestock sector. Aileu District has two types of grazing land: temporary and permanent grazing fields.

The size of grazing land varies across sub-districts in Aileu. Aileu Vila has the largest area of both permanent and temporary grazing fields, with areas of

24.84 ha (62.68%) and 16.63 ha (87.34%), respectively. Based on this data, Aileu Vila has a significant advantage in the area of both permanent and temporary grazing land, making it the sub-district with the largest grazing land area compared to other sub-districts. Remexio has the second-largest area of both permanent and temporary grazing land, with areas of 3.50 ha (35.25%) and 9.35 ha (12.31%), respectively. Laulara has no permanent grazing land and only has 0.40 ha (1.51%) of temporary grazing land, while Liquidoe has the smallest areas of both permanent and temporary grazing land, with sizes of 0.10 ha (0.35%) and 0.15 ha (0.57%), respectively, representing the lowest figures across all sub-districts. The area of grazing land is shown in **Figure 9.8.**

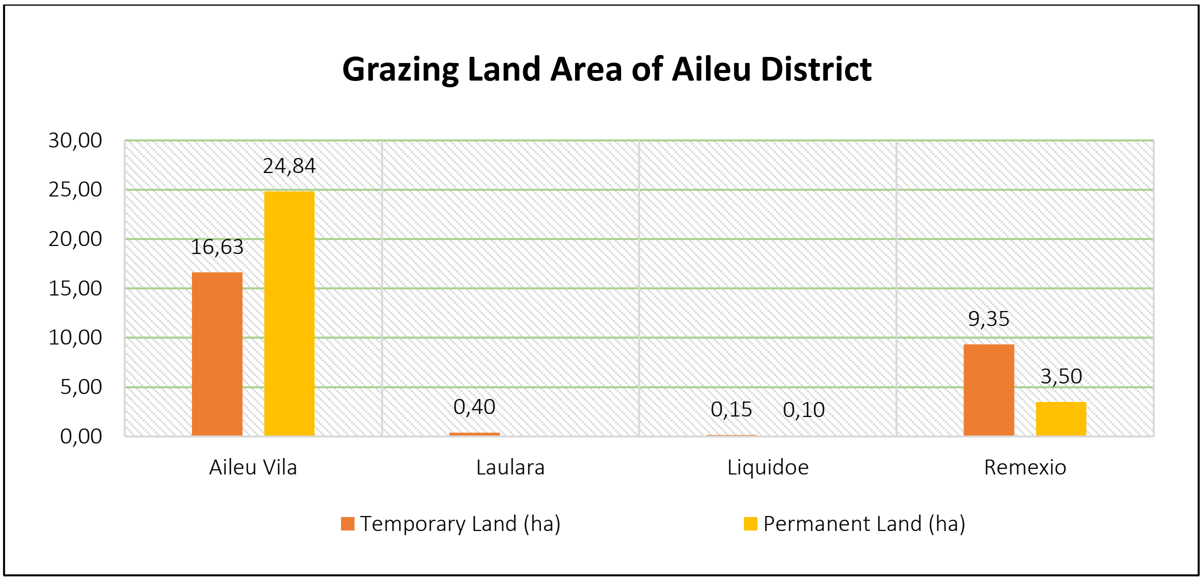


Figure 9.8 Grazing Land Area

(Source: Timor-Leste Agriculture Census, 2019)

B. Existing Conditions of Survey Locations

Observations were conducted at three locations: Fatubosa, Seloi Karaik, and Manucasa, which are planned as areas for the development of ruminant livestock, particularly buffalo and Bali cattle. The success of this development program is highly dependent on the compatibility between the soil characteristics and the types of forage (HPT) that will be cultivated. Therefore, the soil observation results from these three locations will serve as the basis for planning forage planting, including the selection of grass and legume varieties suitable for both soil conservation and as sources of high-quality feed. This data-driven approach is expected to improve the sustainability and productivity of the livestock system in Aileu District as a whole. The existing conditions of the survey locations are shown in **Figure 9.9.**

Figure 9.9 Existing Conditions of Survey Locations in Aileu District
(Source: Researcher's Documentation, 2025)

9.4 DISCUSSIONS

A. Evaluation of Land Suitability for Forage Crops (HPT)

Land suitability analysis for forage crops in Aileu District is a method used to assess the suitability for growing various types of forage crops and grasses in grazing lands of a particular area. The purpose of this analysis is to facilitate the development of livestock feed sources while ensuring their optimal availability. According to Djaenudin *et al*. (2003), land suitability is defined as the degree to which a piece of land is suitable for a particular use. Land suitability can be evaluated based on current conditions (actual land suitability) or after improvements have been made (potential land suitability). The land suitability evaluation in Timor-Leste is conducted using a matching method between the data on land characteristics and quality with the suitability criteria based on plant growth requirements. Some of the forage crops identified for development, according to land resource potential, include elephant grass (Pennisetum purpureum), legumes, and field grasses.

The results of the land suitability evaluation in Aileu District, including Aileu Vila, Laulara, Liquidoe, and Remexio, show that these areas have potential for the development of forage crops such as elephant grass, setaria, legumes, and grazing lands, as presented in **Table 7.3** of this book. The table indicates that, in actual conditions, the grazing land suitability varies from S2 (moderately suitable) to N (not suitable), with limiting factors such as total nitrogen (N-total), available phosphorus (P) and potassium (K), slope, erosion, and surface rocks. Additionally, there are limitations due to dry months affecting grazing areas. These factors can be technically improved through measures such as planting patterns adjustment, adding NPK fertilizer, adding organic matter, planting terrace-strengthening plants, constructing terraces, establishing irrigation systems like sprinklers, and land clearing. However, surface rock outcrops remain a permanent limitation and cannot be improved.

To enhance livestock farming areas, particularly forage crops (HPT), in Aileu District, several crucial steps need to be taken to improve both the quantity and quality of forage crops, including:

1. Planting Legume Forage

The planting of leguminous forage should be a priority, as legumes typically have higher nutritional content than grasses. However, since legumes have limitations in their use, attention must be paid to the proportion of legumes in relation to grasses. As a guideline, Susetyo (1980) recommends that an ideal grazing field composition consists of 60% grass and 40% legume. Additionally, according to Skerman (1977), legumes also play an important role in controlling erosion, even more effectively than forests, due to their strong and deep root systems.

2. Increasing Forage Species Diversity, Both Legumes and Grasses

Increasing the diversity of forage species, both legumes and grasses, is an important aspect of livestock feed development. The greater the diversity of forage species consumed by livestock, especially ruminants, the greater the likelihood of meeting their nutritional needs. Some high-nutrient legume species that show potential for development include Indigofera, Calliandra, Turi, and Stylo. A commonly found local legume species is *Lamtoro taramba*. However, it is important to note that lamtoro should be given carefully to pregnant livestock. Despite its high nutritional content, *lamtoro* leaves contain anti-nutritional substances such as mimosine and cyanide acid, which can be toxic when consumed in excess. This can be mitigated by providing *lamtoro* in moderation, mixing it with other feed, and ensuring that the *lamtoro* is dried or wilted (air-dried) to reduce the levels of anti-nutritional substances.

B. Livestock Potential and Ecological Suitability

Aileu District has a total area of 73,636.41 ha, with 30,409.65 ha designated for livestock sector development. This potential must be utilized optimally through the empowerment of human resources and the effective use of available land. One important factor in determining the potential of an area for livestock development is its ecological suitability or environmental conditions. Areas that do not meet ecological suitability indicators are categorized as less suitable for livestock development. Therefore, the development of livestock in Aileu District must consider ecological suitability factors.

After collecting field measurements for each parameter, such as geophysical parameters like rainfall and temperature, and soil chemical parameters like organic carbon (SOC), total potassium (K-Total), available potassium (Available-K), cation exchange capacity (CEC), base saturation (BS), etc., these data were analyzed using Geographic Information System (GIS) applications to determine the ecological suitability for five types of livestock: sheep, beef cattle, dairy cattle, pigs, and buffalo. The Ecological Physical Suitability Map for Livestock in Aileu District is shown in **Figure 9.10.**

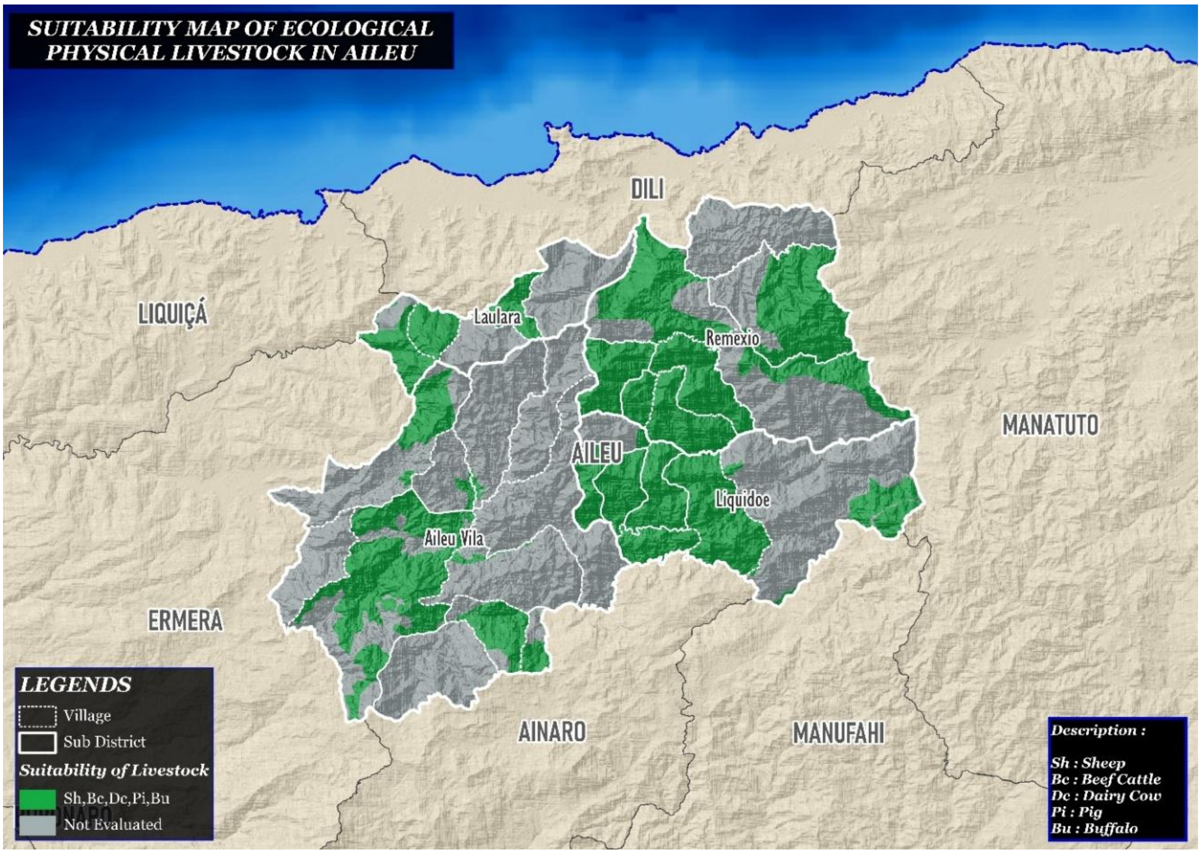


Figure 9.10 Ecological Physical Suitability Map for Livestock in Aileu District

The available land for livestock development in Aileu District includes land designated for mixed plantations and grazing. These areas are categorized as available because they are assumed to be capable of producing forage crops such as grasses, legumes, and agricultural by-products. Land categorized as unavailable for livestock development includes forests and rice fields. Technically, this factor can be addressed by improving the livestock housing system, ensuring good air circulation and ventilation. However, for dairy cattle, temperature is a critical factor that must be met for successful breeding. The area available for livestock development in Aileu District is presented in **Table 9.1.**

Table 9.1 Area for Livestock Development in Aileu District

Sub-District	Results of Livestock Development Suitability					Area (ha)
	Sheep	Beef Cattle	Dairy Cattle	Pig	Buffalo	
Aileu Vila	S	S	S	S	S	7.837,38
Laulara	S	S	S	S	S	2.374,42
Liquidoe	S	S	S	S	S	7.781,40
Remexio	S	S	S	S	S	12.414,01

Based on the data analysis presented in Table 9.1, the ecological suitability of land for the development of large livestock, including sheep, beef cattle, dairy cattle, pigs, and buffalo, shows spatial variation across the study area. Remexio is the dominant area for large livestock development, while Laulara shows the lowest suitability.

The ecological suitability of land for poultry farming in the study area shows a very high and uniform suitability, covering 100% of the land area. This reflects the biological characteristics of poultry, which have a wide adaptation range to different environmental conditions, enabling poultry farming in almost all available land types.

To support the livestock sector development program, it is necessary to identify and map areas that function primarily as livestock farming sites and forage production areas. Aileu District has an average environmental temperature of 21.36°C and receives 1,935.36 mm of rainfall annually, providing favorable ecological conditions for the optimal sustainability of livestock farming. These conditions also support the continuous availability of livestock forage throughout the year.

Environmental temperature plays a central role in determining the thermal comfort and productivity of livestock. Extremely low temperatures can cause cold stress in livestock, leading to increased body heat production and basal metabolic rate. If this condition persists without adequate feed support, the livestock's metabolic energy will decrease, reducing its ability to withstand extreme temperatures. This results in stunted growth, decreased productivity, and significantly increased susceptibility to diseases.

Conversely, excessively high temperatures lead to reduced feed consumption as livestock opt for increased water intake. This decrease in nutrient intake directly impacts livestock performance. Therefore, optimal environmental management, particularly regulating temperature and humidity, is essential for sustainable livestock farming. Such efforts aim to create conditions that support the physiological balance of livestock, maximizing productivity.

C. Socio-Economic Aspects of Livestock Farming

For the people of Aileu District, livestock plays a crucial and multifunctional role, far beyond just being a source of food. Livestock is an integral part of the subsistence farming system and the evolving civilization. It is still common to see people using livestock such as cattle, buffalo, and horses as draft animals for plowing fields. The use of draft animals allows farmers to cultivate larger areas of land and significantly increase agricultural productivity. Furthermore, in some cultures, livestock even holds social, economic, or ritual significance. For instance, in some traditions, livestock is used as a dowry or offering during ceremonies. Moreover, the number of livestock owned by an individual often serves as a measure of wealth and social status within the community.

One of the endemic livestock species in Timor-Leste is the Timor buffalo (*Karaw Timor*). The Timor buffalo holds a significant role in the social life of the people of Timor-Leste, especially as a sacrifice during funeral, birth, and wedding ceremonies. Timor buffalo are also involved in traditional transactions such as land sales, their manure is used as fertilizer, and historically, their milk was consumed as a source of animal protein. This is why Timor buffalo are considered valuable and are often priced highly.

Timor buffalo milk has been consumed by the people since ancient times and is one of the more popular types of milk, alongside cow and goat milk. Timor buffalo milk is thicker and has a distinctive smell compared to cow's milk. Historically, people consumed the milk directly without further processing. Thus, Timor buffalo milk has become an emblem of cultural identity.

Livestock farming, in general, is still practiced using a traditional free-range grazing system, commonly known as an extensive system. According to Williamson and Payne (1993), in the extensive management system, livestock are kept freely and graze on available forage in the environment. In this system, animals are allowed to roam in herds, typically consisting of one male and several females. The key characteristics of extensive farming are the lack of enclosures and the absence of supplementary feeding (Jamili, M.A., 2022). The extensive system has advantages, including fewer labor requirements, short working hours, and the ability of livestock to forage in grazing fields and abandoned farmland. However, livestock in this system face challenges such as difficulty controlling their nutritional intake, and the risk of disease and death is higher. Additionally, free-roaming livestock can lead to social issues such as livestock theft and damage to farmers' crops.

The livestock farming model still relies on local knowledge passed down through generations. The absence of large-scale livestock industries has resulted in production levels not reaching their maximum potential, with many aspects still needing improvement. Livestock distribution in the community is relatively low due to limited capital and the low practice of breeding. This is because increasing the livestock population requires substantial investment and time. As a result, livestock is not viewed as a primary source of income, contributing to the low livestock production in the area (Serey *et al*., 2014).

From the interviews, it was found that households received livestock assistance, including cattle and buffalo, in 2014 from MAPPF. However, over time, due to low oversight and lack of community education, the assistance did not develop as initially intended. The livestock received was used to meet household needs or as dowry. Consequently, attention to the sustainability of livestock breeding has been neglected, which may hinder sustainable development.

Another challenge in the livestock sector is the complex issues faced from production to post-production, as well as the lack of infrastructure that needs to be developed. In terms of breeding, the community still practices natural mating without the use of artificial insemination (AI) technology, making sustainable breeding difficult. Furthermore, the community lacks knowledge of proper livestock management. They have not been educated on good feeding practices to improve livestock productivity. In terms of marketing, farmers can only sell live livestock, making it difficult to increase the selling price of livestock products. While access to Dili, the capital, has improved, infrastructure such as roads remains inadequate, limiting farmers' ability to market their livestock products to a wider market.

Given the many challenges faced from pre-production to post-production, attention is needed to identify key issues and use them as a foundation for designing a master plan for livestock development. Recommendations for improvements include educating the community about breeding practices and introducing AI technology. Additionally, educating the community about the importance of livestock management is essential. This education should aim to motivate the community to focus more on the economic potential of livestock farming rather than just using livestock as household savings. The government should not only educate but also provide financial support through credit schemes to assist farmers in their livestock enterprises. Increasing the marketability of livestock products can be achieved by educating farmers and opening new marketing channels, not just limited to the sale of live animals.

X. FRESHWATER FISHERIES POTENTIAL

10.1 INTRODUCTION

Timor-Leste, as an archipelagic country, possesses very large natural resource potential, particularly in the marine and fisheries sectors. Aileu District, as one of the administrative regions, offers diverse topographic conditions, soils, water quality, and climate that are highly suitable for fisheries cultivation activities. This study focuses on freshwater aquaculture, specifically on aquaculture practices carried out by local communities in lowland and coastal areas. Aquaculture not only contributes to local food security but also creates opportunities for sustainable economic development for surrounding communities.

Nevertheless, the development of aquaculture enterprises requires a thorough assessment of land suitability. Appropriate site selection is a critical determinant of success, as each fish species exhibits different tolerances to environmental factors such as topography and hydrology, soil conditions, water quality, and climate. Therefore, land suitability analysis constitutes an essential initial stage in aquaculture planning.

This study aims to evaluate land suitability in Aileu District based on a set of biophysical parameters identified in an assessment matrix. The matrix comprises four main factor groups, namely topography and hydrology, soil conditions, water quality, and climate. Each factor is assigned a specific weight that reflects its relative importance in determining land suitability for freshwater aquaculture.

The use of the assessment matrix is central to determining whether land in Aileu District can support sustainable and efficient aquaculture production systems. This evaluation emphasizes not only technical analysis but also integrates aspects of local policy, community participation, and customary practices in water resource management, thereby enabling the study results to be applied optimally in Aileu District.

10.2 RESEARCH METHODS

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

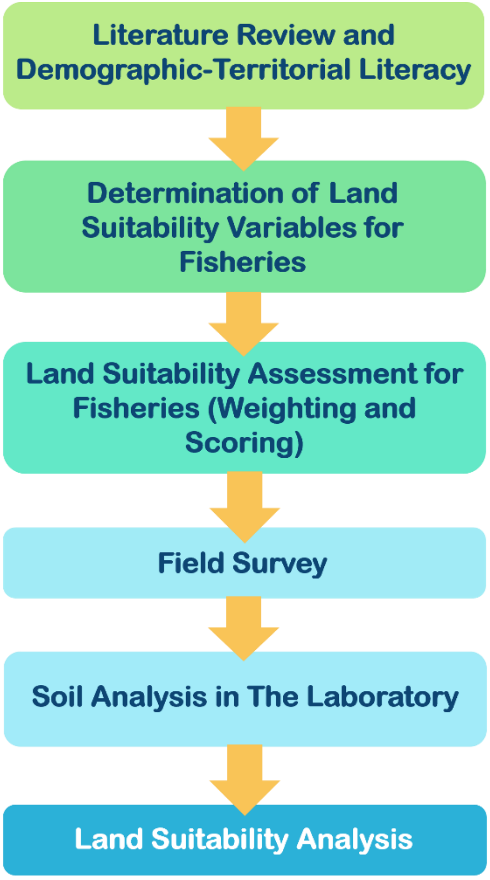


Figure 10.1 Flowchart Of The Research Process for Land Suitability in the Aquaculture Sector

A. Literature Review and Regional–Demographic Information

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

Collection of regional information included a review of the geographic conditions of the study area, comprising: (a) the base map (RBI) of Timor-Leste administrative boundaries, (b) the hydrology map, (c) the most recent Population

Census report (2022), and (d) the most recent Agricultural Census report (2019) for Timor-Leste.

B. Determination of Aquaculture Land Suitability Variables

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

Table 10.1 Considerations for factors assumed in determining variables for aquaculture land suitability

Factors / Variables	The applicable assumptions (employed in this study)
Topography	The fisheries sector requires specific elevation conditions to operate and to determine the design of aquaculture ponds.
Soil Conditions	The simplest medium for aquaculture operations is the earthen pond, in which the soil is in direct contact with the water and strongly influences water quality.
Water Quality	Water is the medium in which fish live, and fish carry out all metabolic and non-metabolic activities in the pond water.
Climate	Water availability derives not only from springs but also from the hydrological cycle, which depends on the rainy season.

C. Design of the Aquaculture Land Suitability Matrix and Parameters

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

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

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

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

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

			Remote Sensing/ Climatology	

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 (NH3) or as ammonium ions NH4 , with NH3 more toxic than NH4 (Poernomo, 1988). NH3 can penetrate cell membranes faster than NH4. NH3 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 NH3 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 Aileu District

No.	Schedule	Sub-District	Village	Purpose (Ownership)
1	16 May 2025	Aileu Vila	Seloi Craic	Business (Individual)
2	16 May 2025	Aileu Vila	Lahae	Business (Individual)
3	16 May 2025	Aileu Vila	-	Business (Individual)

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

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

F. Soil Analysis in the Laboratory

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

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

Soil Parameter	Purpose & Significance	Relationship with Water Quality	Impact on Aquatic Commodity Habitat
Clay Content	Clay fraction plays a key role in soil physical properties such as water retention, permeability, and nutrient retention. High clay content enhances the soil's ability to store nutrients but can hinder aeration.	Affects water infiltration and retention as well as sediment transport.	High clay → ideal habitat for mollusks, but poor for demersal fish that need coarse substrates.
pH_F-pH_{FOX}	The difference between pH_F and pH_{FOX} indicates latent acidity potential. A significantly lower pH_{FOX} indicates potential acid sulfate soils, which is important for wetland restoration or land use planning.	Indicator of latent soil acidity → affects water column pH.	Low pH → physiological stress on fish and shrimp; affects metal bioavailability.

Organic Carbon	Organic carbon is a primary indicator of soil fertility and quality. High organic carbon content suggests healthy soil conditions and has potential as a carbon sink (blue carbon), especially relevant in mangrove and wetland ecosystems.	Source of organic nutrients in remineralization processes → influences DO and primary productivity.	Determines soil fertility for aquaculture and the growth substrate for macroalgae and seagrasses.

G. Aquaculture Land Suitability Analysis

The observations in the field and the results from laboratory analyses are then tabulated into data on aquaculture land characteristics. The land suitability for aquaculture is analyzed by matching the land characteristic data with the habitat requirements for fish and other aquaculture commodities. This results in land suitability classes based on the criteria of Mustafa *et al*. (2012). The land suitability classification is analyzed down to the unit land level. Potential land suitability is determined by considering the inputs and management actions applied to each aquaculture unit, assuming that efforts are undertaken. As an example, the land suitability criteria for tilapia farming are presented in **Table 10.7**, which is the most dominant fish commodity in almost every aquaculture pond in Timor-Leste, and the land suitability criteria for carp farming are presented in **Table 10.8**.

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

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

Source: Mustafa (2012)

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

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

Source : Mustafa (2012)

10.3 EXISTING CONDITIONS AND OBSERVATION RESULTS

A. Capture Fisheries

1. Number of Fishing Households

The number of recorded fishing households in Aileu District is very limited, with only 7 households distributed across three of the four Sub-Districts. Aileu Vila Sub-District has the highest number, with 4 households, or about 57.14% of the total fishing households in the area. It is followed by Lequidoe Sub-District with 2 households (28.57%) and Remexio Sub-District with 1 household (14.29%). Meanwhile, no fishing households were recorded in Laulara Sub-District.

This very small number reflects that fishing activities in natural water bodies, such as rivers or lakes, are not the primary livelihood for the people of

Aileu District. This is likely influenced by Aileu's geographical location in the mountainous region, far from the coastal areas, and the limited natural aquatic resources available for sustainable fishing activities.

This data emphasizes that the focus for developing the fisheries sector in Aileu District should be on freshwater aquaculture, particularly by optimizing pond systems, rice-fish farming, and utilizing underdeveloped potential lands. Although the number of fishing households is very small, there is still significant potential for the development of the fisheries sector if managed with an integrated approach based on the characteristics of the area. Graphs showing the number of fishing households are presented in **Figures 10.2** and **10.3**.

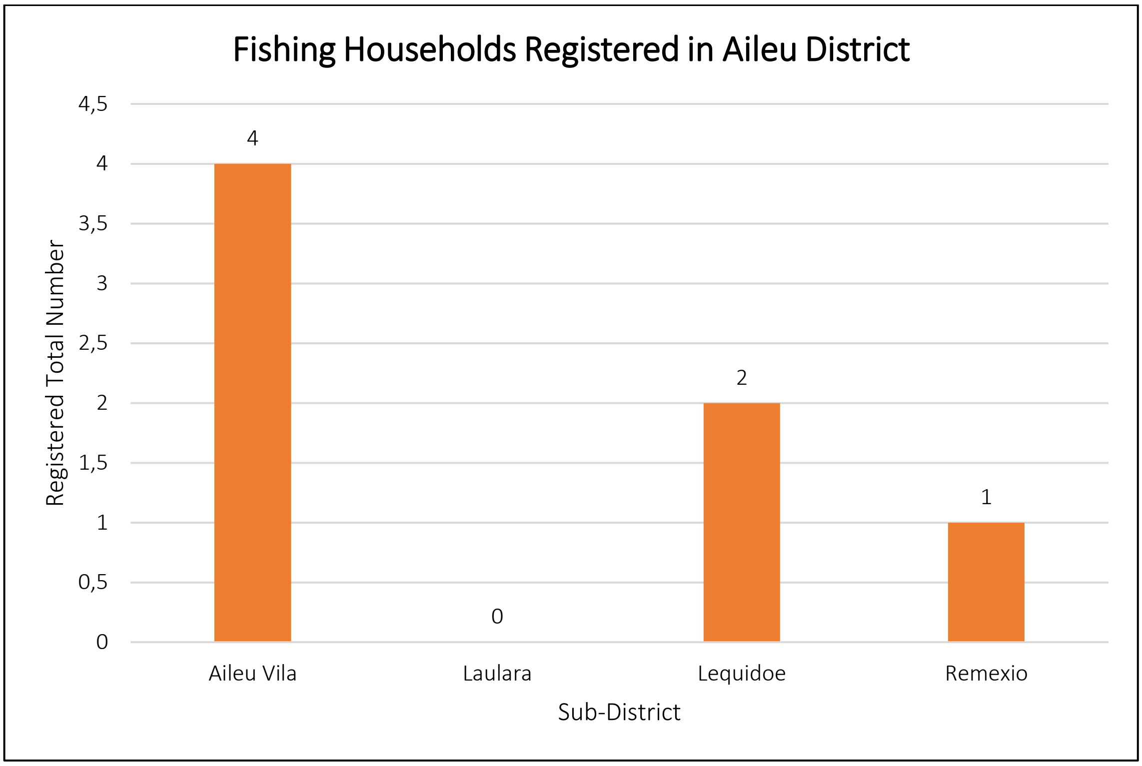


Figure 10.2 Fishing Households in Aileu District
(Source: Timor-Leste Agriculture Census, 2019)

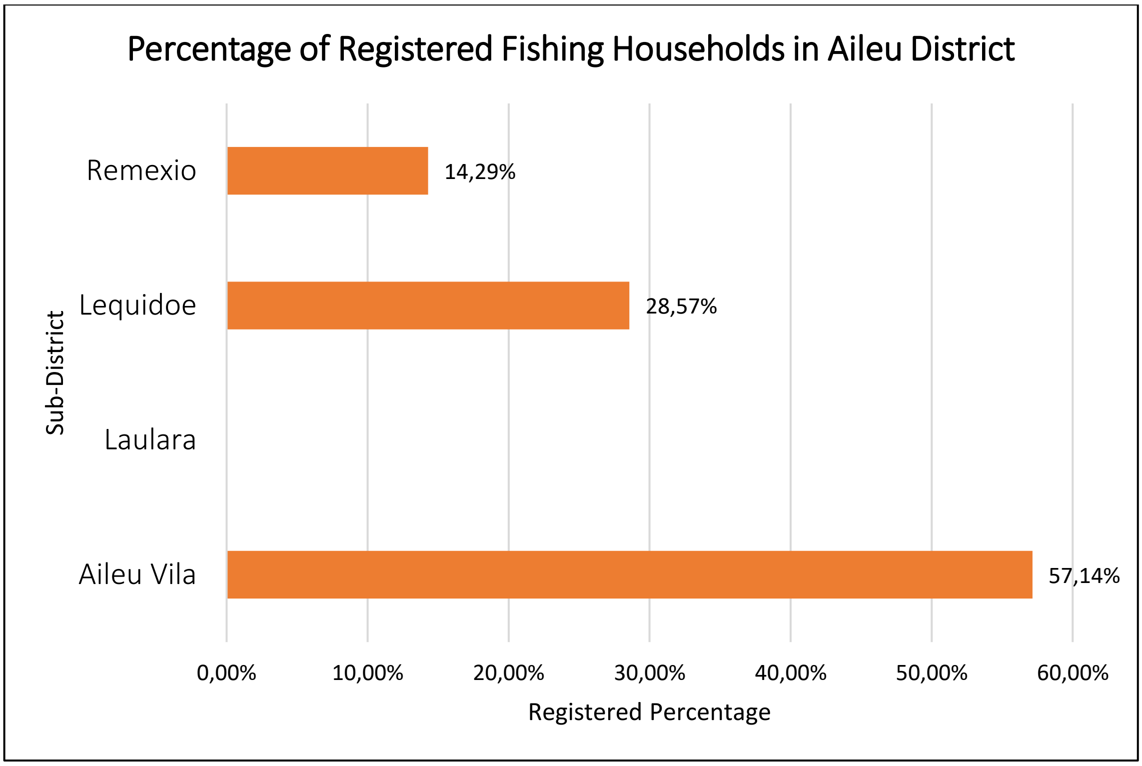


Figure 10.3 Percentage of Fishing Households in Aileu District
(Source: Timor-Leste Agriculture Census, 2019)

2. Households Involved in Fishing Activities

The number of households engaged in fishing activities in Aileu District is very limited, with only 8 households, divided into three categories based on their usage purposes: consumption and social obligations, occasional consumption and sales, and direct sales.

The majority of households (5 households or 62.5%) fish for household consumption and social obligations. This activity is most commonly found in Aileu Vila Sub-District (3 households or 60% of this category) and Laulara Sub-District (2 households or 40%). This indicates that fishing activities in this area are still subsistence-based and carried out on a small scale to meet daily needs and social or cultural requirements.

Next, there are 2 households (25%) that fish for both consumption and occasional sales, all located in Lequidoe Sub-District. This shows some economic potential in fishing activities, although it is still incidental and not a primary livelihood. Only 1 household (12.5%) fishes to sell directly to the market, recorded in Remexio Sub-District. Although this number is very small, it indicates a small but real opportunity to develop a marketing channel for fisheries products in the area. Graphs showing the number of households involved in fishing activities are presented in **Figures 10.4** and **10.5**.

In general, this data shows that fishing activities in Aileu District are still in the very early and limited stages, with a strong dominance of subsistence use and social activities. The low number of households selling their catch also suggests that these activities are not yet integrated into the local economy. Therefore, the development of the fisheries sector in Aileu District would be more promising if focused on structured, productive, and market-oriented freshwater aquaculture.

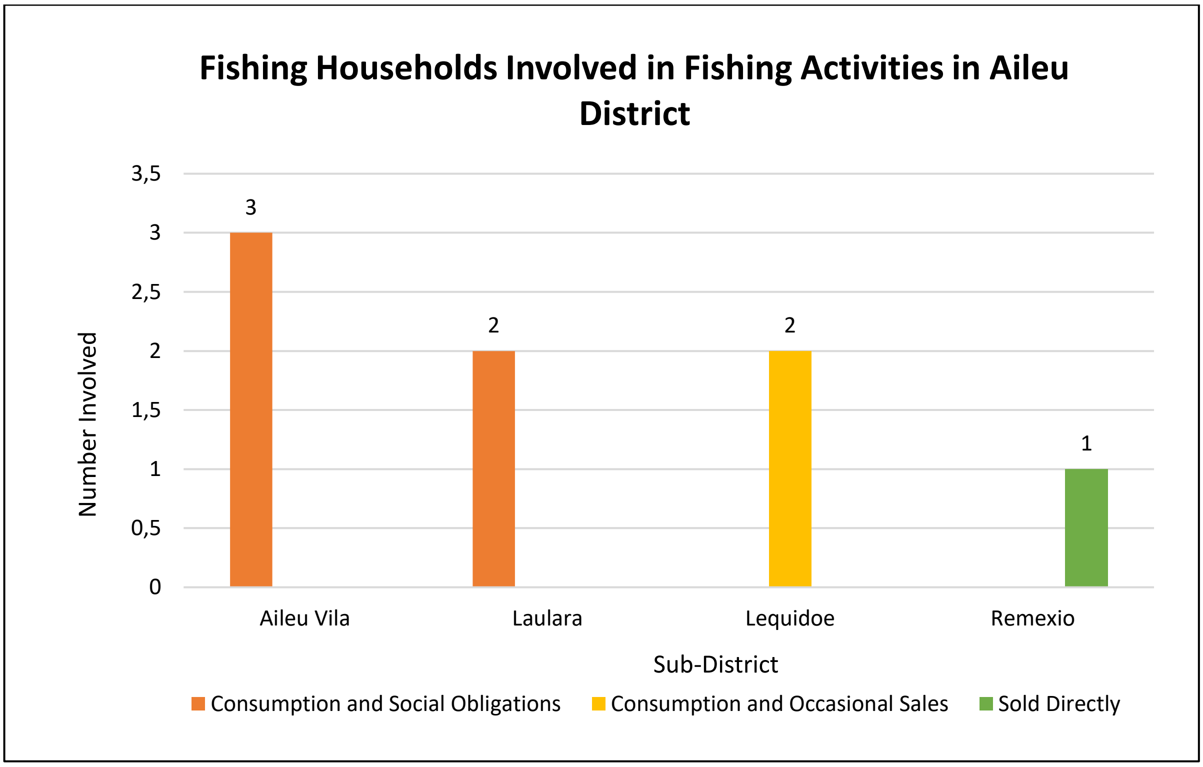


Figure 10.4 Number of Households Involved in Fishing Activities
(Source: Timor-Leste Agriculture Census, 2019)

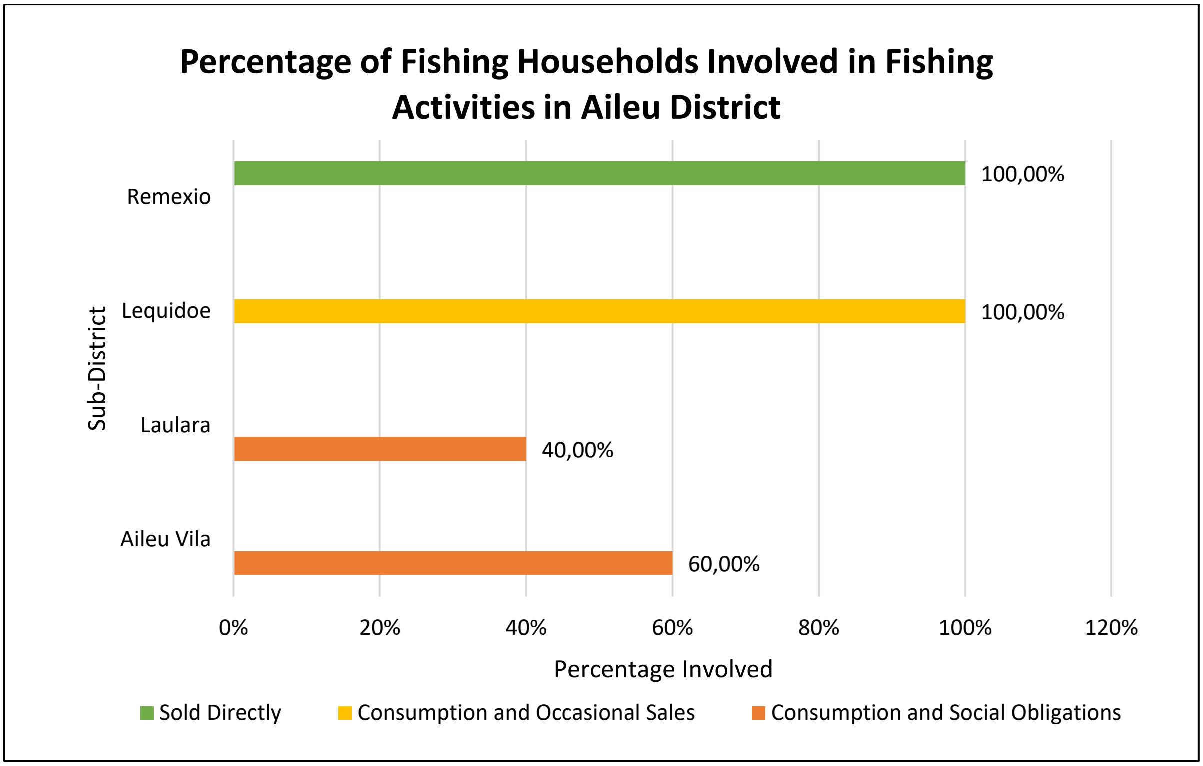


Figure 10.5 Number of Households Involved in Fishing Activities
(Source: Timor-Leste Agriculture Census, 2019)

B. Aquaculture

1. Proportion of Land for Aquaculture

The total area used for aquaculture activities in Aileu District is 31.18 ha, with a very uneven distribution across the Sub-Districts. Aileu Vila Sub-District dominates absolutely, with a total of 28.77 ha, or about 92.27% of the total aquaculture land in the district. This dominance reflects Aileu Vila's position as the center of aquaculture activities, supported by better infrastructure, water access, and more favorable topographic conditions compared to the other Sub-Districts.

In contrast, other Sub-Districts such as Laulara, Lequidoe, and Remexio contribute very small portions of the total aquaculture land area. Laulara has 0.29 ha (0.93%), Lequidoe has 1.47 ha (4.71%), and Remexio has 0.65 ha (2.08%). This indicates that the potential for aquaculture development in these three Sub-Districts is still very limited, both in terms of land use and intensity.

This uneven distribution of land is an important consideration for the future development of aquaculture in Aileu District. While Aileu Vila plays a dominant role, identifying land potential and strengthening technical support in the other Sub-Districts is needed to encourage sustainable and equitable expansion of aquaculture areas. This approach will open up new economic opportunities and improve local food security in the inland areas of Timor-Leste. The proportions of land for aquaculture are presented in **Figures 10.6** and **10.7**.

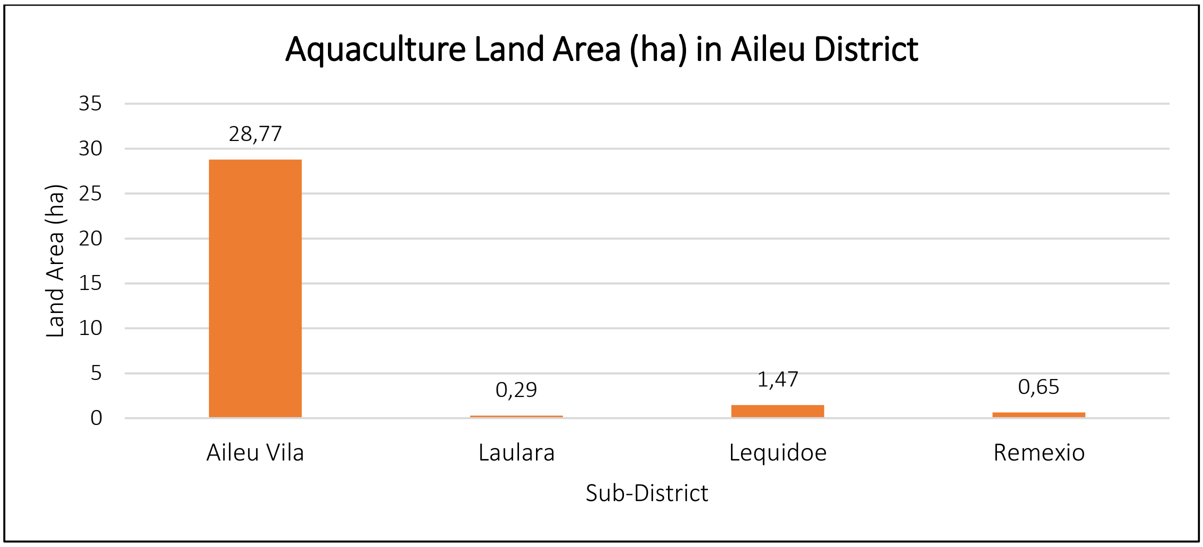


Figure 10.6 Aquaculture Land Area in Aileu District
(Source: Timor-Leste Agriculture Census, 2019)

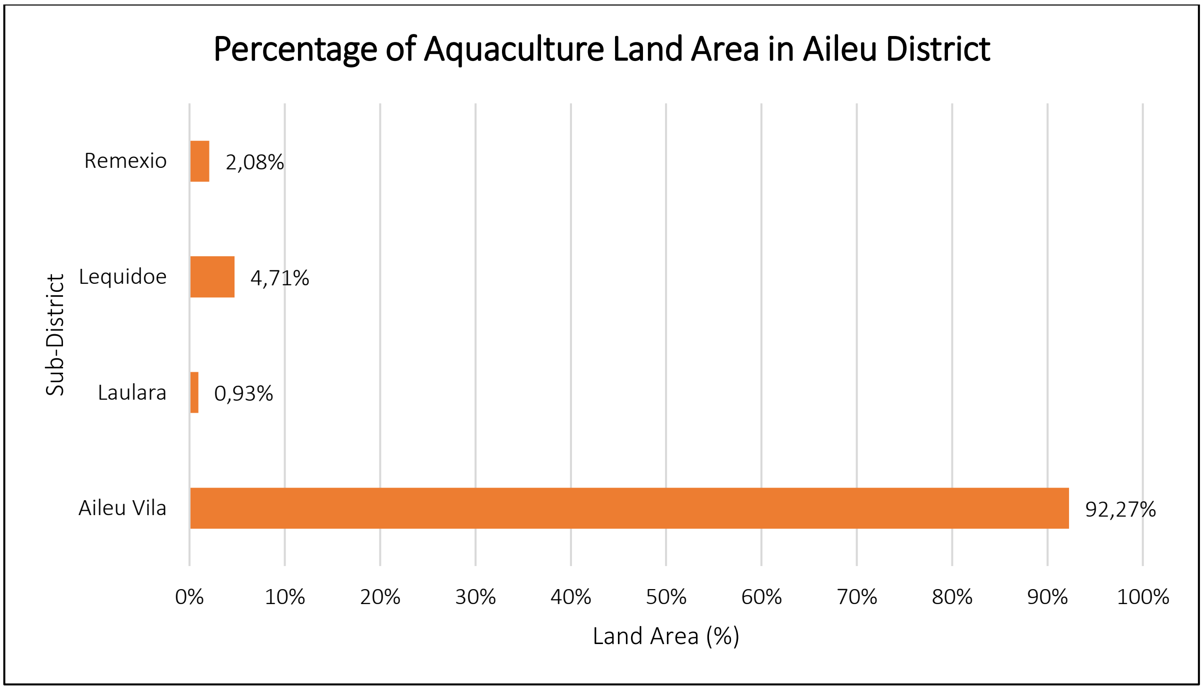


Figure 10.7 Percentage of Aquaculture Land in Aileu District
(Source: Timor-Leste Agriculture Census, 2019)

2. Aquaculture Households

Aquaculture activities in Aileu District involve 555 households, spread across the four Sub-Districts with varying levels of participation. The distribution of aquaculture households shows the highest concentration in Aileu Vila Sub-

District, with 361 households, or about 65.05% of the total aquaculture households in the district. This strengthens Aileu Vila's position as the primary center of aquaculture activities in Aileu District, reflecting better infrastructure, water resources, and accessibility compared to the other Sub-Districts.

Lequidoe Sub-District ranks second with 142 households (25.59%), showing significant potential for aquaculture development in the area, although aquaculture facilities are still limited compared to Aileu Vila. Meanwhile, Laulara Sub-District has 41 households (7.39%), and Remexio Sub-District has the lowest number with only 11 households (1.98%). The number of aquaculture households in Aileu District is shown in **Figures 10.8** and **10.9**.

This distribution shows that aquaculture activities in Aileu District are not yet evenly distributed, with a strong dominance in one Sub-District. This imbalance should be considered in the planning of future aquaculture development, with a focus on ensuring equitable empowerment programs, capacity building, and providing supporting infrastructure in the Sub-Districts with currently low participation. This effort is crucial to optimize local potential and achieve fishery-based food security in the inland areas of Timor-Leste.

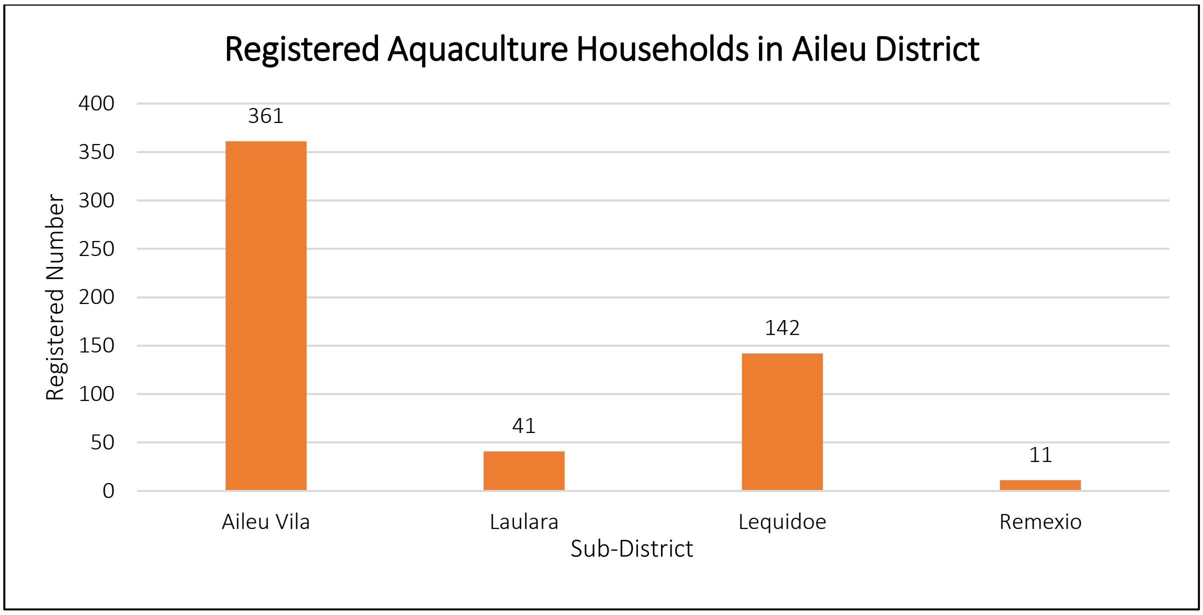


Figure 10.8 Aquaculture Households in Aileu District
(Source: Timor-Leste Agriculture Census, 2019)

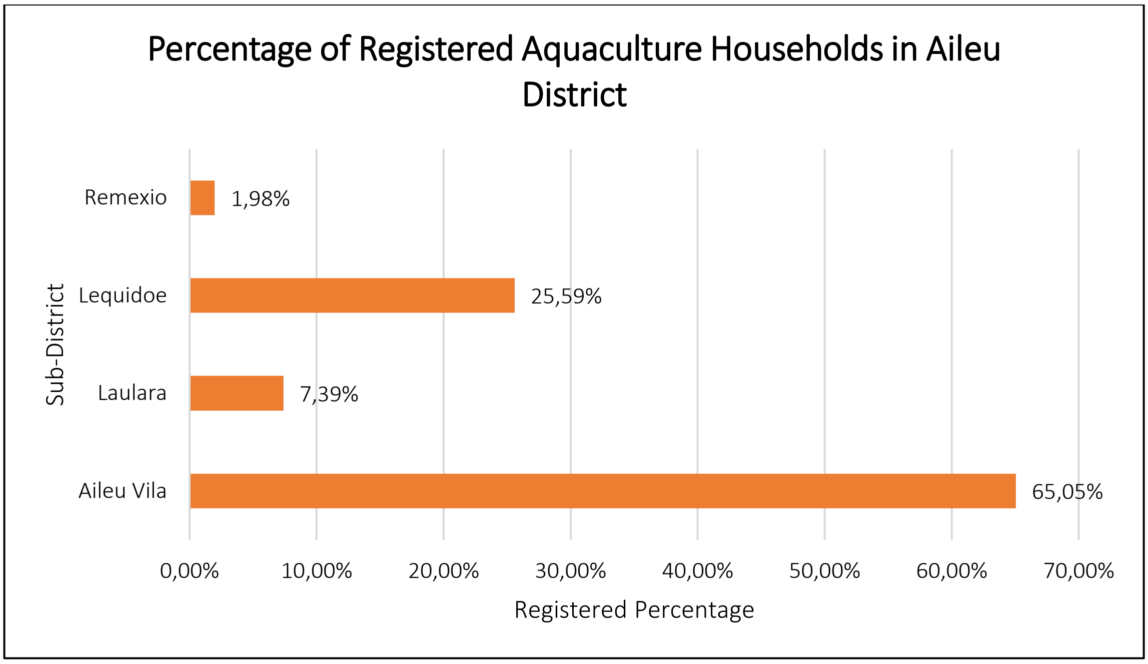


Figure 10.9 Percentage of Aquaculture Households in Aileu District
(Source: Timor-Leste Agriculture Census, 2019)

3. Aquaculture Systems

The aquaculture farming system in Aileu District is still dominated by fish pond farming and rice-fish systems, with a small contribution from fish ponds and almost no significant fish cage farming or fish hatchery activities. Based on data collected from the four Sub-Districts, the total number of fish ponds is 331 units, with the highest concentration in Aileu Vila Sub-District (247 units or 74.62%). Laulara Sub-District follows with 49 units (14.80%), while Liquidoe Sub-District and Remexio Sub-District have much lower numbers, with 19 units (5.74%) and 16 units (4.83%), respectively. The dominance of fish ponds in Aileu Vila indicates that this area is the main center of freshwater aquaculture farming in the district.

In the rice-fish system, 475 units are recorded, almost all of which are concentrated in Aileu Vila Sub-District, contributing 90.95% of the total units. This indicates a strong integrated practice of rice farming and fish cultivation in the area. Laulara Sub-District also contributes a small number of rice-fish units (43 units or 9.05%), while the other two Sub-Districts, Liquidoe and Remexio, have not developed this system.

Fish ponds are only found in two Sub-Districts, Aileu Vila and Laulara, with 1 unit each. These fish ponds are very limited and have not become the main farming system in Aileu District. Meanwhile, fish cages are not found at all in any Sub-District. This is suspected to be due to the geographic conditions of Aileu, which is mostly mountainous, making it unsuitable for large bodies of water such as lakes or reservoirs, which are necessary for cage farming. Fish hatchery activities are also very limited, with only 1 unit recorded in Aileu Vila, showing a low level of local hatchery independence and possible dependence on seed supply from other areas.

Overall, the aquaculture farming system in Aileu District is still focused on traditional systems, such as fish ponds and rice-fish systems, with limited involvement in modern or intensive farming systems such as cages and ponds. The concentration of activities in Aileu Vila also shows potential for further development in the other Sub-Districts, particularly in diversifying farming systems and improving hatchery facilities. Graphs showing aquaculture facilities used in Aileu District are presented in **Figures 10.10** and **10.11**.

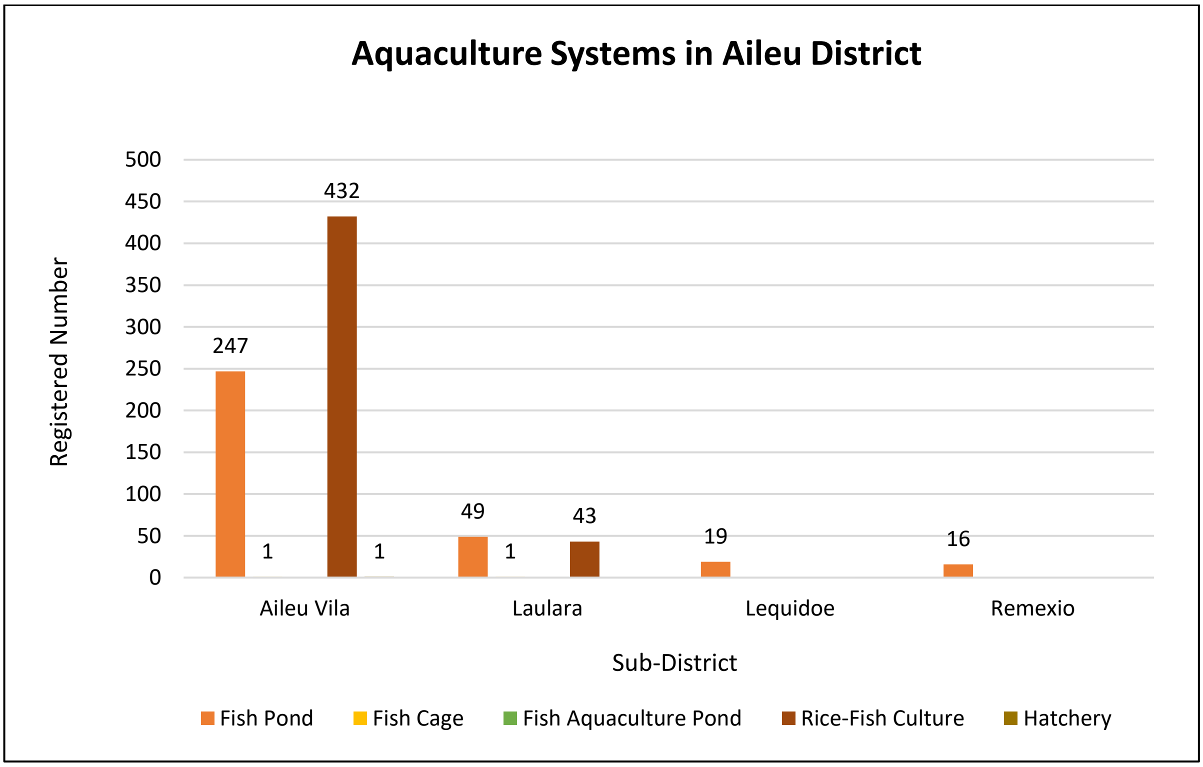


Figure 10.10 Aquaculture Systems in Aileu District
(Source: Timor-Leste Agriculture Census, 2019)

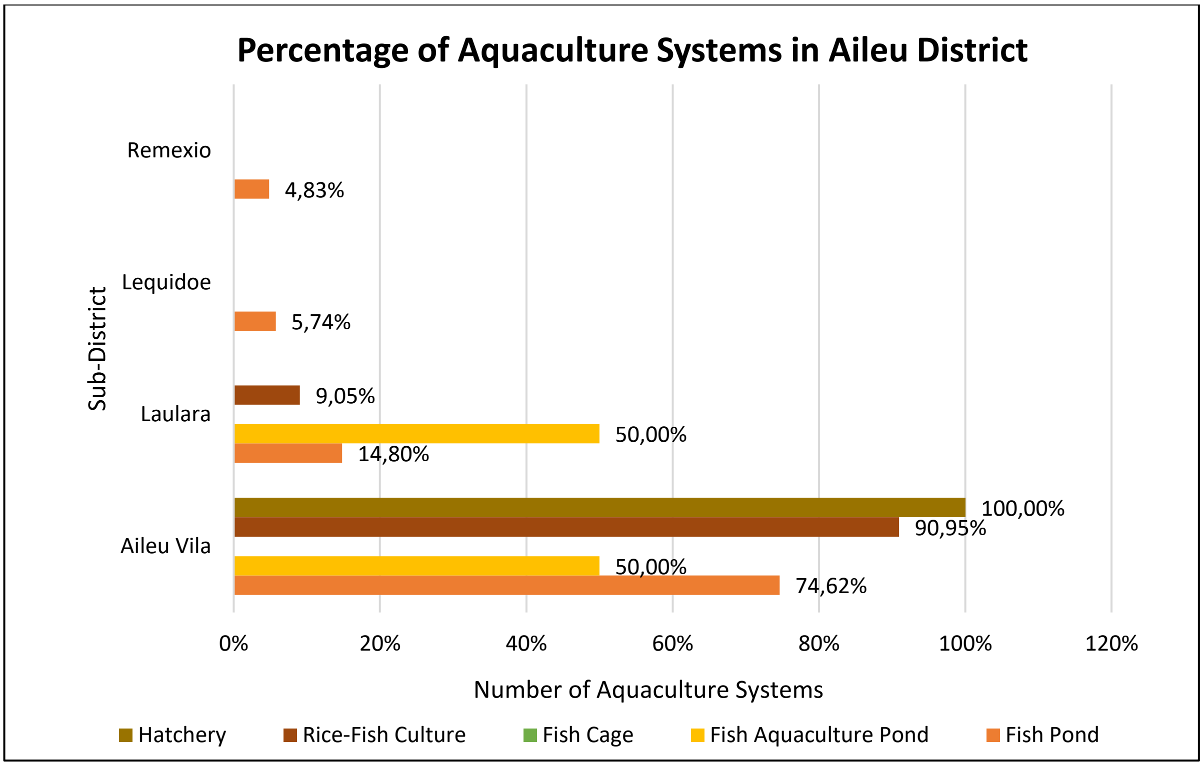


Figure 10.11 Percentage of Aquaculture Systems in Aileu District
(Source: Timor-Leste Agriculture Census, 2019)

C. Field Observation Results

Aquaculture activities in Aileu District are still small-scale with simple management and are strongly influenced by the limited demand in the local market. Some locations show potential for abundant natural resources, especially water availability, but these have not been optimally utilized for sustainable and economically viable aquaculture activities.

In Lahae Village, aquaculture is run by individual farmers with a high school education. The commodity farmed is carp, with a population of around 100 fish per pond. The ponds are semi-permanent, with concrete walls and a dirt floor. Water comes from a natural spring with a strong flow, which is channeled through a ditch, so water availability is not a major technical constraint in this location.

Figure 10.12 Aquaculture Pond in Lahae Village
(Source: Research Documentation, 2025)

However, the production scale is relatively small, and there is no significant management of the aquaculture. This is due to the low interest of the local market in carp, as the commodity is mostly consumed by foreign tourists. The market price for harvested carp is about $10 per kilogram, with a feed requirement of seven bags of pellets per farming cycle. Due to the limited demand, farmers consider expansion of the aquaculture to be unfeasible.

A similar situation is found in Raifusa Village, where conventional earth ponds that were previously used for farming have now been abandoned because they were considered unprofitable. Farming activities are no longer active, and the ponds are left neglected. Although water remains available from the same spring that irrigates the surrounding agricultural land, there are no plans for further development. The main constraint remains the low market prospects for freshwater fish farming in this area.

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

Meanwhile, in Seloi Craic Village, there is potential for aquaculture development through a more integrated approach. This area is part of Seloi Craic Lake, which has been designed as an integrated agricultural, tourism, and aquaculture development zone. Although there are no physical aquaculture ponds yet, fishing activities carried out by the community show the presence of natural fish stocks and recreational fishing potential. The availability of water from the spring that flows into the lake and the surrounding rice fields strengthens the potential of this area to be developed as an ecotourism-based aquaculture site.

Figure 10.14 Seloi Craic Lake
(Source: Research Documentation, 2025)

Overall, Aileu District has adequate water resources, but aquaculture activities are still constrained by market aspects and the economic value of the commodities. The utilization of potential sites such as Seloi Craic Lake could serve as an alternative strategy for developing the fisheries subsector based on tourism, while still considering technological interventions and market facilitation for local farmers. Institutional support and the promotion of fish consumption at the local level are also necessary to rekindle interest in aquaculture businesses in this area.

10.4 COMPREHENSIVE LAND SUITABILITY ANALYSIS FOR AQUACULTURE

A. Aquaculture Land Suitability in Aileu District

Land suitability refers to the degree of appropriateness of a given area for a specific use, in this case, for aquaculture. This assessment evaluates whether the land has the physical, chemical, and climatic characteristics that support optimal and sustainable cultivation of aquatic commodities. The suitability evaluation is carried out through two conditions: actual (current state) and potential (after improvements).

Actual suitability is determined based on field survey results that describe the land's capacity in its natural state without any interventions. The steps involve identifying land quality, determining limiting factors, scoring, and calculating the final evaluation. This provides a clear picture of existing limitations before improvement efforts are made.

Potential suitability describes the land's degree of suitability after improvements are made to the limiting factors. For example, land that is considered marginally suitable (S3) under actual conditions can be upgraded to moderately suitable (S2) or even highly suitable (S1) through interventions like topographic modifications or water quality management.

With proper technology and management, land with low suitability can still be improved to higher suitability classes. However, not all constraints can be addressed; some require technology that is not yet available or intensive management levels. Therefore, in land use planning for aquaculture, the main focus is on potential suitability, as this evaluation provides a picture of the maximum potential of the land post-improvement. This information is essential for designing effective and sustainable land use and determining the necessary corrective measures to achieve optimal results.

B. Results of Aquaculture Land Suitability Evaluation in Aileu District

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

The data collected is then analyzed based on the growth requirements of each commodity, both under actual conditions and potential conditions after land improvements such as topographic modifications, water quality management, or the application of adaptive cultivation techniques. This process generates comprehensive information that can be used to prioritize development, identify limiting factors, and design appropriate technical solutions. This scientific approach forms the foundation for the land suitability evaluation in Aileu District.

The analysis results provide strategic directions to optimize land productivity while maintaining the sustainability of aquatic resources in the region. The data used in the evaluation, from both field and laboratory sources, is presented in the relevant supporting documents. A soil distribution map for aquaculture land in Aileu District is shown in **Figure 10.15**.

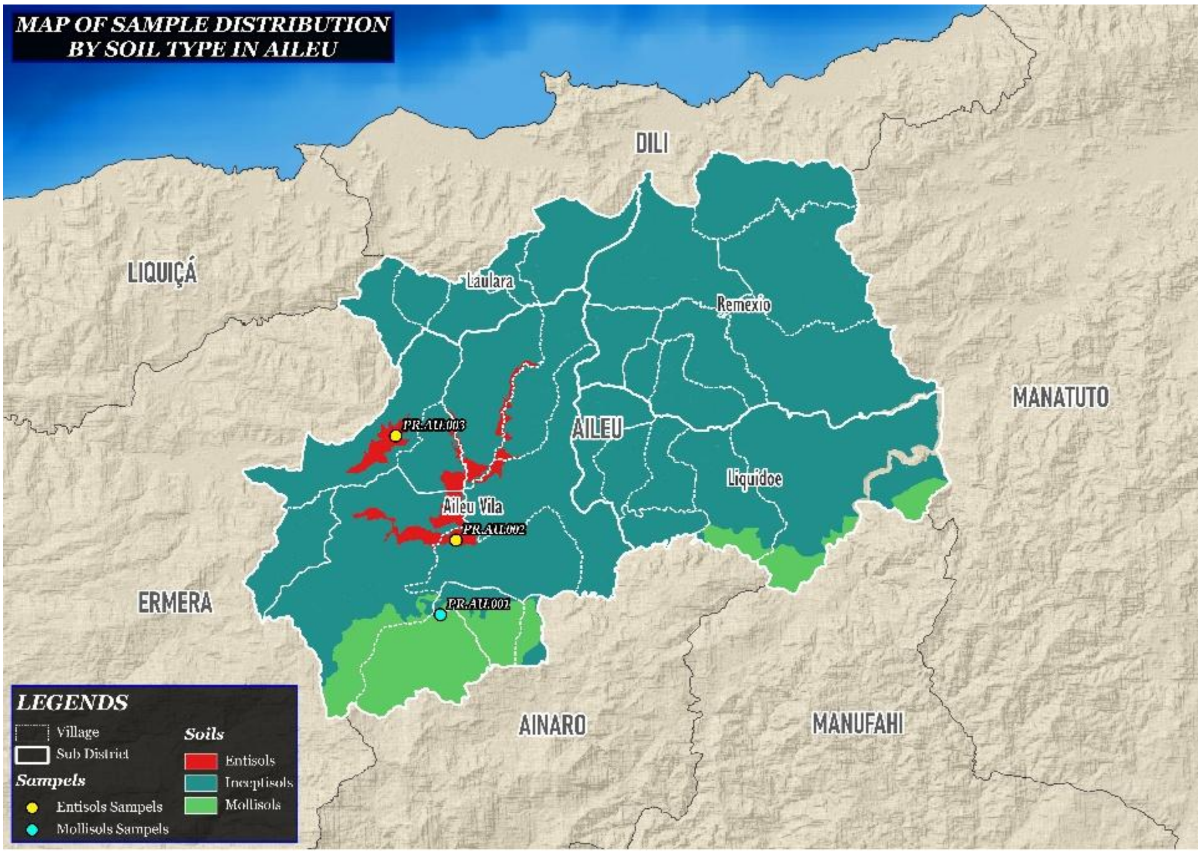


Figure 10.15 Map of Soil Distribution on Aquaculture Land in Aileu District

a. Land Suitability Evaluation in Aileu Vila Sub-District

Aileu Vila Sub-District is a highland area located in the mountainous region, far from the sea, and does not have natural brackish water sources. Based on **Table 10.9**, the land suitability evaluation shows significant limiting factors, especially related to topographic and climatic conditions. The three factors that consistently appear for almost all commodities are slope gradient, dry season duration, and rainfall.

Despite this, some parameters can still be improved through management interventions, depending on the level of difficulty. For example, a terraced pond system can be applied to overcome slope gradient constraints, thereby increasing land suitability. These technical solutions are explained further in **Table 10.10**. However, climatic factors such as the dry season and rainfall are categorized as non-improvable, so land suitability for these aspects remains unchanged even when improvements are made to other parameters.

In addition to climate and topography, the low air temperature in Aileu Vila causes the pond water to be colder than optimal for tropical fish growth, so the growth of freshwater commodities like gourami (*Ospronemus gouramy*), catfish (*Clarias batrachus*), carp (*Cyprinus carpio*), and tilapia (*Oreochromis niloticus*) shows limited actual suitability. Both gourami and tilapia are also constrained by low temperatures, categorized as S2. Similarly, tilapia is not only affected by temperature but also by suboptimal water pH. In contrast, carp has an advantage over other freshwater commodities because it does not have temperature constraints under actual conditions. This indicates that carp is more tolerant of low temperatures, making it better suited for farming in the cool climate of Aileu Vila.

Meanwhile, for brackish water commodities such as milkfish, vannamei shrimp, and mangrove crabs, the limiting factors are not only topography and climate but also salinity. In Aileu Vila, which is far from the coastline, the natural salinity is very low, making it unsuitable for the cultivation of marine species. Although options like mixing seawater with pumps to increase salinity exist, this solution is difficult to apply economically due to the distance from the sea and limited infrastructure. Therefore, brackish water commodities are not recommended for development in Aileu Vila. The land suitability analysis for aquaculture commodities in Aileu Vila is presented in **Table 10.9**.

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

Commodity	Current Land Suitability Limiting Factors	Current Final Evaluation	Potential Land Suitability Limiting Factors	Potential Final Evaluation
Gourami (*Ospronemus gouramy*)	N: Slope gradient, dry months S3: Rainfall S2: Low temperature	3.17	N: Dry months S3: Rainfall, slope gradient	3.34
Catfish (*Clarias batrachus*)	N: Slope gradient, dry months S3: Rainfall	3.22	N: Dry months S3: Rainfall, slope gradient	3.34
Carp (*Cyprinus carpio*)	N: Slope gradient, dry months S3: Rainfall	3.22	N: Dry months S3: Rainfall, slope gradient	3.34
Tilapia (*Oreochromis niloticus*)	N: Slope gradient, dry months S3: Rainfall S2: pH, low temperature	3.16	N: Dry months S3: Rainfall, slope gradient	3.34
Milkfish (*Chanos chanos*)	N: Dry months, slope gradient S3: Low salinity S2: pH, low temperature, rainfall	2.9	N: Dry months S3: Slope gradient S2: Rainfall	3.34
Mangrove crab (*Scylla serrata*)	N: Low salinity, dry months S3: Slope gradient S2: Low temperature, DO, rainfall	2.9	N: Dry months S3: Slope gradient S2: Rainfall	3.34
Vannamei (*Litopenaeus vannamei*)	N: Slope gradient, dry months S3: Low salinity, rainfall S2: Low temperature, pH	2.9	N: Dry months S3: Rainfall, slope gradient	3.34

C. Aquaculture Land Improvement Efforts

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

Based on **Table 10.10**, there are various improvement efforts with different levels of management difficulty. The management difficulty levels are categorized into three: low, medium, and high. These levels are then used to assess the potential for improving actual land quality to potential suitability, as shown in **Table 10.11**.

Table 10.10 Recommended Improvement Measures for Limiting Parameters

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

Description :

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

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

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

Description:

\- *Not feasible for improvement*

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

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

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

XI. RECOMMENDATION

11.1 RECOMMENDATIONS FOR THE AGRICULTURE SECTOR

1) Land Potential and Spatial Distribution

The territory of Aileu District shows localized diversity in agronomic potential. Clusters of irrigated rice fields are suitable for development in Aileu Vila (Seloi Craic, Hoholau, Liurai, Seloi Malere, Fahiria, Saboria, Lausi, Fatubosa), while rainfed rice fields are suitable in Bandudato and Fatubosa. Intensive grazing pasture is found in Bandudato and Aisirimou, dominated by elephantgrass (*Pennisetum purpureum*) and gamal (*Gliricidia sepium*). Spatial planning can therefore be directed toward irrigation blocks, grazing corridors, and efficient cultivation mosaics that follow contour lines and water sources.

2) Food Diversification and Cool-Highland Horticulture

Food crops (sweet potato, cassava, corn, taro, kacang tundis, porang) are widely distributed and interspersed with cool-climate vegetables (lettuce, water spinach, pakchoi, shallot, garlic, broccoli, chayote, caisim, chili, cabbage, cauliflower, tomato, long beans, carrot). This combination strengthens local carbohydrate sources, enables seasonal rotation, and supplies urban markets from high-elevation zones with cool microclimates.

3) Economically Valuable Tropical Fruit

Jackfruit, banana, rambutan, mango, breadfruit, avocado, guava, orange (sweet, mandarin, pomelo, lime, limau), pineapple, soursop, snakefruit, and papaya are widely distributed and ready to be upgraded in value through strengthened post-harvest handling (grading, packaging) and access to cold chains, so that quality losses and price volatility can be reduced.

4) Industrial Crops and Arabica Coffee

Coconut, areca nut, and Arabica coffee are found throughout the district. For Arabica coffee, soil and water conservation practices on slopes, shade from timber trees, and quality certification will increase productivity, improve cherry quality, and enhance access to premium markets.

5) Landscape Buffers: Forestry Vegetation

Groups of pine, bamboo, kapok, gamal, acacia, casuarina, Eucalyptus, teak, mahogany, Leucaena, calliandra, sandalwood, tamarind, agarwood, sugar palm, and Albizia are distributed in Aileu Vila, Laulara (Talitu, Madabeno), Liquidoe

(Faturilau), and Remexio (Faturasa, Liurai, Talutaque). These clusters function as erosion-control belts, sources of organic matter, and microclimate stabilizers that reinforce the productivity of surrounding cultivated land.

6) Local Spice and Medicinal Agroforestry

The integration of candlenut, pepper, turmeric, clove, betel, ginger, and lemongrass with horticulture and forestry in Fahiria, Acubilitoho, Faturasa, and Acumau demonstrates an adaptive mixed farming model. This pattern maintains soil fertility, suppresses erosion, reduces crop failure risk, and adds income streams (for example: orange-coffee-banana-spices-tubers; candlenut-orange-teak/pine-coffee-calliandra; clove-tubers-banana-avocado-mango-coffee-corn).

7) Priority Commodities and Production Clusters

Irrigated rice, cassava, corn, banana, orange, rambutan, pineapple, leafy vegetables and cabbage-group crops, chili, and Arabica coffee are designated as leading commodities. Establishing location-specific production clusters, providing technical support, supplying improved seed, and developing tiered marketing contracts will secure economies of scale, price stability, and access to premium markets.

8) Land Improvement, Water Conservation, and Integrated Erosion Control

Sustainable productivity requires balanced fertilization based on soil testing, addition of organic matter (compost or manure), terracing and contour-aligned planting, groundcover or legume strips, thick mulching, and water conservation through farm ponds, reservoirs, and rainwater wells or storage reservoirs. This integrated package increases water and nutrient storage capacity, protects topsoil, and buffers the impacts of drought on both sloping and flat land.

9) Nutrient Management and Cropping Patterns

Gaps in fertilization practices, which generally rely only on fallen leaves at land preparation with minimal maintenance, need to be addressed through simple standard operating procedures (rates, timing, and methods of application), location-specific soil test demonstration plots, and staged nutrient recommendation cards throughout the season. A shift from single-crop monoculture to rice-rice-secondary crops rotation (for example corn or legumes) will improve soil structure, break pest cycles, and stabilize yields.

10) Specific Issue: Dieback in Rambutan

Management is directed toward orchard sanitation, selective pruning, balancing K, Ca, and Mg nutrients, shade regulation, and monitoring of pests and diseases. Integrated control demonstration plots are recommended to break inoculum sources, restore shoot vigor, and reduce yield losses.

11) Strengthening Capacity, Infrastructure, and Input Policies

Thematic farmer field schools (nutrients, micro-irrigation, Integrated Pest Management/PHT) and simple visual modules need to be aligned with improvements to farm access roads, post-harvest facilities (grading, packaging, cold chain), strengthening of cooperatives or off-takers, and policies on targeted fertilizer subsidies, incentives for organic matter (composters or dedicated pits), and microcredit for water conservation equipment so that good practices are adopted rapidly and farm production costs remain manageable.

12) Implementation Phasing and Principles of Sustainability

Quick wins include soil-test-based fertilization SOPs, rice-secondary crop rotation demonstration plots, mulching and legume strips, and improvement of small water channels. In the medium term, priorities include village-scale ponds or reservoirs, block-scale terracing, spice-coffee agroforestry, and partnerships for premium horticulture. All expansion of cultivated land must be aligned with conservation zoning, water-saving principles, maintenance of long-term soil fertility, and diversification of commodities to support the economic resilience of farm households.

11.2 RECOMMENDATIONS FOR THE LIVESTOCK SECTOR

1) Strategic Potential in Remexio Sub-District, Aileu District

Remexio Sub-District shows substantial potential to be developed as a breeding center for high-quality livestock in Timor-Leste, based on the results of a comprehensive evaluation of land suitability and ecological conditions.

2) Land Suitability for Forage Crops

The land suitability analysis for forage crops indicates that this area has fertile soils that support the sustainable growth of high-quality livestock forage, which forms the primary foundation for livestock productivity.

3) Availability of Natural Resources

Geographical conditions and the availability of natural resources, including access to water and natural vegetation, support year-round provision of livestock feed.

4) **Optimal Climatic Conditions**

Temperature and rainfall in Remexio Sub-District are relatively stable, creating a micro-environment that is ideal for livestock growth, health, and reproduction.

5) **Reduced Risk of Stress and Disease**

Stable climatic conditions significantly reduce the risk of heat stress and disease transmission in livestock, which often constitute major constraints to farm performance.

6) **Support for Genetic Quality of Breeding Stock**

A conducive environment supports genetic viability and increases the growth rate of breeding stock, thereby ensuring the genetic quality of the livestock produced.

7) **Development as a High-Quality Breeding Center**

Developing breeding facilities in Remexio Sub-District will optimize the production of high-quality livestock breeding stock that meets national needs for livestock genetic resources.

8) **Center for Innovation and Modern Livestock Technology**

This area has the potential to become a center for research, development, and application of modern livestock technologies, including integrated breeding systems and climate-responsive housing management.

9) **Living Laboratory for Innovation**

This center can function as a living laboratory for testing best practices, feed innovations, and livestock reproduction management systems within the local context of Timor-Leste.

10) **Knowledge Transfer and Training**

The facilities will enable knowledge transfer to local farmers, extension officers, and academics, thereby encouraging the adoption of sustainable livestock farming practices.

11) **National Demonstration Model**

Remexio Sub-District has the potential to become a national demonstration model for sustainable livestock development that can be replicated in other regions of Timor-Leste.

12) Contribution to National Food Security

By producing high-quality livestock breeding stock on a large scale, this center will make a significant contribution to increasing livestock populations and strengthening national food security.

11.3 RECOMMENDATIONS FOR THE FISHERIES SECTOR

As part of efforts to increase the productivity and economic value of the fisheries sector in Aileu District, location-specific technical recommendations were formulated based on the identification of key problems and local potential in each Village, as presented in **Table 11.1.**

1. Location-Specific Technical Recommendations

Table 11.1 Location-Specific Technical Recommendations in Aileu District

Location	Main Problem	Technical Recommendation
Lahae Village	Low demand for common carp commodities	Diversify cultured commodities to higher-value species such as catfish and gourami. Optimize rice–fish systems to improve land-use efficiency and generate dual production.
Fatubosa Village	Inactive aquaculture due to low economic value	Revitalize ponds through incentives for farmers, institutional strengthening, and market extension. Establish cooperatives to strengthen bargaining power.
Seloi Craic Village	Untapped potential; absence of aquaculture ponds	Develop a lake-based fisheries ecotourism area. Design and construct mini-cage systems and recreational fishing zones as an integrated conservation–production approach.

1. Designation of Pilot Project Locations

Based on technical and socio-economic assessments, Seloi Craic Village is recommended as the location for an Ecotourism-Based Integrated Aquaculture Pilot Project. This selection is based on:

1. The presence of a natural lake with stable water supply potential.
2. Access that allows integration of the fisheries sector with tourism and agriculture.

3. Ecological conditions that are suitable for the development of conservation-oriented farming systems.

As an alternative, Lahae Village is recommended as the location for a Community-Based Rice-Fish Farming Pilot, with catfish and gourami as leading commodities.

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

a) Implement programs to identify and activate idle land for aquaculture through participatory approaches with community groups.
b) Develop empowerment programs for farmer groups, particularly in areas where activities are stagnant or have been abandoned.
c) Develop local markets and fish distribution chains to increase demand and selling prices.
d) Promote the establishment of aquaculture farmer organizations and provide technical training on farm management and product processing.
e) Facilitate local markets through trade partnership schemes with cooperatives, development of fresh fish markets, and integration with village tourism activities.
f) Promote cross-sector collaboration, particularly among the agriculture, tourism, and environment services, to design sustainable fisheries zones based on local carrying capacity and community empowerment.
g) Develop research and technological innovation for adaptive aquaculture in sloping and highland areas, including culture systems using tarpaulin-lined ponds and mini net cages.

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Aileu Municipality

Aileu Municipalityhas a land use structure dominated by agroforestry systems, accounting for 63.79 % of the total area, reflecting its strategic role in maintaining a balance between ecological functions and production. Dryland agriculture covers approximately 18.18 %, while rainfed rice fields and irrigated rice fields account for 6.69 % and 1.64 %, respectively. From a conservation and livestock-support perspective, protected forest areas comprise 8.58 %, and grazing zones account for 1.12 % of the total area of Municipality Aileu.

Based on the results of the land suitability analysis, Municipality Aileu has potential for leading commodities across multiple subsectors that support integrated agricultural development. These include irrigated lowland rice in wetland areas; rainfed rice and corn in dryland areas; fruit horticulture such as orange and banana; and vegetable horticulture including potato and carrot. The Municipality is also suitable for the development of spice crops such as ginger and cinnamon, as well as industrial crops including clove and tobacco. In addition, the area supports forage-based grazing systems dominated by elephantgrass and setaria, the development of forestry species such as mahogany and pine, Bali cattle and buffalo livestock with notable potential in Administrative Post Remexio, and inland fisheries with gourami and carp as key commodities in Villages Lahae, Fatubosa, and Seloi Craic through sustainable aquaculture systems.

A specific issue faced in Municipality Aileu is citrus tree mortality in Administrative Post Liquidoe, caused by very acidic soil conditions and low soil fertility, which induce nutrient leaching, aluminum dominance, and physiological stress in plants. Addressing this problem requires an integrated technical approach, including liming with dolomite; the addition of organic matter and biofertilizers; balanced fertilization with phosphorus (SP-36) at 150 to 250 g tree^{-1}, urea at 200 to 300 g tree^{-1} year^{-1}, and KCl at 150 to 250 g tree^{-1} year^{-1}; improved water and drainage management; and the use of citrus varieties tolerant of acidic soils to support sustainable productivity. The implementation of these policy measures and technical interventions is expected to strengthen national food security, enhance productivity and competitiveness in the agricultural sector, and support Timor-Leste's readiness to address regional dynamics, including within the context of ASEAN membership.