Land Suitability Evaluation & Regional Potential Mapping

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

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

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FOREWORD

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

With heartfelt gratitude to God Almighty, we warmly welcome the publication of the book titled "*Land Suitability Evaluation and Mapping of Agricultural, Livestock, Fisheries, and Forestry Potential in Baucau District, Timor-Leste*." This book is the result of a successful collaboration between the Ministry of Agriculture, Livestock, Fisheries, and Forestry of Timor-Leste and the Faculty of Agriculture, Udayana University, and is fully supported by the Government of Timor-Leste through Contract No. 24/MAPPF/IV/2024.

Baucau District is one of the strategic areas for agricultural sector development in Timor-Leste, with significant and diverse land resource potential. This area contains various soil types that are highly potential for sustainable development. The majority of the region consists of well-developed soils such as Inceptisols, Entisols, Vertisols, Mollisols, and the Alfisol-Ultisol association, which are highly conducive to the growth of various agricultural commodities. With these soil characteristics, Baucau District has great potential to increase food production, support national food security, and boost the local economy.

This book responds to the challenges faced by Baucau District in managing natural resources optimally, sustainably, and adaptively to global climate change. It is hoped that the land suitability evaluation and mapping of regional potential conducted will serve as an important guide for strategic agricultural development planning, contributing to the achievement of the Sustainable Development Goals (SDGs), particularly in efforts to reduce hunger, face climate change, and preserve terrestrial ecosystems.

We highly appreciate the hard work of the entire research team, academics, and practitioners involved in the preparation of this book. May the results of this research become an important reference for decision-making and bring tangible benefits to sustainable agricultural development, improve community welfare, and preserve the environment in Baucau District in particular and Timor-Leste as a whole.

Sincerely,

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Fisheries, and Forestry
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EXECUTIVE SUMMARY

A. GENERAL DESCRIPTION OF THE STUDY AREA

This chapter presents an overview of Baucau District as an essential background for evaluating land suitability and potential for developing agricultural, plantation, horticultural, and forestry commodities. The information provided includes demographics, soil types, land use, and existing field conditions, with a comprehensive and data-driven approach

1. Demographics: Foundation of Human Resource Potential

Baucau, with its dominance of dry land and a significant farming population in several Sub-Districts such as Quelicai and Venilale, shows great potential for agricultural sector development as the backbone of national food security. These areas have a high proportion of farmers, supporting the implementation of agricultural technology innovations. However, areas like Baucau Sub-District require specific strategies to increase community involvement in land management.

2. Soil Types: Basis for Land Suitability Evaluation

The diversity of soil types in Baucau District, such as Inceptisols, Entisols, Vertisols, Mollisols, and Alfisols-Ultisols, which are fertile and potential, reflects high productivity potential with proper management. However, soils vulnerable to erosion, such as Entisols and Vertisols, require intensive conservation strategies to ensure sustained productivity. Alfisols-Ultisols require specific soil management strategies to support agricultural productivity.

3. Land Use: Ecosystem Dynamics and Human Activities

Baucau District has various types of land use that form an important foundation for developing agricultural and forest commodities. The dominant land use in the study area includes forest land, covering 108,217.4 ha (71.87%), followed by agricultural land at 22,237.83 ha (14.76%). Other uses include unused dry land at 18,567.72 ha (12.33%), settlements and industrial areas at 952.33 ha (0.63%), and rural settlements at 614.35 ha (0.41%)

4. Field Conditions: Problems and Potential

Agricultural areas in Baucau District face challenges in managing water resources, with many rice fields in the highlands becoming unproductive. However, there is significant potential for developing irrigated rice fields in the highland areas by utilizing water sources from the mountains. The forest land in this area is dominated by valuable industrial tree species such as teak, sandalwood, eucalyptus, and mahogany. Additionally, mixed plantations produce high-value commodities such as coconut and breadfruit.

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

The invasive species *Chromolaena odorata* in Timor-Leste presents significant ecological challenges, but it also holds great potential as organic fertilizer, traditional medicine, and bioenergy. A utilization-based strategy involving local communities and the private sector is key to sustainably managing this plant.

B. RESEARCH METHODS

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

Research Procedure

1. Soil Sampling
   a) Soil samples are taken in composite form at the following depths:
      - **0–30 cm** for annual crops.
      - **0–60 cm** cm for perennial crops.
2. Laboratory Analysis

   The following physical and chemical soil parameters were analyzed:
   a) **Organic Carbon (%):** Walkley and Black method.
   b) **Total Nitrogen (%):** Kjeldahl method.
   c) **Soil Texture:** Pipette method.
   d) **Soil pH:** Potentiometric method (H^2O 1:2.5).
   e) **Available Phosphorus & Potassium (ppm):**
      - Bray-1 method for pH < 7 (converted to mg/100 g).
      - Olsen method for pH > 7 (converted to mg/100 g).
   f) **Salinity**: dS/m using potentiometer (H^2O 1:2.5)
   g) **Cation Exchange Capacity (CEC) (cmol/kg)** and **Base Saturation (BS) (%):** NH_4OAc 1N pH 7.

h) **Soil Fertility Status:** Based on the PPT method (1995).

i) **Erosion Hazard:** Field observations and Universal Soil Loss Equation (USLE).

Land Suitability Classification Steps

1. Actual Land Suitability

   Initial classification assesses land suitability under existing conditions without improvements.

2. Land Improvement Recommendations:

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

3. Potential Land Suitability:

   Land suitability is evaluated after considering improvements to maximize the land's potential.

4. Commodity Development Potential Zoning:

   Zoning is determined by integrating Baucau District's Agroecological Zones, based on land suitability and specific agroecosystem requirements.

C. AGRICULTURAL AND FOREST LAND CHARACTERISTICS

1. Temperature

Air temperature is a key parameter in land suitability evaluation, with analysis based on integrating field measurement data and the SRTM Digital Elevation Model (DEM) using the Braak approach. Temperature distribution varies across districts, reflecting complex topography and microclimates. In Baucau District, air temperatures predominantly fall within the 24–26°C range, which generally supports agricultural activities and local ecosystems in tropical climates. Lowland areas with temperatures >26°C are susceptible to evapotranspiration.

2. Rainfall

Rainfall analysis based on CHIRPS data shows the largest proportion of the area receives moderate to high rainfall (1500–2000 mm/year), which supports stable agricultural activities. Areas with high rainfall (>2000 mm/year) face erosion challenges, while low rainfall zones (<1000 mm/year) require adaptive technologies such as micro-irrigation. Sub-Districts such as Baguia and Baucau exhibit stable distribution with great potential for efficient agricultural management.

3. Dry Months

The characteristic of dry months in various Sub-Districts of Baucau District shows significant variation. Baguia Sub-District experiences 5-6 dry months (58%), while Baucau Sub-District mainly has 0-1 and 2-3 dry months, representing 39%. Laga Sub-District mostly experiences 2-3 dry months (67%), while Quelicai Sub-District is dominated by 2-3 dry months (54%), with some areas experiencing up to 5-6 dry months. Venilale Sub-District has 3-4 dry months dominating nearly 82% of the area, while Vemasse Sub-District experiences mainly 0-1 dry months, with variations extending to more than 6 dry months in some areas.

4. Drainage

Drainage characteristics in Baucau District show a dominance of well-drained areas, such as in Quelicai Sub-District (92%), Baguia (74%), and Venilale (73%). Most other areas have restricted drainage, such as Laga Sub-District, where 58% of the area is categorized as such. The dominance of well-drained areas influences soil oxygen availability, supporting optimal water distribution for crop needs.

5. Soil Texture

Soil texture in various regions of Baucau District shows significant variation. Baguia Sub-District is dominated by slightly fine soil texture (53%), while Baucau and Laga Sub-Districts mainly have medium texture, covering 36% and 58% of their areas, respectively. Quelicai, Vemasse, and Venilale Sub-Districts are dominated by fine texture soils, with Vemasse having the highest percentage (77%). Fine soils enhance water retention and organic matter storage, while coarse textures support better soil aeration.

6. Coarse Fragments

The distribution of coarse fragments in Baucau District is dominated by soils with low coarse fragment content (<5%) at 45%, supporting water retention and soil fertility, ideal for agriculture. Some areas have medium coarse fragment content (10-15%) at 15%, providing stable soil structure and supporting drainage. Some areas have higher coarse fragment content, such as 15-20% and 20-25% (each 5%), and >50% (4%), requiring special management to improve productivity. Soils with high coarse fragment content tend to contain gravel or stones, necessitating irrigation and organic fertilization to support plant growth.

7. Surface Rocks

The distribution of surface rocks in Baucau District is dominated by the 0-5% category (52%), which shows high potential for agriculture because the soil is easier to till. Areas with surface rocks between 5-10% cover 18%, still suitable for agriculture and infrastructure development. Some areas have higher surface rock content, such as the 20-50% category (13%) and >50% (11%), which require special management to enhance land productivity.

8. Rock Outcrops

The distribution of rock outcrops in Baucau District shows that 52% of the area has low surface rock levels (0-5%), ideal for agricultural activities due to ease of tillage. Areas with 5-10% surface rock cover 18%, still suitable for agriculture and infrastructure development. Some areas have higher rock outcrop levels, such as the 20-50% category (13%) and >50% (11%), more suitable for conservation or activities with specific geological considerations.

D. SOIL FERTILITY STATUS

Soil analysis results show that the majority of soils in Baucau District have a moderate fertility status. The fertility evaluation indicates three categories: low, moderate, and high fertility. The analysis shows that 47.52% of the soil has moderate fertility, which is the dominant category in this area. High fertility soils cover 27.23%, while low fertility soils make up 25.25%.

This categorization is determined based on chemical soil parameters such as cation exchange capacity (CEC), base saturation (KB), organic carbon (C-organic), phosphorus (P), and potassium (K). Low fertility is attributed to several key factors, such as low organic carbon and potassium content, as well as the tendency for nutrient leaching in areas with high rainfall. Additionally, soil sampling in Timor-Leste during the dry season results in low organic matter availability, reduced water retention, and nutrient availability in coarse-textured soils, along with environmental pressures such as drought/increased humidity regimes, which accelerate soil chemical degradation.

Spatial Distribution of Soil Fertility

The district has a widespread distribution of soils with moderate and high fertility, especially in the central and eastern parts. Low fertility soils are more dominant in the southern and southwestern regions.

E. EROSION AND AGROFORESTRY BASED CONSERVATION

1. Soil Erosion

Soil erosion plays a significant role in land suitability evaluation and land use sustainability. In Baucau District, factors such as steep slopes, low vegetative cover, granular soil structure, and minimal conservation practices accelerate erosion. Analysis results show that Baucau District has very severe erosion at 17.93%, severe erosion at 10.76%, moderate erosion at 50.32%, and light erosion at 20.99%

Major causes of erosion in this area include:

a) **Topography**: Dominant steep slopes, especially in Baguia, Laga, Quelicai, Vemasse, and Venilale Sub-Districts.

b) **Soil types**: Inceptisols, Vertisols, and Entisols, which are prone to erosion, especially on slopes >15%.

c) **Rainfall**: High rainfall intensity causes heavy to very severe erosion.

d) **Low vegetative cover**: Contributes to the loss of topsoil due to surface runoff.

e) **Anthropogenic**: Improper management without conservation principles accelerates erosion.

2. Agroforestry-Based Conservation

Agroforestry-based conservation has become the main effective approach to combat soil erosion in Baucau District. Agroforestry integrates forest trees, 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 organic contributions from leaves and roots.

c) **Sustainable water management**: By retaining water in the soil layers through deep root systems.

Key benefits of agroforestry in soil and water conservation include:

a) **Erosion mitigation**: Trees and plants act as natural barriers to prevent soil loss from surface runoff.

b) **Increased water infiltration**: Tree root systems enhance the soil's ability to absorb water.

c) **Biodiversity enhancement**: Combining crops and trees creates a more diverse and stable ecosystem.

d) **Increased agricultural productivity**: Through agroforestry components supporting diverse harvests.

3. Agroforestry Implementation in Baucau District

The agroforestry systems applied in Timor-Leste vary according to agroecological zones. Effective agroforestry-based conservation systems include:

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

b) **Living fences**: Using erosion-resistant plants such as vetiver to strengthen slopes.

c) **Living terraces**: Using perennial plants like Leucaena to prevent erosion, combined with pepper and other climbing plants.

d) **Layered planting**: Combining trees, shrubs, and groundcover plants to stabilize soil and reduce runoff.

e) **Silvopastoral systems**: Integrating forest vegetation with livestock to manage erosion in grazing areas.

4. Conservation Recommendations

a) **Enhancing agroforestry practices** in erosion-prone zones, such as Venilale, Laga, Baguia, and Vemasse.

b) **Spatial data-based management** to determine priority conservation intervention locations.

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

d) **Strengthening soil conservation policies** with integration of agroecology-based approaches in regional spatial planning.

F. LAND SUITABILITY EVALUATION FOR AGRICULTURE

1. Baguia Sub-District

- Baguia Sub-District has potential for the development of food crops such as irrigated rice, upland rice, corn, cowpea, and cassava.
- Horticultural crops that can be developed include tomato, eggplant, and chili. Fruit horticulture such as mango and pineapple have significant potential with a sufficiently suitable suitability level.

- Additionally, ornamental flowers such as roses, cananga, and gladiolus can be cultivated.
- Industrial crops such as tobacco, sugarcane, and cotton can be developed. Coconut, quinine, and melinjo are also suitable, although only marginally.

2. Baucau Sub-District
   - Food crops that can be developed include irrigated rice, sorghum, corn, cowpea, and sweet potato.
   - Horticultural crops such as chili, bitter melon, eggplant, and lettuce are rated as sufficiently suitable. Fruit crops like breadfruit are also suitable for development.
   - Industrial crops such as tobacco, coconut, cotton, kapok, and quinine are suitable for development.
3. Laga Sub-District
   - Food crops that can be developed include irrigated rice, sorghum, corn, cowpea, and sweet potato. Food crops that can be developed include irrigated rice, upland rice, corn, sorghum, cassava, and legumes.
   - Plantation crops such as coconut, tobacco, sugarcane, and cotton are rated as sufficiently suitable.
4. Quelicai Sub-District
   - Food crops that can be developed include irrigated rice, upland rice, and corn.
   - Industrial crops that can be developed include tobacco and sugarcane.
5. Vemasse Sub-District
   - Food crops that can be developed include irrigated rice, upland rice, corn, and peanuts.
   - Industrial crops that can be developed include coconut, melinjo, and kapok.
   - Spices such as aromatic ginger, turmeric, and galangal can also be developed.
   - Ornamental horticultural flowers that can be developed include roses, cananga, tuberose, and hairgrass.
6. Venilale Sub-District
   - Food crops that can be developed include irrigated rice, upland rice, corn, sorghum, mung beans, cowpea, cassava, sweet potato, and hui.

- Horticultural vegetables such as chili and tomato are suitable for development.
- Fruit crops such as papaya, starfruit, avocado, durian, and pineapple can be developed.
- Spices such as candlenut, vanilla, aromatic ginger, and turmeric can also be developed.

G. BAUCAU LIVESTOCK POTENTIAL IN BAUCAU DISTRICT

The results show that livestock in Baucau District is dominated by cattle, pigs, goats, and chickens, with significant grazing land potential, especially in Baucau Sub-District. The land suitability evaluation places livestock forage crops such as elephant grass, setaria, and legumes in the sufficiently suitable category (S2), although limitations in pH, nutrients, slope, and rainfall may affect development. Most areas are suitable for the development of cattle, pigs, buffalo, and sheep, except for Vemasse Sub-District, which has ecological limitations.

Key issues include limited access to quality forage, traditional extensive husbandry practices, low adoption of breeding technology, and limited marketing access. Strategic solutions include improving forage crops with a combination of 60% grass and 40% legumes, using superior breeding stock and artificial insemination, enhancing farmer capacity through training, and providing credit support and market access. Based on this analysis, Triloca in Baucau Sub-District is recommended as a pilot project for cattle breeding, as it has suitable land, good accessibility, and strong community support. This location is considered promising for developing a productive, modern, and sustainable livestock system.

H. FISHERIES POTENTIAL IN BAUCAU DISTRICT

1) Caibada Makasai Village (Baucau Sub-District): The existing reservoir, which currently functions only as a transit point, needs improvements such as the installation of portable aerators, simple filtration systems, and converting part of the reservoir into a grow-out pond with better water quality management.
2) Gari Uai Village (Baucau Sub-District): To address limitations in production scale and access to fish seed, strengthening the fish farming community's institutions is essential. This should include providing subsidies for superior

fish seeds and training in pond-based farming according to technical standards.

3) **Triloca Village (Baucau Sub-District)**: Small-scale catfish breeding efforts can be supported by installing pumps and water reserve tanks, training in self-produced feed using local materials, and facilitating partnerships with hatcheries.
4) **Vemasse Tasi (Vemasse Sub-District)**: Underutilized government facilities should be directed to become a Demonstration Farm (Demfarm), integrating community training, local seed production, and strengthening production record-keeping and technical monitoring through digital systems.

Pilot Project Location

The priority location for the pilot project is the Vemasse Tasi Fish Hatchery. This government facility is well-equipped and has already cultivated commodities such as milkfish, tilapia, and mangrove crab with good survival rates. Considering accessibility, institutional readiness, and potential for technological advancement, Vemasse Tasi Fish Hatchery is the most strategic location for establishing an integrated aquaculture pilot project in Baucau District.

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

- Priority technical assistance and production equipment (pumps, aerators, fiber ponds) for active participants in Gariuai and Triloca Villages.
- Promote the formation or strengthening of fish farming groups at the village level to facilitate technical assistance, capital access, and market development.
- Strengthen the Vemasse Tasi Hatchery facility as a training center, field research hub, and superior seed development site.
- Diversify strategic commodities such as milkfish, catfish, gourami, and tilapia through special assistance programs in high-value and high-potential locations.
- Launch campaigns to increase the consumption of aquaculture fish, as per capita consumption is low. A nutrition and processed products promotion program should target schools and households.

I. AGRICULTURAL COMMODITY DEVELOPMENT ZONING IN BAUCAU DISTRICT

Baucau District has significant land resource potential to support the development of the agricultural, forestry, and livestock sectors. Based on the land suitability evaluation, the zoning is systematically designed through field observations, laboratory analyses, and agro-climatic mapping. The zoning aims to maximize land management efficiency, support food security, and improve community welfare.

1. Irrigated Rice (9.26% of total area)
   - Area: 139.51 km², at low elevation (0–100 m asl) with a slope of 0–8%.
   - Main Areas: Baucau Sub-District (58.05 km²), Venilale Sub-District (41.25 km²), and Vemasse Sub-District (15.22 km²).
   - Strategy: Irrigation system development, such as piped water from rivers.
2. Rainfed Rice (22.77% of total area)
   - Area: 342.94 km², located at an elevation of 100–500 m asl.
   - Main Areas: Baucau Sub-District (137.85 km²), Vemasse Sub-District (54.96 km²), Laga Sub-District (34.05 km²), Baguia Sub-District (47.47 km²), and Quelicai Sub-District (48.67 km²), with Venilale Sub-District having the smallest area at 19.93 km².
   - Strategy: Recommended strategies include building water reservoirs, using drought-resistant rice varieties, and managing water resources to improve yields.
3. Dryland Agriculture (29.55% of total area)
   - Area: 445 km², at an elevation of 100–500 m asl with a slope of 8–25%.
   - Main Areas: Baucau Sub-District (123.03 km²), Laga Sub-District (102.19 km²), Vemasse Sub-District (93.14 km²), Venilale Sub-District (57.31 km²), Quelicai Sub-District (41.63 km²), and Baguia Sub-District (27.71 km²).
   - Key Commodities: Corn, cassava, peanuts, soybeans, taro (food crops); vegetables, fruits, ornamental flowers (horticulture); and tobacco, cotton, cacao, and spices (industrial crops).
   - Strategy: Soil conservation techniques such as strip cropping and crop rotation.
4. Grazing Areas (2.76% of total area)
   - Area: 41.54 km², dominated by grasslands and savannas.

- Main Areas: Baucau Sub-District (22.52 km²), Baguia Sub-District (9.37 km²), Laga Sub-District (8.68 km²), with Quelicai Sub-District having the smallest grazing area at 0.97 km².
- Strategy: Rotational grazing systems and agroforestry integration.

J. FORESTRY POTENTIAL

Agroforestry (23.05% of total area)

- Area: 347.21 km², at elevations of 500–1,000 m asl with slopes of 25–45%.
- Proportion: 30–40% agricultural plants, 60–70% shade trees (orange, jackfruit, and avocado).
- Strategy: Small-scale livestock integration for income diversification.

Protected Forest and Conservation Areas (12.50% of total area)

- Area: 188.30 km², at elevations >1,000 m asl with slopes >45%.
- Purpose: Soil and water conservation, biodiversity preservation, land degradation and erosion mitigation.
- Strategy: Reforestation and ecosystem restoration to reduce land degradation.

K. RESEARCH RECOMMENDATION

1. Land Zoning Management
    a) Irrigated and Rainfed Rice: Optimize land use in Baucau, Laga, Venilale, and Vemasse Sub-Districts to support national food security.
    b) Agroforestry and Forestry: Focus on robusta coffee, oil palm, coconut, fruit and vegetable horticulture such as avocado, mango, tomato, and chili, and high-value trees in agroforestry zones, while maintaining protected forests for ecosystem conservation and climate change mitigation.
    c) Grazing Areas: Implement rotational grazing systems to improve livestock productivity, combined with agroforestry for ecological and economic benefits. Grazing areas in Baucau District are primarily found in Baguia and Baucau Sub-Districts.
2. Productivity Improvement Strategies
    a) Improving Land Limiting Factors: Implement technologies such as liming for acidic soils, sulfur fertilization for alkaline soils (high pH), organic matter addition, drainage improvements, and site-specific fertilization to address soil fertility issues.

b) **Invasive Weed Utilization**: Use *Chromolaena odorata* as organic fertilizer, biochar, or medicinal material to support sustainable land management.

3. Soil and Water Conservation
   a) **Erosion Mitigation**: Implement terracing, soil cover vegetation, mulching with crop residues, and check dam technologies to protect land from erosion on steep slopes.
   b) **Rainwater Utilization**: Build water reservoirs, infiltration wells, and drainage systems in agricultural areas to support year-round water availability.
4. Community Empowerment
   a) **Training and Education**: Provide training on soil and fertility conservation, agroforestry, and invasive weed management in collaboration with universities for farmers.
   b) **Farmer Commitment**: Activities to improve land productivity.
   c) **Multisector Partnerships**: Involve the government, academia, and the private sector to support research and technology development.
5. Policy and Incentives
   a) **Economic Incentives**: Subsidies and micro-credit for farmers adopting environmentally friendly technologies.
   b) **Zoning Regulations**: Establish land-use regulations according to zoning to ensure the sustainability of natural resources.
6. Monitoring and Evaluation
   a) **GIS Technology**: Use GIS to monitor the effectiveness of land management strategies, land cover changes, and land capability in Timor-Leste.
   b) **Local Participation**: Involve local communities in evaluation and planning to ensure the sustainability of programs.

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I. INTRODUCTION

New Context: ASEAN, SDGs, and Population Pressure

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

In this new regional context, Timor-Leste faces significant challenges in meeting its national food security needs. This pressure is particularly evident in **Baucau District**, which has the second-largest population after the capital, Dili. The population density in this area demands effective food solutions

Achieving the Sustainable Development Goals (SDGs), specifically food security (SDG 2), clean water management (SDG 6), and climate action (SDG 13), is now a central agenda. For Baucau, the challenge lies in achieving these targets in a region with unique agro-climatic characteristics.

Technology Regional Focus: Topographic Challenges vs. Technological Opportunities

Baucau District faces significant topographic challenges, with most of its area dominated by steep slopes. Data show that 34.69% of the district has a slope class of 25-45%, and 17.84% has slopes greater than 45%.

These conditions generally hinder intensive agriculture based on conventional irrigation methods. However, great potential lies in the **northern coastal region** of Baucau District. The key to unlocking this potential is not through traditional methods but through the application of **adaptive and innovative irrigation technology**.

Technical Foundation: Potential for Modern Irrigation

The potential in the northern coastal area is supported by three technical foundations:

1. **Hydrological Potential:** The river network (0.62% of the area) can be optimized using modern irrigation technologies such as piped systems, pump systems, and drip irrigation.
2. **Geological Conditions:** The northern coastal area is dominated by reefal limestone formations (25.40%) and chaotic boulder fragments in a scaly clay matrix (38.93%). This geological structure is ideal for building modern

irrigation infrastructure based on piped systems, as it provides good structural stability.

3. **Soil Characteristics:** The **Entisols (14.36%)** and **Vertisols (12.82%)** in the area, while challenging, can be improved through proper management, such as adding organic matter and managing drainage (Soil Survey Staff, 2014).

Opportunities for Integrated Sector Development (Four Pillars)

Considering the challenges of steep land and the potential for modern irrigation on the coast, Baucau's strategy must include four integrated pillars:

1. **Agriculture Sector:** Focus on developing agriculture in the northern coastal region using modern irrigation systems (piping, drip irrigation) to increase water-use efficiency and overcome topographical challenges.
2. **Forestry Sector:** In areas with steep slopes, the forestry sector is crucial. Implementing agroforestry systems (wanatani) is a strategic solution for soil and water conservation, reducing carbon emissions, and increasing community income (Nair, 2011).
3. **Livestock Sector:** The land in the northern coastal area and other natural grazing areas can support livestock development (cattle, goats) as a source of animal protein.
4. **Fisheries Sector (Freshwater and Brackish Water):** The presence of the coastal area and the optimization of river networks through irrigation also open up opportunities for fisheries, both freshwater aquaculture and brackish water aquaculture (pond farming) along the northern coast.

Objective of the Evaluation in This Report

Thus, the research underpinning this report aims to evaluate land suitability and map the development potential in Baucau District. The focus is on the four pillars: **agriculture (with an emphasis on modern irrigation), forestry (agroforestry), livestock, and fisheries (freshwater and brackish water)** as integrated supporting sectors.

This report is intended to provide strategic recommendations for the government and other stakeholders to design sustainable development policies, supporting food security for the large population of Baucau and contributing to the achievement of Timor-Leste's SDGs in the new ASEAN era.

Historically, Baucau District was initially under the authority of traditional rulers before the arrival of the Portuguese administration and the establishment of a colonial bureaucracy. In 1698, the Portuguese government under Governor António Coelho Guerreiro established posts across Timor to intervene in local authority. On 20 April 1859, the Portuguese Governor instituted a division into 11 districts in Timor-Leste, designating Baucau as a district under the name Vemasse that included Vemasse, Fatumarto, and Venilale. In 1908, Governor Celestino da Silva established Baucau as a military base. In 1920, Governor Paulo de Sousa Gentil restored the district's status as a civil jurisdiction consisting of five Sub-Districts, namely Baucau Vila, Baguia, Laga, Vemasse, and Venilale. In 1974, Baucau was designated as the Conselho de Administração comprising the Sub-Districts of Baucau Vila, Baguia, Laga, Vemasse, Quelicai, and Venilale.

II. GENERAL OVERVIEW OF THE AREA

2.1 DEMOGRAPHY

Baucau District is one of the administrative regions of Timor-Leste comprising six Sub-Districts, namely Baguia, Baucau, Laga, Quelicai, Vemasse, and Venilale, with a geospatial position at 8°27′46″ S and 126°27′13″ E. The District borders Lautém District to the east, Viqueque District to the south, Manatuto District to the west, and the Timor Sea to the north. Geographically, Baucau occupies a strategic position that has implications for social and economic dynamics and for the use of natural resources, as illustrated in the Administrative Map of Baucau District in **Figure 2.1.**

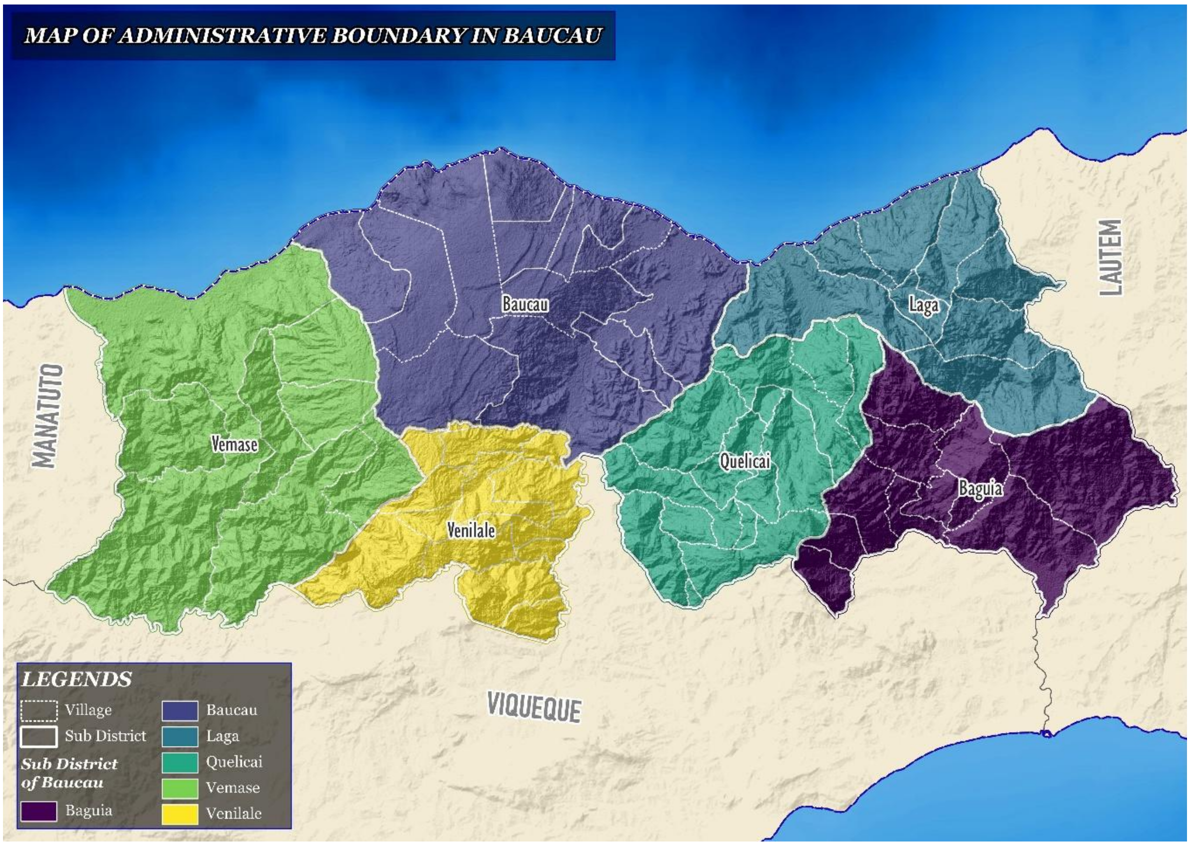


Figure 2.1 Administrative Area of Baucau District

Baucau District had a population of 163,462 with a density of 83.98 persons per km^2 across an area of 1,501.67 km^2 (Autoridade Munisípiu Baucau, 2025). These data indicate that Baucau is one of the districts with a relatively large population in Timor-Leste and reflect demographic distributions that have implications for regional development planning and resource management. Area by Sub-District is presented in the table below **(Table 2.1).**

Table 2.1 Area (ha) in Baucau District

Sub-District	Area (ha)
Baguia	20,593.01
Baucau	36,961.73
Laga	15,113.77
Quelicai	20,621.37
Vemasse	37,395.15
Venilale	19,904.89

Historically, Baucau District was initially under the authority of traditional rulers before the arrival of the Portuguese administration and the establishment of a colonial bureaucracy. In 1698, the Portuguese government under Governor António Coelho Guerreiro established posts across Timor to intervene in local authority. On 20 April 1859, the Portuguese Governor instituted a division into 11 districts in Timor-Leste, designating Baucau as a district under the name Vemasse that included Vemasse, Fatumarto, and Venilale. In 1908, Governor Celestino da Silva established Baucau as a military base. In 1920, Governor Paulo de Sousa Gentil restored the district's status as a civil jurisdiction consisting of five Sub-Districts, namely Baucau Vila, Baguia, Laga, Vemasse, and Venilale. In 1974, Baucau was designated as the Conselho de Administração comprising the Sub-Districts of Baucau Vila, Baguia, Laga, Vemasse, Quelicai, and Venilale.

2.2 SOIL TYPES

Information on soil types in Timor-Leste has been classified using Soil Taxonomy based on the 1992 Keys to Soil Taxonomy. The classification was carried out to the great group level and comprises 7 soil orders, 16 suborders, and 22 great groups. These data provide an essential basis for determining the potential and sustainable management strategies for land resources, particularly for the development of agricultural commodities.

In Baucau District, the dominant soil order is Inceptisols, covering 906.84 km^2 or approximately 60.22 % of the total area. These soils are evenly distributed across the study area. Inceptisols have a moderately developed soil profile and generally adequate fertility to support agriculture, particularly when managed under soil conservation systems. In addition, other soil orders with substantial areal extent are as follows:

a) Entisols, covering 216.28 km^2 (14.36 %). These young soils have weakly developed profiles and are often found in areas with high erosion activity or recent deposits
b) Vertisols, covering 192.89 km^2 (12.82 %). These soils have high clay content and are prone to cracking when dry, but are highly fertile when properly managed.
c) Mollisols, covering 98.8 km^2 (6.51 %). These soils have high organic matter content and are highly suitable for intensive agriculture.
d) Alfisols-Ultisols, covering 82.38 km^2 (5.47 %). These soils are generally found in areas with stronger weathering, have moderate to low fertility, and require additional inputs to support agricultural productivity.

The composition of soil types in Baucau District reflects diverse soil conditions that must be considered in land-use planning and management. The dominance of Inceptisols together with the distribution of other soils indicates considerable potential for agricultural development, provided that soil management is aligned with the characteristics of each soil type.

This information provides a scientific basis for developing site-specific, agroecosystem-based land resource management strategies. Understanding the distribution and characteristics of the soil types enables agricultural planning to maximize the potential of each soil while minimizing the risk of ongoing land degradation. The areas of soil types in Baucau District are presented in **Figure 2.2**, and their distribution map is shown in **Figure 2.3.**

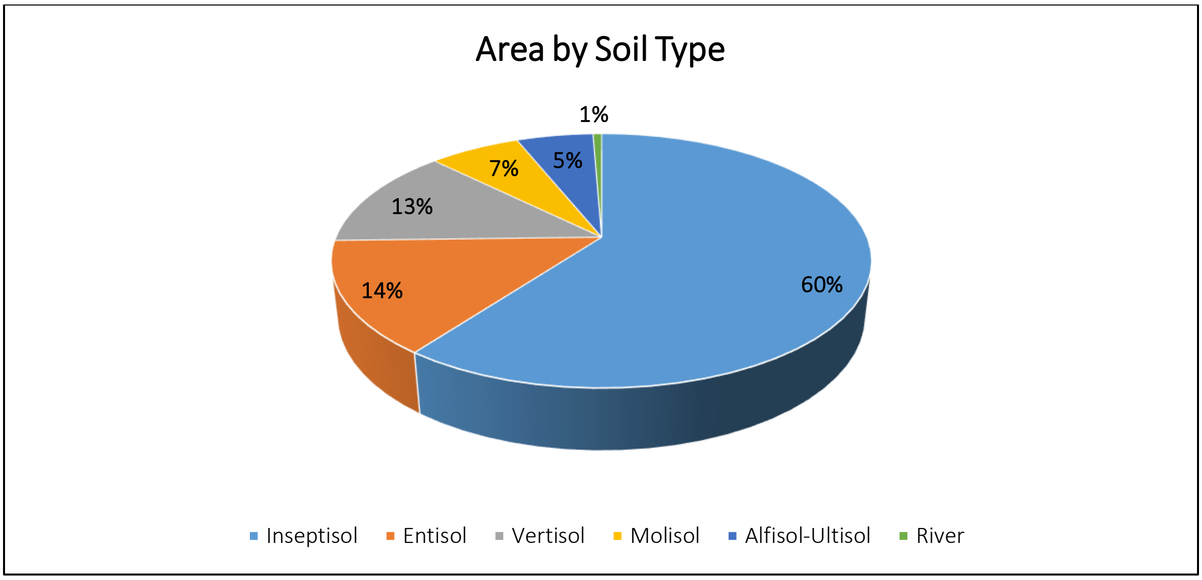


Figure 2.2 Area of Soil Types in Baucau District

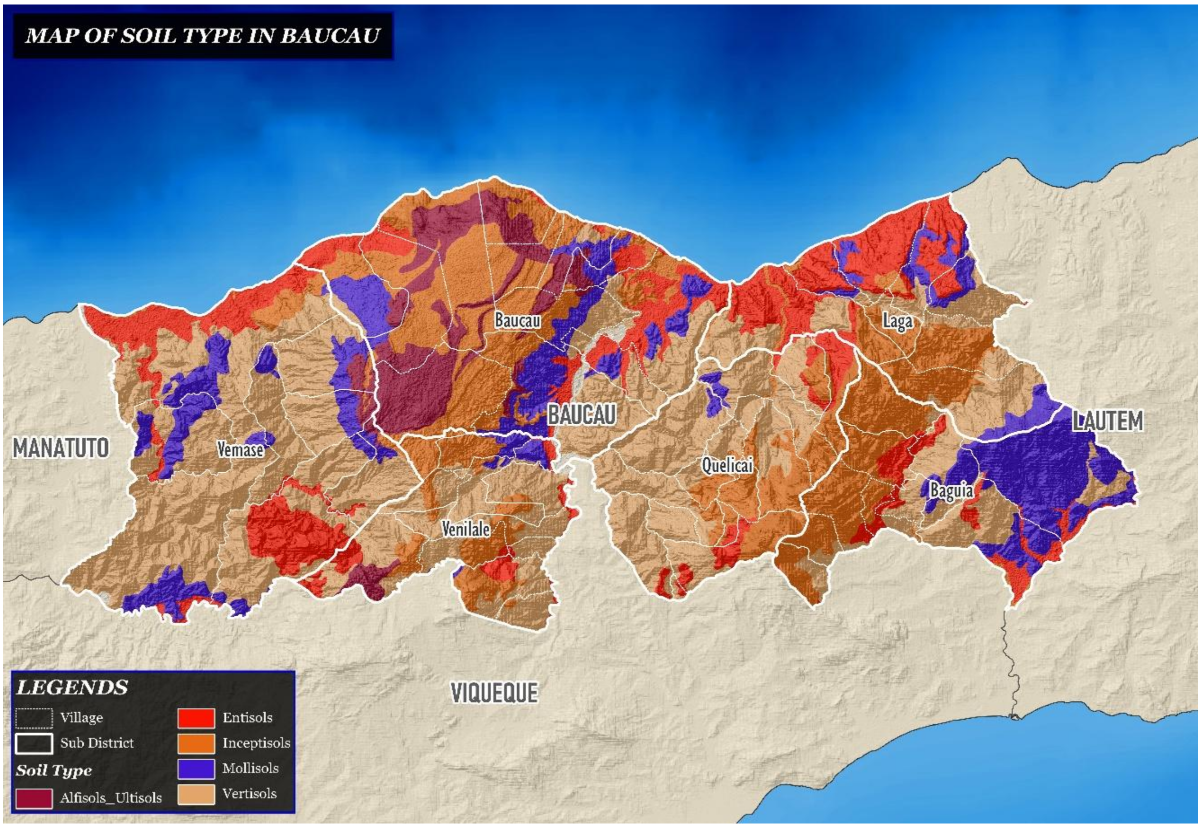


Figure 2.3 Soil Type Map of Baucau District

2.3 LAND USE

Baucau District has diverse land use types that provide an important basis for the development of agricultural and forest commodities. Dominant land uses are forest land with an area of 108,217.4 ha (71.87 %) and agricultural land with an area of 22,237.83 ha (14.76 %). These are followed by unused dry land with an area of 18,567.72 ha (12.33 %), settlements and industrial areas with an area of 952.33 ha (0.63 %), and rural settlements with an area of 614.35 ha (0.41 %). The land use types in Baucau District are presented in **Figure 2.4.**

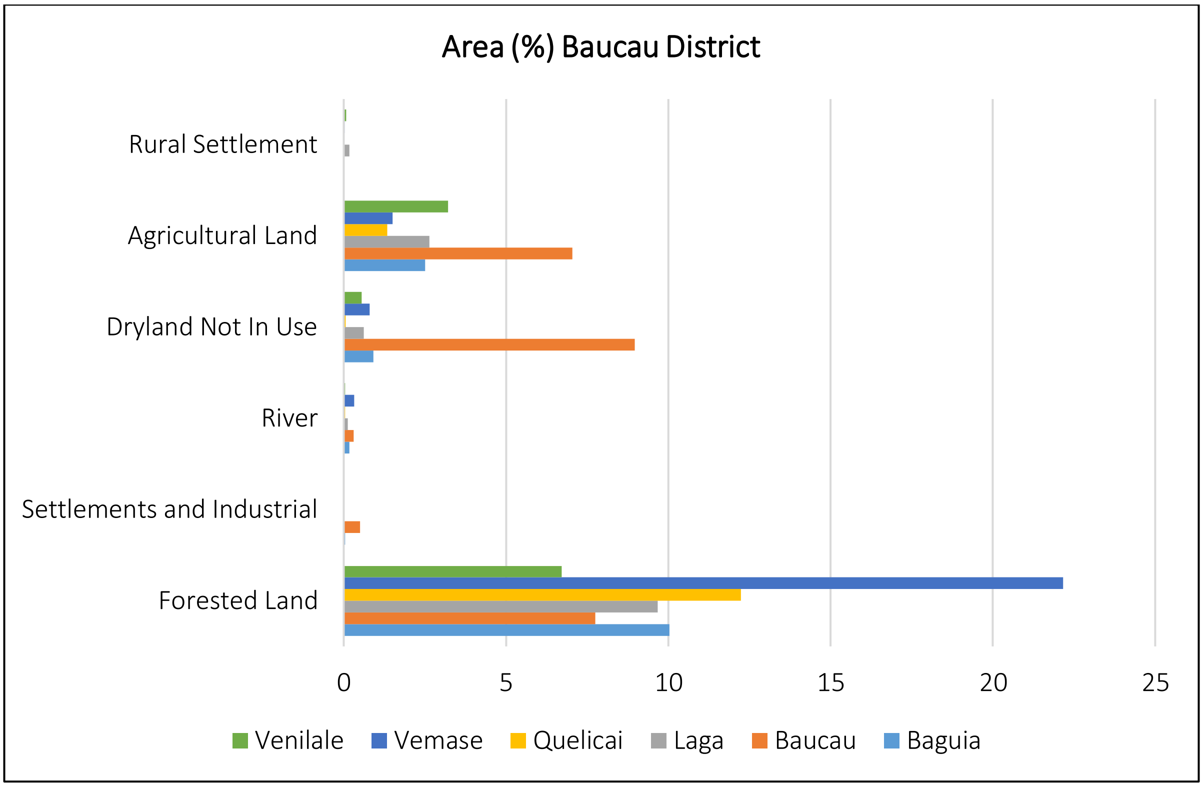


Figure 2.4 Area of Each Land Use Type (%) in Baucau District

Baguia Sub-District had forest covering 10.04 % of its total area and agricultural land covering 2.5 %. The total river area in Baguia Sub-District was 0.8 %, with unused dry land covering 0.92 % and settlements and industrial areas only 0.04 %. Baucau Sub-District had forest covering 7.75 % and agricultural land covering 7.04 %. Unused dry land in this area covered 8.96 %, the river area was 0.3 %, and settlements and industrial areas covered 0.5 %.

Laga Sub-District had forest covering 9.67 % and agricultural land covering 2.64 %, with unused dry land covering 0.61 %. The river area was very small at only 0.13 %, and rural settlements covered 0.18 %.

Quelicai Sub-District had agricultural land covering 1.34 % and unused dry land covering only 0.06 %. Forest cover was 12.24 %, indicating the important role of forests in the local ecosystem, and the river area covered only 0.04 %. The potential of Quelicai for developing forest commodities should focus on sustainable conservation approaches, while existing agricultural land can be optimized through appropriate conservation agriculture practices.

Vemasse Sub-District had agricultural land covering 1.51 % and unused dry land covering only 0.8 %. Forest cover was 22.16 %, the largest forest area in Baucau District, indicating the critical role of forests in the local ecosystem. The river area covered only 0.33 %, and rural settlements covered 0.02 %. The potential of Vemasse for developing forest commodities should focus on sustainable conservation approaches, while existing agricultural land can be optimized through appropriate conservation agriculture practices.

Venilale Sub-District had agricultural land covering 3.21 % and unused dry land covering only 0.56 %. Forest cover was 6.71 %, with the total river area covering only 0.05 % and rural settlements covering 0.07 %. Overall, land use in Baucau District indicates both challenges and substantial opportunities. The dominance of forest land provides room to develop sustainable forest commodities, while the dispersed agricultural land requires sustainable intensification strategies. The land use map of Baucau District is presented in Figure 2.5.

With support from the Ministry of Agriculture, Fisheries, Livestock, and Forestry of Timor-Leste, integrated and data-driven planning is necessary to ensure the optimization of land use, increase agricultural productivity, and support national food security on a sustainable basis.

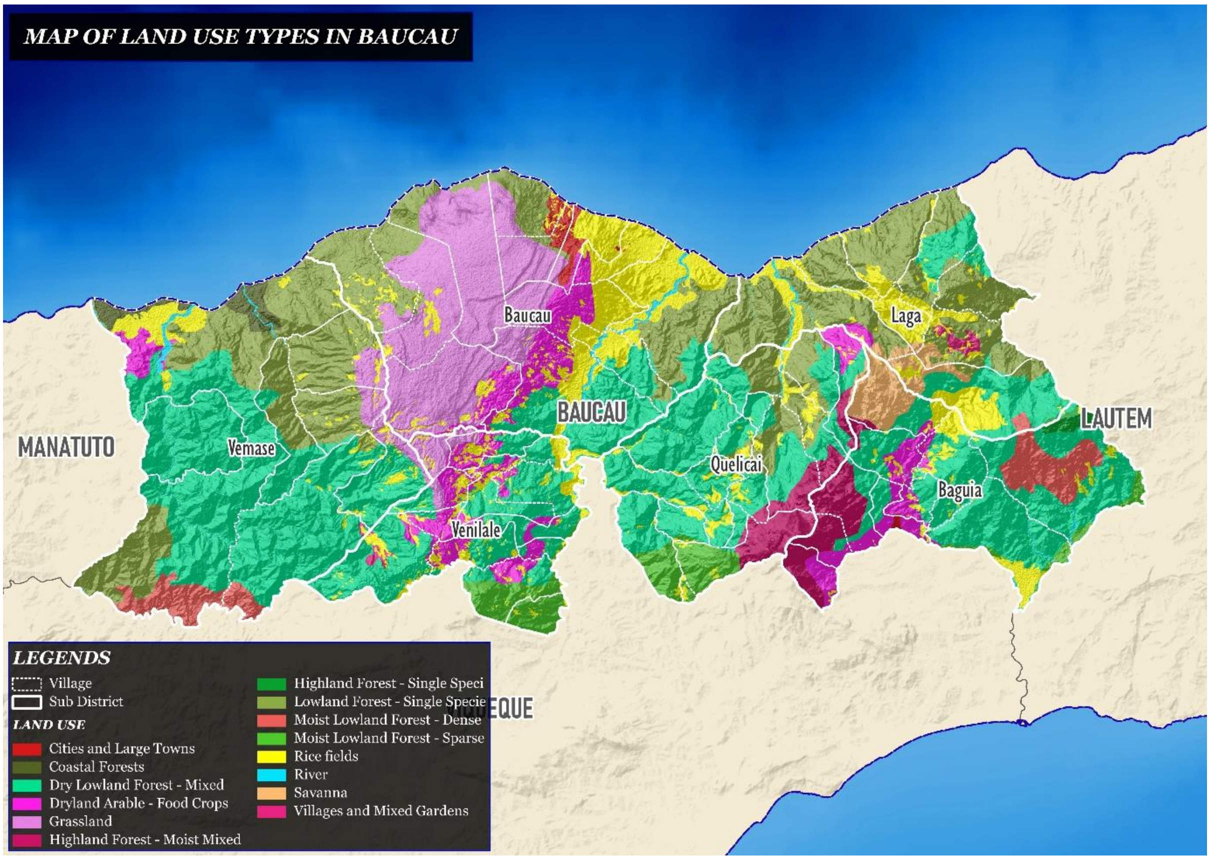


Figure 2.5 Land Use Map of Baucau District

2.4 EXISTING CONDITIONS

The main issue faced in Baucau District is the suboptimal use of water resources for agricultural activities, particularly in Rice fields (**Figure 2.6**). In general, the District is dominated by rainfed Rice fields that produce only one harvest per year. In addition, many Rice fields in highland areas have become unproductive and turned into fallow land. These unproductive Rice fields are often converted into grazing areas or grasslands. The primary problems are inadequate water management and limited water availability. Most agricultural land consists of red soils with low nutrient content. Furthermore, agricultural and forest lands located on steep slope gradients are highly susceptible to erosion.

Figure 2.6 Conditions of Rice Fields in the Field
(Source: Researcher Documentation, 2024)

In addition to areas with potential for developing food commodities on rainfed agricultural land, the study also identified zones suitable for developing irrigated Rice fields in highland areas, where water sources originate from the mountains. In forest lands, several dominant tree species were found, including *Tectona grandis* (teak), *Santalum album* (sandalwood), *Eucalyptus* spp., and *Swietenia macrophylla* (mahogany), which have high industrial value (**Figure 2.7**). Meanwhile, in mixed gardens, commonly found commodities include coconut (*Cocos nucifera*) and breadfruit (*Artocarpus altilis*), with breadfruit being one of the leading commodities in Baucau District.

Figure 2.7 Productive Areas for the Development of Teak, Coconut, Breadfruit, and Productive Rice Fields
(Source: Researcher Documentation, 2024)

2.5 *Chromolaena odorata*

Chromolaena odorata (**Figure 2.8**), commonly known as Siam weed, is a flowering weed in the family *Asteraceae* that thrives in tropical and subtropical regions. The species grows on various soil types, including nutrient-poor marginal lands, with an optimal elevation range of 500 to 2,000 m asl (Westaway *et al*., 2018). It is widely found on dry lands in Baucau District.

Figure 2.8 C. odorata Plants in the Baucau Area
(Source: Researcher Documentation, 2024)

Although regarded as a harmful weed, *C. odorata* has potential to improve soil fertility through plant biomass mixed with manure. Ethnopharmacologically, *C. odorata* has properties for treating burns, diabetes, hypertension, and skin infections, supported by various scientific studies (Jamatia *et al*., 2024). In addition, *C. odorata* biomass can be processed into high-quality vermicompost through biodegradation using the earthworm *Eisenia fetida*.

III. RESEARCH METHODS

This study was conducted in Baucau District, Timor-Leste, with the primary objective of evaluating land suitability for agricultural sector development. Data collection was carried out through field surveys, laboratory analysis, and the use of geographic information systems (GIS). The research activities took place from July to August 2024, with a primary focus on field observation, soil sampling, interviews with local farmers, and GIS-based mapping. Each stage was systematically implemented to obtain accurate information, which could serve as a foundation for sustainable land management planning.

3.1 RESEARCH DESIGN

A. Methodological Approach

This study adopts both quantitative and qualitative methods. The quantitative approach was used to obtain numerical data, which were then analyzed statistically, while the qualitative approach aimed to explore the perceptions of local farmers regarding agricultural practices in the study area (Trigunasih, 2016). The survey was conducted through field observations and laboratory analyses, which included soil data collection and interviews with local farmers.

B. Sample Point Determination

Sample points for this study were determined using the land unit approach, derived by overlaying various thematic maps, including Land Use Map, Soil Type Map, Geology Map, and Slope Map. The analysis and delineation of land units were performed using QGIS 3.10 software (Trigunasih *et al.*, 2023). Soil samples were collected randomly and compositely using the soil boring technique. Each land unit was represented by one composite soil sample, collected at depths of 0-30 cm for annual crops and 30-60 cm for perennial crops. Each soil sample was approximately 1 kg and was analyzed further in the laboratory.

C. Soil Morphology Observation

During soil sampling, environmental conditions around the sampling sites were observed and recorded using soil observation forms. The parameters observed included soil color, texture, structure, consistency, and drainage conditions. For further analysis, ring samples were used to obtain undisturbed soil samples to measure bulk density (BD) and soil porosity, which are indicators of soil fertility and water retention capacity (Sukarman *et al.,* 2017).

D. Interviews and Questionnaires

In conjunction with the field survey, interviews and questionnaires were systematically conducted with farmers using purposive sampling or judgmental sampling, based on the respondents' experience and expertise in agricultural land management (Sekaran & Bougie, 2013). The data collected included information on crop patterns, agricultural challenges, and the land use systems in place in the study area.

E. Evaluasi Kesesuaian Lahan

The results from the field surveys, climate data, and laboratory analyses were tabulated and evaluated using an agroecosystem land suitability evaluation system based on the criteria of Ritung *et al*. (2011). The land suitability classification method applied was based on the FAO system (1976), using a matching approach to compare land characteristics with the requirements of the evaluated crops. The agricultural commodities studied in this research included food crops, horticulture, forestry, industry, livestock feed, and grazing areas.

3.2 RESEARCH PROCEDURE

A. Literature Review

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

B. Land unit Analysis

The land unit analysis aimed to identify land units for planning field observation. The land units derived from this analysis served as a reference for soil sample collection and land suitability mapping. The land unit analysis process included:

a. Interpretation of Digital Elevation Model (DEM) maps to support land unit analysis and delineation based on landform and slope gradient.
b. Satellite image analysis to confirm actual land use, particularly in developed areas such as Rice fields, settlements, and other infrastructures.
c. Utilization of Supporting Data such as slope maps, geological maps, and soil type maps to reinforce land unit mapping.
d. Overlaying of various thematic maps to produce land units for soil sample collection.

C. Field Survey

Field surveys were conducted to verify the actual conditions of land units in the field. If discrepancies between map analysis and field conditions were observed, adjustments were made through re-delineation. Sample points were determined based on the results of land unit analysis and current field conditions.

During the field survey, interviews were also conducted with local farmers to obtain additional information about agricultural practices and the challenges they face in land management. Observations also covered environmental factors that influence agricultural productivity, such as soil drainage, effective soil depth, erosion risk, flood risk, and surface rock content (Ritung *et al.,* 2011).

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

Table 3.1 Relationship between 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 the properties or characteristics of the soil samples analyzed in the laboratory are:

a. Organic carbon (C-organic) by the Walkley and Black method (%).
b. Total nitrogen (N-total) by the Kjeldahl method (%).
c. Soil texture by the pipette method.
d. Soil pH by the potentiometer method (H_2O 1:2.5).
e. Available phosphorus (P-available) and potassium (K-available) (ppm) by the Bray-1 method, if the soil pH is below 7, and by the Olsen method if the soil pH is above 7, with unit conversion to (mg/100 g).

f. Salinity (dS/m) by the potentiometer method (H_2O 1:2.5).
g. Cation exchange capacity (CEC) (cmol) and base saturation (KB) (%) by NH_4OAc extraction at pH 7.
h. Total Phosphorus (mg /100 g) using the 25 % HCl method
i. Total Kalium (mg/100 g) using the 25 % HCl method
j. Soil fertility status determination based on the PPT method (1995).
k. Erosion hazard using the Universal Soil Loss Equation (USLE).

E. Land Suitability Analysis

The results from field observations and laboratory analyses were tabulated to create data on land characteristics/quality for the agroecosystem. The agroecosystem land suitability analysis was performed by matching land characteristics/quality with the growth requirements of bamboo, teak, mahogany, pine, coffee, cacao, and coconut, leading to the determination of land suitability classes based on Ritung *et al.* (2011) criteria. The land suitability classification was analyzed down to the land unit level.

Land suitability classes were divided into actual and potential suitability. The actual land suitability of each land unit was determined using a matching method between land characteristics/quality and crop growth requirements, without improvements to limiting factors. Potential land suitability was determined considering inputs and management actions to be applied to each land unit, assuming improvements to limiting factors.

F. Agricultural Commodity Development Planning

Commodity planning was based on evaluating the potential land suitability for the agricultural commodities being developed, with the highest suitability class for each crop as the main parameter. Other parameters included the main land use in each land unit and the feasibility of farming activities.

G. Land Use Direction

Land use direction was developed at the land unit level, based on the highest land suitability class, followed by lower suitability classes, addressing limiting factors, and recommending improvement efforts for each land unit in Baucau District. The creation of digital maps using GIS facilitates reading of information. This information includes agroecosystem land suitability, land use direction, and agricultural commodity zoning. The land suitability map was produced based on land units and agroecosystem land suitability classification results.

The land suitability classification for each crop commodity was mapped for the evaluated crop groups. Land suitability for crop commodities was presented in the agricultural commodity zoning map, while land use planning was presented in the land use direction map. A systematic flowchart of the research process is shown in **Figure 3.1.**

H. Data Analysis with Geographic Information Systems (GIS) Technology

The land suitability information system consists of spatial data (land unit maps) and attribute data (land suitability classes). The integration of both components produces information using QGIS 3.10 software, providing land suitability classes for food crops, horticulture, and plantation commodities based on their suitability evaluation. The land suitability maps were compiled, along with the associated database and land resource information, based on data and land suitability criteria in accordance with its use, such as crop varieties, cultivation technologies, and land management.

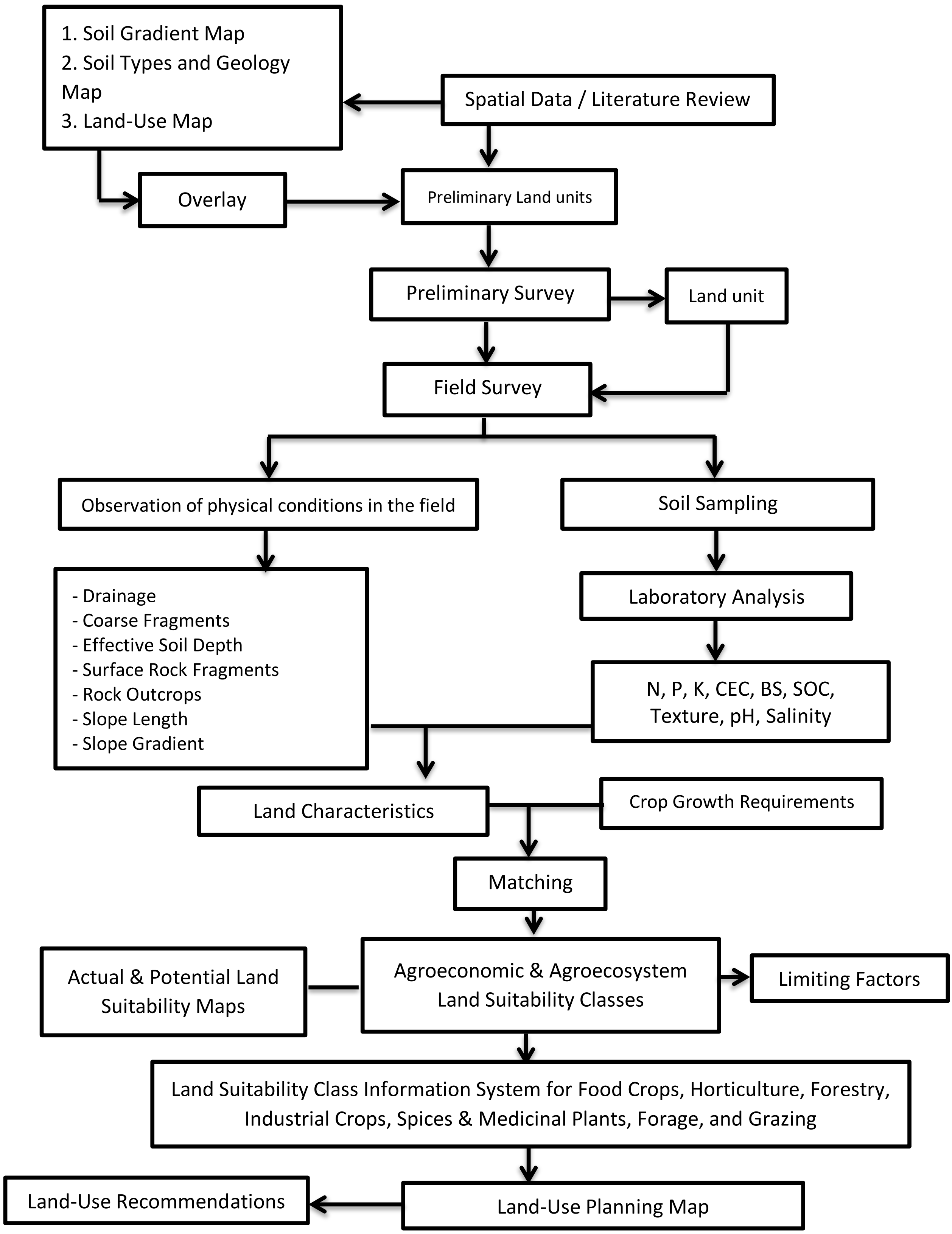


Figure 3.1 Research Process Flowchart

Land use planning maps were obtained based on land suitability classification and commodity zoning. These thematic digital maps inform land use direction for various crop commodities, horticulture, and plantations. The digital maps are the result of converting primary and secondary data and information from raster and analog formats into digital data. The advantage of digital maps includes the ease of editing errors, easy duplication, long-term storage, and the ability to measure distances and areas on-screen without needing field measurements, which are time-consuming and costly (Nugroho and Yarianto SBS, 2010). The produced maps are available in digital format as an analog or hard copy in *.jpeg format, which can be printed, and the digital format as *.dbf or shapefile in *.shp format, which is integrated, easy to copy, and informative. The map border displays the map name, followed by the creator's name, scale, and legend items (land unit, study area, soil type, slope, and land use), source, latitude and longitude coordinates, and the datum system used.

3.3 GEOGRAPHIC INFORMATION SYSTEM TECHNOLOGY

Geographic Information System (GIS) is a system that contains spatially referenced data, which can be analyzed and transformed into information for specific purposes. According to Murai (2006), GIS is a system that can:

1. Collect, store, and display information based on spatial locations.
2. Identify locations within a certain area that meet established criteria.
3. Explore the relationships between various data sets within a particular area.
4. Facilitate the selection and distribution of data for analytical application models that can predict the impact of alternatives on specific conditions in a region.
5. Present a specific area graphically and numerically, both before and after analysis (Murai, 2006).

From various definitions of GIS, several key terms are common: geographically referenced data, data analysis (spatial and attribute) to produce information, and a specific purpose. Therefore, it can be concluded that compared to other systems, GIS has the capability to handle data and information from a geographical perspective, which is particularly relevant in development planning, as planning is carried out within the context of a specific area (region).

The term "Geographic" is part of spatial (or geographical) terms. These terms are often used interchangeably or mixed, resulting in the term "geospatial." All three terms have the same meaning in the context of GIS. The use of the term "Geographic" refers to issues concerning the Earth: its two- or three-dimensional surface (Prahasta, 2005).

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

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

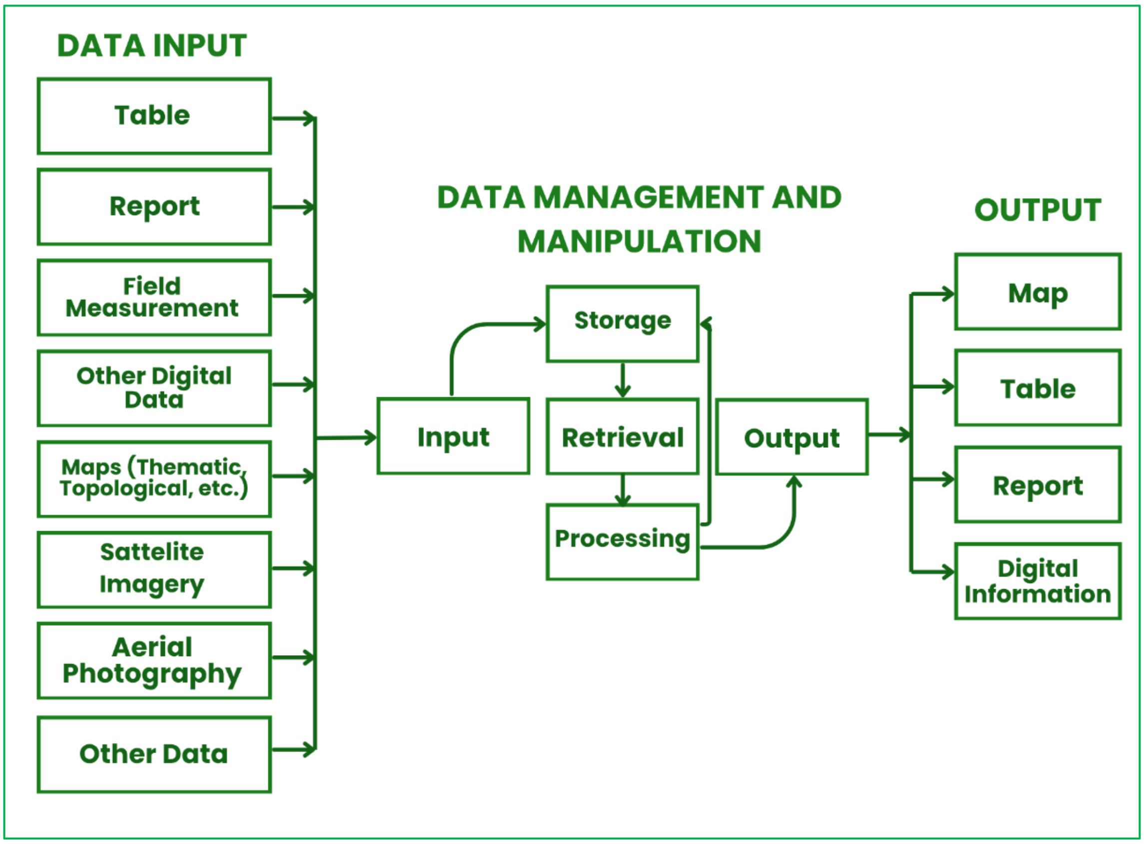


Figure 3.2 GIS Components
(Source: Prahasta, 2005)

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

1. Cartographic Capability

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

2. Data Management Capability

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

3. Analytical Capability

   Analytical capability refers to interpreting and studying collected data and information for specific purposes. This includes engineering function analysis, forecasting abilities, calculation operations, demographic analysis, sociocultural analysis, regional and district analysis, graphic and tabular presentations, overlay analysis, logical analysis, and selection analysis.

4. GIS and Multimedia Integration

   The ability to integrate GIS with multimedia is one of the creative outputs from Bali's local talents. Through the integration of multimedia systems with GIS, the final output of GIS analysis becomes more engaging and easier to understand.

A. GIS Process and Components

GIS essentially performs six processes (Prahasta, 2005):

1. Data Input

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

2. Data Transformation

   The data types used in GIS may need to be transformed or manipulated in various ways to be compatible with the system. For example, if there are scale differences, data must be transformed to the same scale before integration. This transformation can be temporary for display purposes or permanent for analysis.

3. Editing

   The editing stage involves correcting digital data, which may include adding or removing arcs or features, editing excessive arcs (overshoot), or adding missing arcs (undershoot). Editing also includes manually adding arcs, such as creating polygons, lines, or points.

4. Data Management

   After spatial data is entered, the next step is to process descriptive data, including annotation (adding text to coverage), labeling (adding information to maps), and attributing, where each label ID is supplemented with attributes providing information about the polygon or arc it represents.

5. Query and Analysis

   A query in GIS is essentially an analysis process carried out in a tabular format. Fundamentally, analysis in GIS uses spatial analysis. GIS excels in spatial analysis, with two important features:

   a) Proximity Analysis

      This is a geographic analysis based on the distance between layers. Questions such as how many houses are located within a river basin are answered using buffering processes in GIS.

   b) Overlay Analysis

      The process of integrating data from different layers is called overlay. This process requires multiple layers to be physically combined. For example, overlay analysis integrates soil data, slope, and vegetation data or land ownership with tax assessment values.

6. Visualization

   For many geographic operations, the best final output is in the form of maps or graphics. Maps are highly effective for storing and providing geographic information.

B. GIS Components

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

1. Hardware

This refers to the computer system on which GIS operates. Currently, GIS can function on a wide range of hardware, from centralized server computers to desktop computers used as standalone or networked systems.

2. Software

GIS software provides the functions and tools necessary for creating, processing, analyzing, and displaying geographic information. These tools include:

a. Data input and manipulation tools.
b. a database management system.
c. Tools that support query, analysis, and geographic visualization.
d. Graphical User Interface (GUI) for accessing these tools.

3. Data

A key component in GIS is data. Fundamentally, GIS operates using two types of geographic data models: vector data models and raster data models. The vector data model represents, positions, and stores spatial data using points, lines or curves, or polygons along with their attributes. The raster data model represents, positions, 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, which can be at the grid corner, at the center of the grid, or elsewhere. The accuracy of these data models depends heavily on the resolution or size of the pixels (grid cells) on the Earth's surface

4. People

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

5. Methods

A good GIS integrates a well-designed system with real-world rules. The methods and models applied will vary depending on the problem at hand.

C. Data Processing in GIS

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

1. Base Map Digitization

Digitization of maps was carried out on the 1:25,000-scale Rupabumi Indonesia map, which will be used as the base for surveys and map digitization, including data updating. The conversion of data into digital format was performed layer by layer, with topology included.

2. Data Import

Data import was performed on satellite imagery with a format different from the software used for processing. Data format conversion is typically the initial step in image processing.

3. Image Geometry Correction

Geometry correction is necessary to ensure that satellite images have a map reference or coordinate system. This can be done using three methods: image-to-image (previously corrected), image-to-ground, which uses GPS (Global Positioning System) for direct field measurements, and image-to-map.

4. Digital Image Processing

The satellite imagery will be digitally processed to enhance the spatial resolution from the standard 25 m in the multispectral bands to 15 m in color. This process is carried out using a digital image processing model known as image data fusion with the Brovey Transform method. The objective of this process is to facilitate the visual interpretation of planimetric objects, such as transportation networks, rivers, and other planimetric features present in the area.

5. Satellite Image Classification

Another process undertaken was digital classification, enhanced with a knowledge base approach for extracting spatial information on land use. The classification process was performed using supervised classification methods along with filtering processes. This digital classification model, with accuracy far superior to visual grouping by the human eye, was complemented by visual interpretation of data from the Brovey transformation. The digital classification model was carried out by grouping objects identified as samples (sampling areas). The image processing software automatically searches for pixel arrangements similar to the sample area, thus forming distinct classes. The classified image was then field-tested to identify deviations and to verify any questionable pixels. The deviation from the field test must not exceed 3% of the test area. The results from this clarification were used to update the digitized topographic map of Indonesia using the digital light table effect and raster-vector overlay methods.

6. Spatial Information Updating

Spatial information on the map was updated using the raster-vector overlay method, supplemented by a light table effect for interpretation and analysis of spatial land use information. Planimetric spatial information updating was carried out using raster-vector overlay. This integration model involved digital image classification and visual image interpretation to obtain accurate spatial data from the updated results. Certain objects that were deemed important to map but were not clearly visible on the image were mapped using GPS tools during field surveys. The final outcome of this updating process is spatial land use data in a digital GIS format.

7. Field Survey

Field surveys were conducted to correct errors in laboratory interpretations, to gather spatial information about questionable objects on the image, and to plot the position of key objects that could not be extracted directly from the image.

8. Re-interpretasi dan Editing

This task involved correcting inaccurate image interpretations based on fieldwork results. The corrections were made digitally in the laboratory to ensure updated and final spatial information.

9. Edge Matching

Edge matching was performed to ensure the alignment between adjacent map sheets. This process was done digitally across all layers.

10. Digital Cartography and Map Production

Cartographic processes were fully digital to produce standardized map layouts in accordance with established cartographic principles. The cartographic model used in this project adhered to the thematic map model set by the Geospatial Information Agency.

11. Database Development and Modeling

Database development was carried out on all GIS spatial data generated from the work, including land use spatial data, attribute data, and the thematic maps produced.

IV. LAND CHARACTERISTICS

4.1 TEMPERATURE

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

Based on **Figure 4.1**, which shows the air temperature distribution in Baucau District, it can be seen that the 24–26°C category has the largest proportion, at 40%. This indicates that the majority of the region in Baucau experiences relatively warm temperatures, but still within a moderate range. This temperature range generally supports various agricultural activities and local ecosystems in tropical climates.

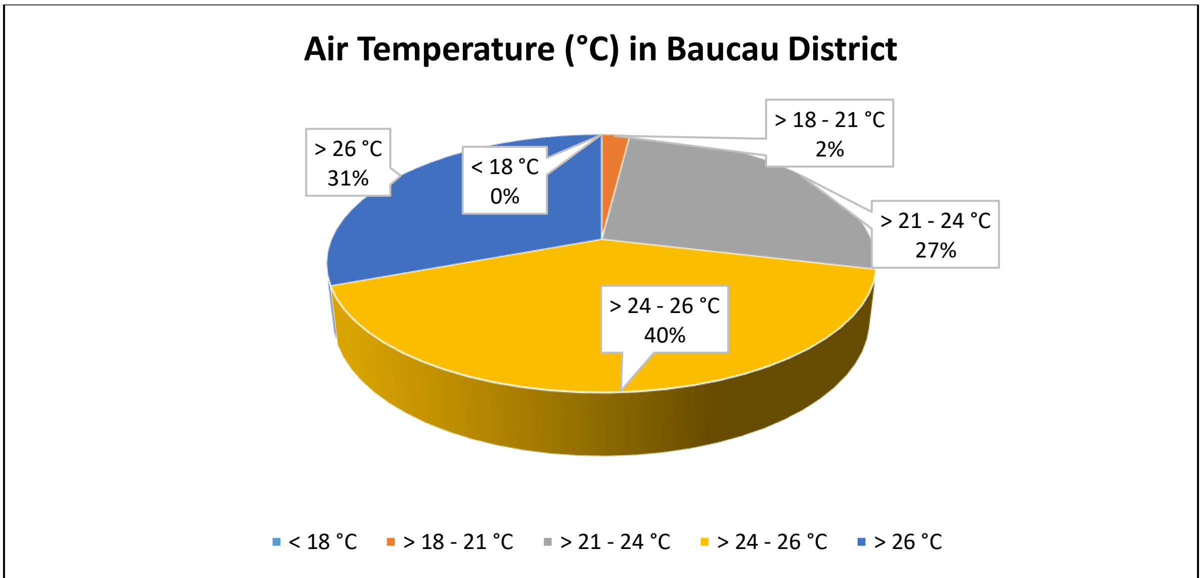


Figure 4.1 Air Temperature Data in Baucau District

The next category, temperatures >26°C, accounts for 31% of the total distribution, indicating that nearly one-third of the region in Baucau experiences higher temperatures, likely due to geographic factors such as low elevation or areas with sparse vegetation. Furthermore, the 21–24°C temperature category accounts for 27%, showing that some areas in Baucau also experience cooler conditions compared to the dominant group.

Interestingly, the 18–21°C temperature category accounts for only 2%, while temperatures <18°C represent 0%. This suggests that cold temperatures are rare or even absent in this region, indicating that Baucau District tends to have a warmer climate compared to other regions with more varied temperature distributions. Overall, the analysis shows that Baucau District is dominated by air temperatures in the 24–26°C and >26°C ranges, reflecting a generally warmer climate. The absence of temperatures below 18°C also indicates that the region tends to have a more stable thermal environment with minimal fluctuations toward colder temperatures.

4.2 RAINFALL

The land characteristics in Baucau District, based on field observations related to rainfall, dry months, drainage, soil texture, slope gradient, and erosion hazard, were analyzed. Field observations of rainfall indicate that Baguia Sub-District predominantly experiences annual rainfall between 1,500 and 2,000 mm, with some areas exceeding 2,000 mm per year. In contrast, Baucau Sub-District predominantly receives between 1,000 and 1,500 mm of rainfall annually (**Figure 4.2**).

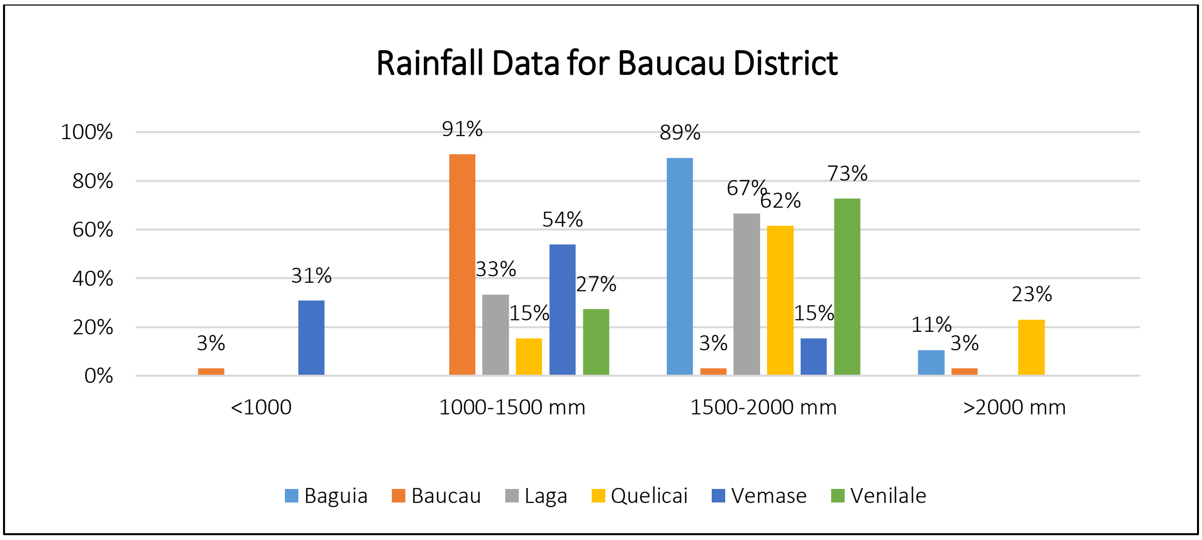


Figure 4.2 Rainfall Data in Baucau District

4.3 DRY MONTHS

Land characteristics based on the number of dry months also show variation across different regions. In Baguia Sub-District, the most dominant category is 5 to 6 dry months, covering 58% of the area, followed by 4 to 5 dry months in 16% of the region, 2 to 3 dry months and >6 months in 11% of the area each, and 3 to 4 dry months in 5% of the area. In Baucau Sub-District, the most dominant categories are 0 to 1 dry month and 2 to 3 dry months, each covering 39% of the area, with 18% of the area having 3 to 4 dry months and 3% with 5 to 6 dry months. Sub-District Laga predominantly experiences 2 to 3 dry months, covering 67% of the area, followed by 0 to 1 dry month and 3 to 4 dry months in 17% of the area each (**Figure 4.3**).

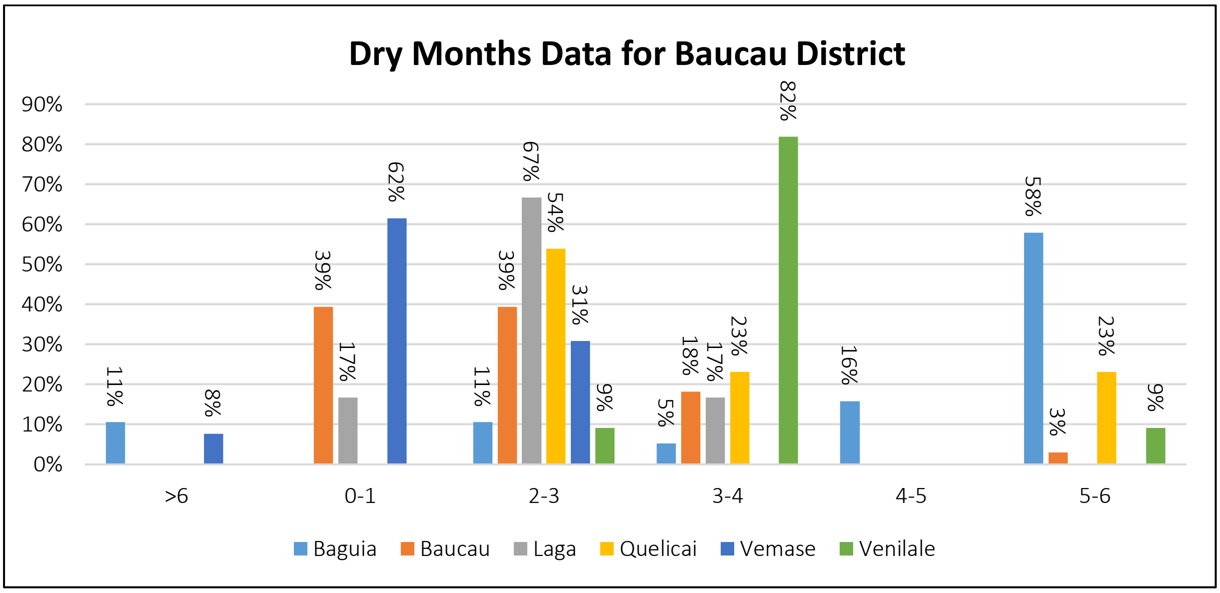


Figure 4.3 Dry Months Graph for Baucau District

In Quelicai Sub-District, 54% of the region experiences 2 to 3 dry months, with 3 to 4 dry months and 5 to 6 dry months each covering 23% of the area. In Vemasse Sub-District, the most dominant category is 0 to 1 dry month, covering the majority of the area, with 31% of the region experiencing 2 to 3 dry months and some areas experiencing >6 dry months. In Venilale Sub-District, 82% of the area experiences 3 to 4 dry months, with 2 to 3 dry months and 5 to 6 dry months each covering 9% of the region.

4.4 DRAINAGE

Land characteristics based on drainage show variation across different regions. In Baguia Sub-District, 74% of the area has good drainage, while 16% has impaired drainage and 11% has moderately impaired drainage. In Baucau Sub-District, 64% of the area has good drainage, while 33% has impaired drainage, and 3% has moderately impaired drainage. In Sub-District Laga, 42% of the area has good drainage, while 58% of the area has impaired drainage (**Figure 4.4**).

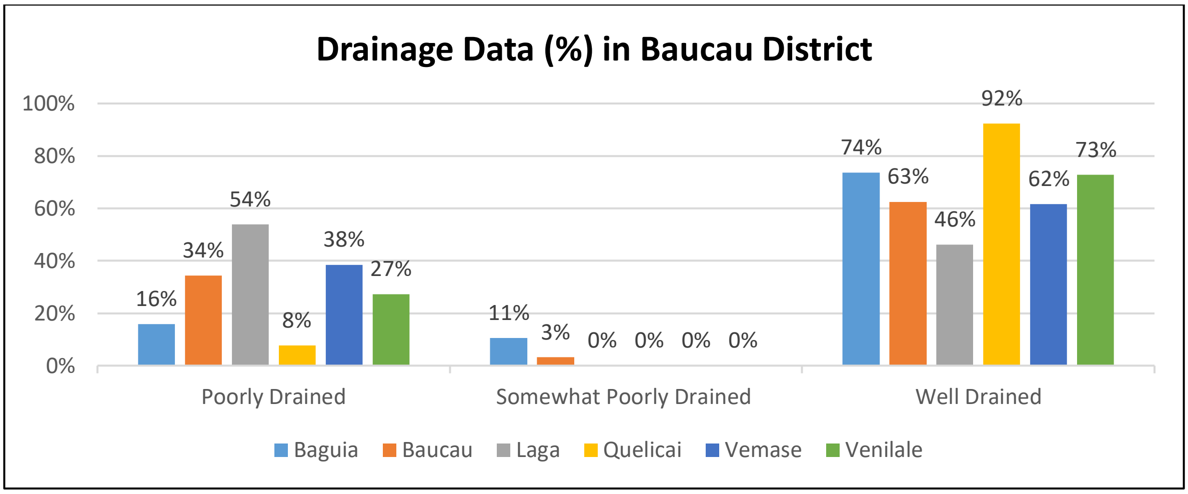


Figure 4.4 Drainage Data (%) in Baucau District

In Quelicai Sub-District, 92% of the area has good drainage, with the remaining 8% experiencing impaired drainage. In Vemasse Sub-District, 62% of the region has good drainage, while 38% has impaired drainage. In Venilale Sub-District, 73% of the area has good drainage, and 27% has impaired drainage. The most dominant drainage class in District Baucau is good drainage, which affects the availability of oxygen in the soil, allowing water to be properly distributed to meet plant water requirements.

4.5 SOIL TEXTURE

The soil texture characteristics in various regions of District Baucau exhibit a range of soil texture classes. In Baguia Sub-District, 53% of the area has a slightly fine texture, while 16% of the area has fine, medium, and slightly coarse textures, respectively. In Baucau Sub-District, 36% of the area has a medium texture, 33% has a fine texture, 27% has a slightly fine texture, and 3% has a slightly coarse texture. In Laga Sub-District, 58% of the area has a medium texture, 33% has a fine texture, and 8% has a slightly coarse texture. In Quelicai Sub-District, 54% of the area has a fine texture, 31% has a medium texture, and 15% has a slightly fine texture. In Vemasse Sub-District, 77% of the area has a fine texture, 15% has a slightly fine texture, and 8% has a medium texture. In Venilale Sub-District, 64% of the area has a fine texture, 27% has a slightly fine texture, and 9% has a medium texture (**Figure 4.5**). Finer soil textures influence organic matter availability and water retention, while coarser textures improve soil aeration.

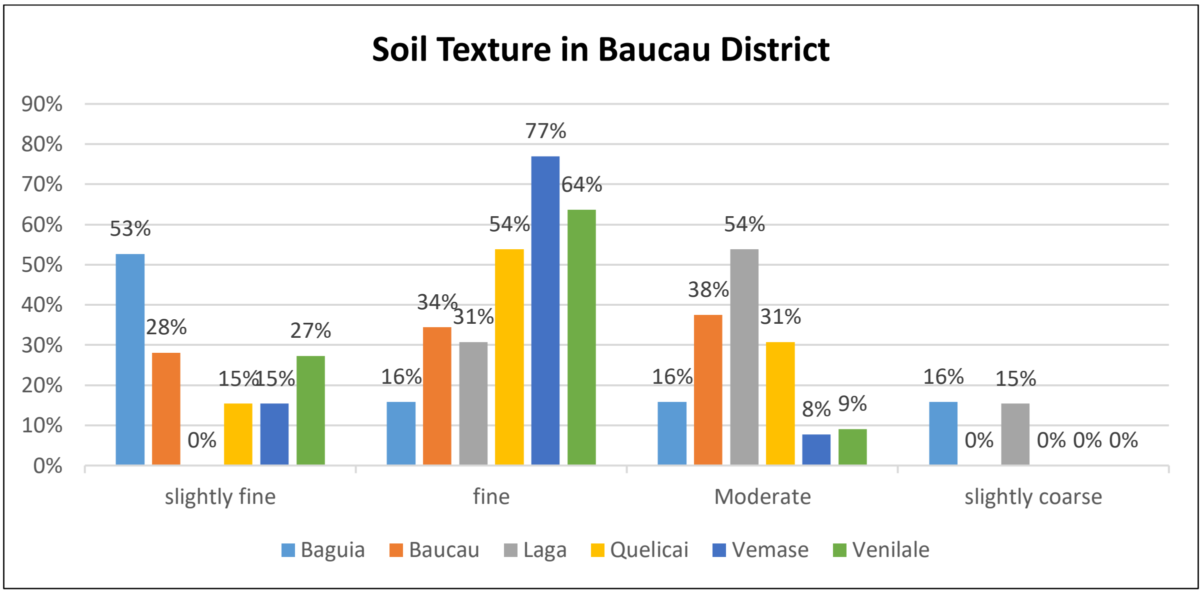


Figure 4.5 Soil Texture in Baucau District

4.6 COARSE FRAGMENTS

Based on **Figure 4.6**, which shows the percentage distribution of coarse fragments in District Baucau, the largest category is <5%, accounting for 45%. This indicates that nearly half of the region has very low coarse material content. Soils with low coarse material content typically have finer textures, such as clay or silty soils, which tend to have better water retention and are more fertile for agriculture.

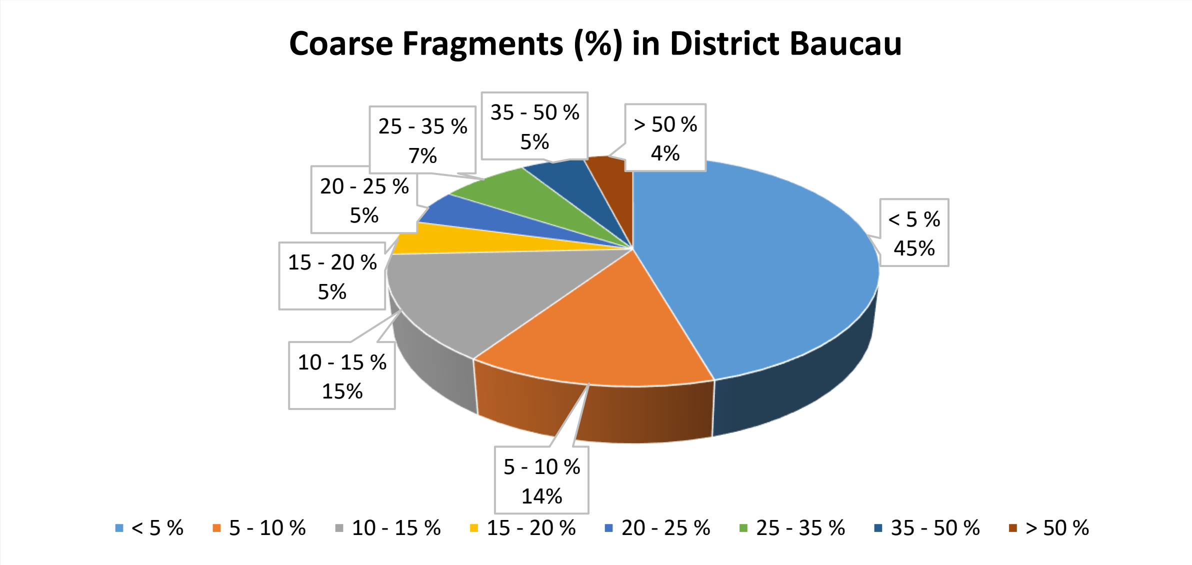


Figure 4.6 Coarse Fragments Data (%) in Baucau District

The next category is 10-15%, covering 15% of the total area. This indicates that some regions have moderate coarse material content, which can contribute to more stable soil structure and support good drainage. Additionally, the 5-10% category accounts for 14%, showing that many areas in District Baucau have relatively low to moderate coarse material content. The categories of 15-20% and 20-25% each account for 5%, while the 25-35% category makes up 7%. These percentages suggest that some areas have higher coarse material content, which may indicate soils with more sand or other coarse fragments. The 35-50% category makes up 5%, while areas with more than 50% coarse material account for 4% of the total area. Soils with high coarse material content often contain a lot of gravel or stones, which can limit plant growth due to the soil's reduced capacity to retain water and nutrients.

The coarse material distribution indicates that most of District Baucau has soils with low to moderate coarse material content, which generally supports agriculture. Soils with low coarse material content (<5%) tend to have good water retention and fertility, ideal for crops like rice, leafy vegetables, and tubers. However, regions with higher coarse material content (>20%) may require better land management strategies, such as proper irrigation and the use of organic fertilizers to improve soil fertility. Overall, District Baucau has good agricultural potential, especially in areas with low to moderate coarse material content. For areas with higher coarse material content, effective soil conservation methods need to be applied to enhance land productivity and prevent soil erosion.

4.7 SURFACE ROCK

Based on **Figure 4.7**, which shows the percentage distribution of surface rock covers in District Baucau, the largest category is 0-5%, accounting for 52%. This suggests that more than half of District Baucau has very low surface rock cover content. Soils with low surface rock cover content are generally easier to till and more suitable for various agricultural activities and other land uses.

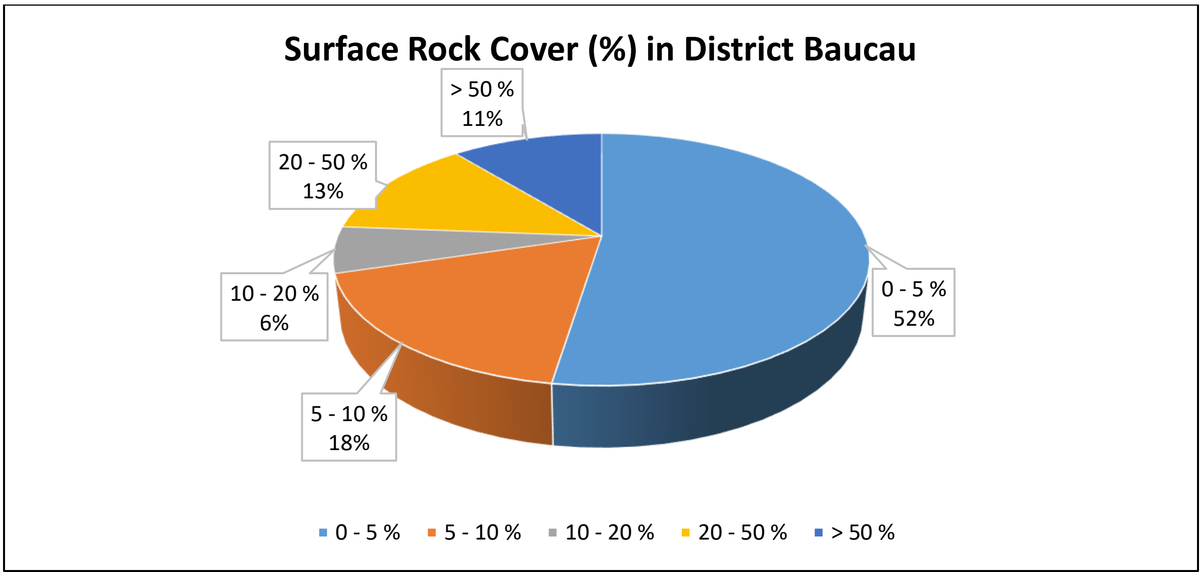


Figure 4.7 Surface rock cover Cover Data (%) in District Baucau

The next category is 5-10%, which accounts for 18% of the total area. This indicates that a significant portion of the region has moderate surface rock cover content, which may still be manageable for agriculture and infrastructure development. The 20-50% category accounts for 13%, showing that some areas have a higher amount of surface rock covers, which can affect land use. Meanwhile, the 10-20% category accounts for 6%, indicating that some areas have moderate surface rock cover content but are not overwhelmingly dominated by it. On the other hand, areas with very high surface rock cover content (>50%) account for 11%, indicating that some regions in District Baucau are dominated by surface rock covers. These areas are likely less suitable for intensive agriculture and may be better suited for conservation or development with specific geological considerations.

The surface rock cover distribution provides important insights into land suitability for agriculture. Areas with 0-5% surface rock cover (52%) have good agricultural potential because they are easier to till and offer higher accessibility. Food crops like rice, corn, vegetables, and horticultural crops can grow optimally in these areas. However, in regions with higher surface rock cover content (10-50%), the soil may be more rocky and less fertile, requiring specialized farming techniques such as the use of stronger mechanized equipment, more efficient irrigation systems, and the addition of organic matter to improve soil fertility. Areas with surface rock cover content >50% may be less suitable for conventional agriculture and are better suited for protected forests, extensive livestock farming, or conservation activities. Overall, District Baucau has substantial agricultural potential, especially in areas with low surface rock cover content. However, for rocky areas, appropriate land management strategies are needed to maintain soil productivity and optimize land use based on its characteristics.

Figure 4.8 Percentage of Relatively High Surface rock covers in the Field, Image Taken in Baucau District
(Source: Researcher Documentation, 2024)

4.8 ROCK OUTCROPS

Based on **Figure 4.9**, which shows the percentage distribution of rock outcrops in District Baucau, the largest category is 0-5%, accounting for 52%. This indicates that more than half of District Baucau has very low surface rock content. Soils with low surface rock content are generally easier to cultivate and more suitable for various agricultural activities and other land uses.

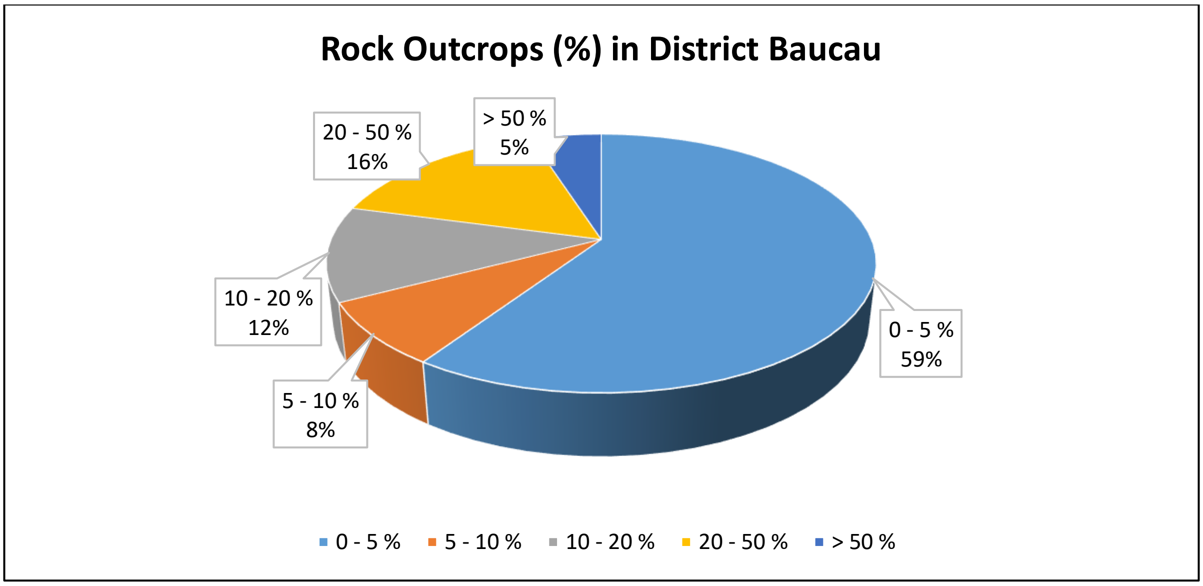


Figure 4.9 Rock Outcrops Data (%) in Baucau District

The next category is 5-10%, which covers 18% of the total area. This indicates that a significant portion of the region has moderate surface rock content, which can still be effectively managed for agriculture and infrastructure development. The 20-50% category accounts for 13%, showing that some areas have higher surface rock content, which can influence land use. The 10-20% category accounts for 6%, indicating regions with moderate surface rock content, though not overwhelmingly dominant. On the other hand, areas with very high surface rock content (>50%) make up 11%, indicating that some areas in District Baucau are dominated by large amounts of surface rocks. These areas are likely less suitable for intensive agriculture and may be more appropriate for conservation or development with specific geological considerations.

The surface rock distribution provides important insights into land suitability for agriculture. Areas with 0-5% surface rock (52%) have good agricultural potential because they are easier to cultivate and have higher accessibility. Food crops such as rice, corn, vegetables, and horticultural crops can grow optimally in these areas. However, in regions with higher surface rock content (10 to 50%), the soil may be rockier and less fertile, requiring special agricultural techniques such as the use of stronger mechanized equipment, more efficient irrigation systems, and the addition of organic matter to improve soil fertility. Areas with surface rock content >50% may be less suitable for conventional agriculture and more suited for protected forests, extensive livestock farming, or conservation activities. Overall, District Baucau has significant agricultural potential, especially in areas with low surface rock content. However, for rocky areas, appropriate land management strategies are needed to maintain soil productivity and optimize land use according to its characteristics.

Figure 4.10 Rock Outcrop Condition in Vemasse Sub-District, Baucau District
(Source: Researcher Documentation, 2024)

V. SOIL FERTILITY STATUS

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

Soil fertility status evaluation is crucial for assessing the types and amounts of nutrients to be applied. This evaluation is carried out by diagnosing nutrient issues in the soil and providing fertilization recommendations. The diversity of chemical soil characteristics can support the life of plants as agricultural commodities, as well as the availability of nutrients in the soil, which is why soil is classified as fertile or otherwise (Utomo *et al.*, 2016). Evaluating soil fertility status is important to assess and monitor soil fertility so that nutrient limitations for plants can be identified. Determining soil fertility status is aimed at assessing soil characteristics and identifying major soil fertility constraints, with status determined based on the criteria set by the Soil Research Centre (PPT, 1995).

Soil fertility evaluation in Baucau District used several parameters, including Cation Exchange Capacity (CEC), Base Saturation (BS), soil organic carbon (SOC) content, phosphorus (P_2O_5) content, and potassium (K_2O) content. The results of the soil fertility evaluation in Baucau District show three fertility status categories: low (red), moderate (yellow), and high (green), as presented in Figure 5.1.

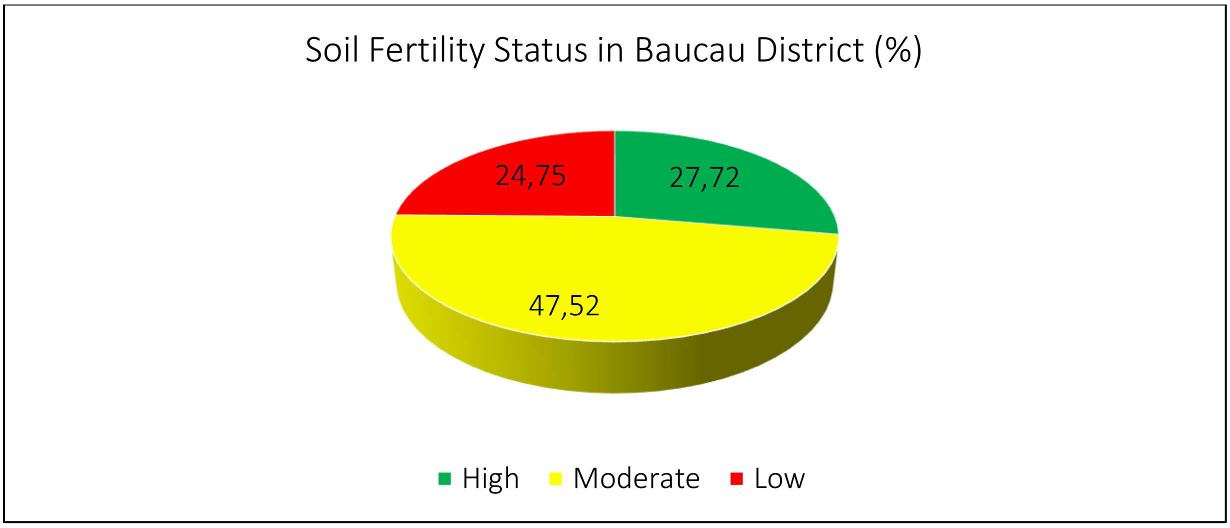


Figure 5.1 Soil Fertility Status in District Baucau

Figure 5.1 shows the total land area categorized by soil fertility status. Analysis results indicate that 47.52% of the land has moderate fertility, which is the dominant category in the region. High fertility land accounts for 27.23%, while low fertility land comprises 25.25%. These data suggest that nearly half of Baucau's land has fairly good agricultural potential with moderate fertility, while more than a quarter of the area contains very fertile soil. However, over a quarter of the remaining area has low fertility, which needs attention for improving land productivity.

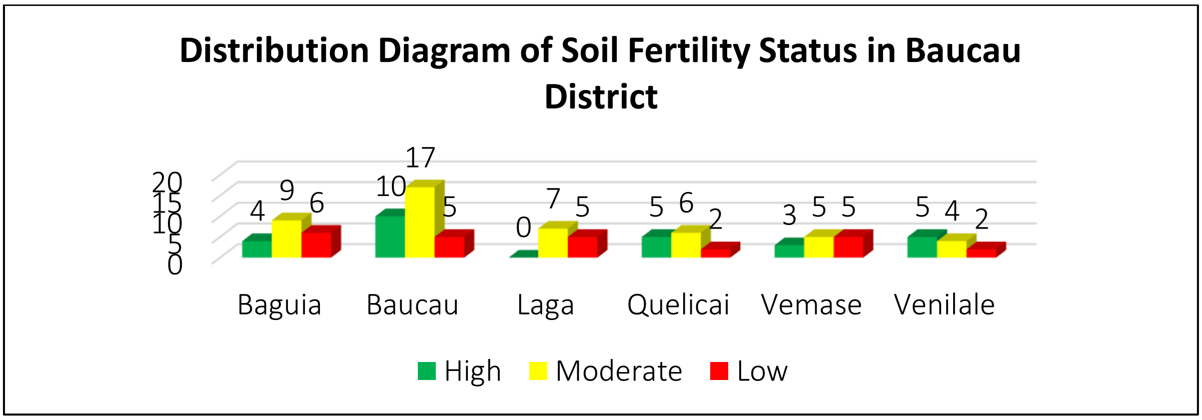


Figure 5.2 Soil Fertility Status in Baucau District

Based on soil fertility distribution data from six Sub-Districts in District Baucau, it appears that Baucau Sub-District has the highest number of land units with moderate fertility, totaling 17 units, followed by Baguia with 9 units, and Laga with 7 units (**Figure 5.2**). This shows that Baucau Sub-District has considerable agricultural potential with fertile land areas. For high fertility soil, Baucau Sub-District also dominates with 11 units, while other Sub-Districts have fewer units. Baguia has 4 units of high fertility land, while Quelicai and Venilale each have 5 units. Vemasse Sub-District has 3 units, while Laga is the only Sub-District without high fertility land, consisting solely of moderate and low fertility categories. Low fertility land is spread across various Sub-Districts, with the largest numbers in Baguia (6 units) and Baucau (5 units). Quelicai and Venilale each have 2 units with low fertility, while Laga and Vemasse each have 5 units of land in this category. Overall, Baucau Sub-District has the best land conditions compared to other Sub-Districts, as it has a combination of high and moderate fertility land in significant quantities. However, there are still some areas with less fertile land that require management for optimal agricultural use.

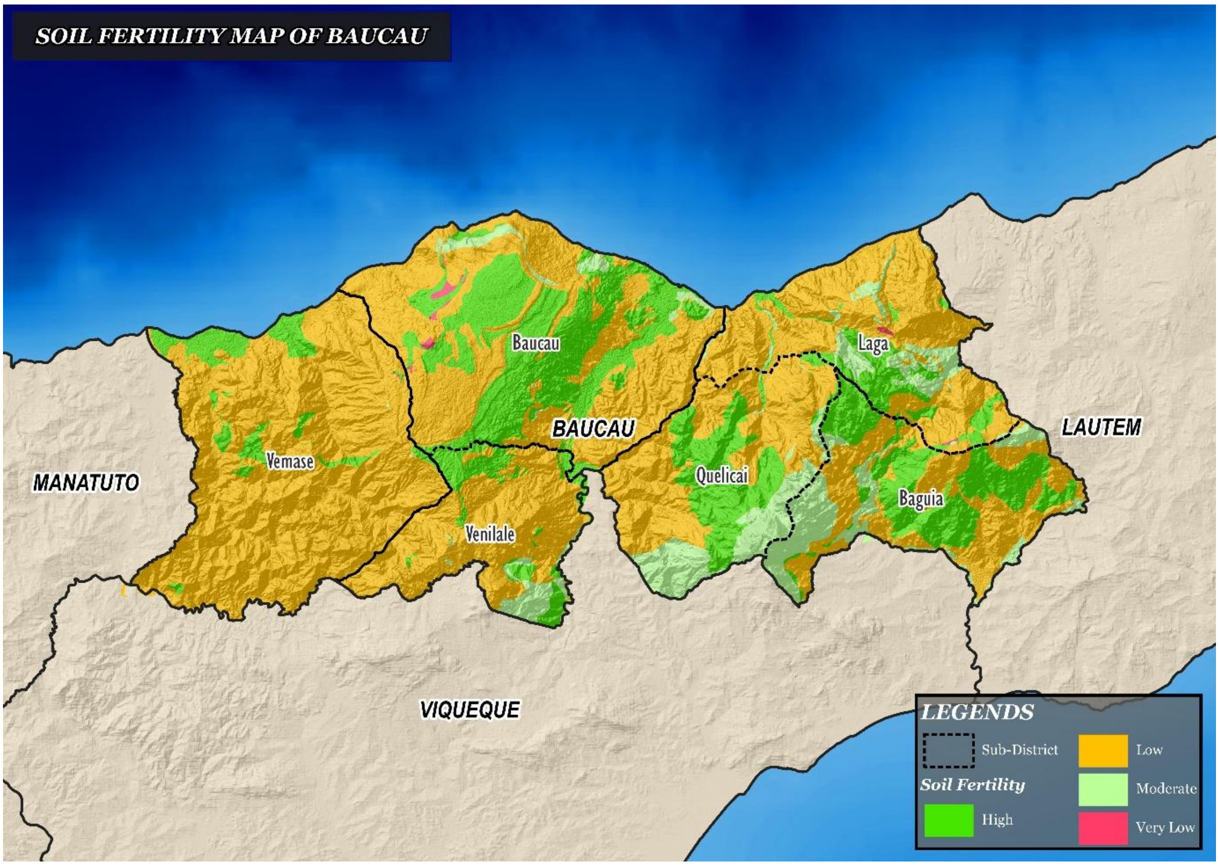


Figure 5.3 Map of Soil Fertility Status in District Baucau

Figure 5.3 depicts the soil fertility distribution in Baucau District based on three main categories: high (green), moderate (yellow), and low (red). From the map, it is evident that the region has a relatively wide distribution of moderate and high fertility land, especially in the central and eastern parts. Meanwhile, low fertility soil is more dominant in the southern and southwestern regions. The presence of rivers and roads also appears to influence the soil fertility pattern, with more fertile areas generally located around water sources. This information is crucial for determining more effective land management strategies for each region.

VI. SOIL EROSION AND CONSERVATION

6.1 SOIL EROSION

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

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

In Baucau District, soil erosion is classified as very severe at 17.93%, severe at 10.76%, moderate at 50.32%, and light at 20.99%. While the percentage of very severe erosion is relatively small, with moderate and light erosion levels being dominant, the region still faces the risk of soil degradation, particularly in rainfed agricultural areas. Soils with low nutrient retention capacity, due to the dominance of sand and limestone rock structures, exacerbate this situation. Erosion data for Baucau District is presented in **Figure 6.1.**

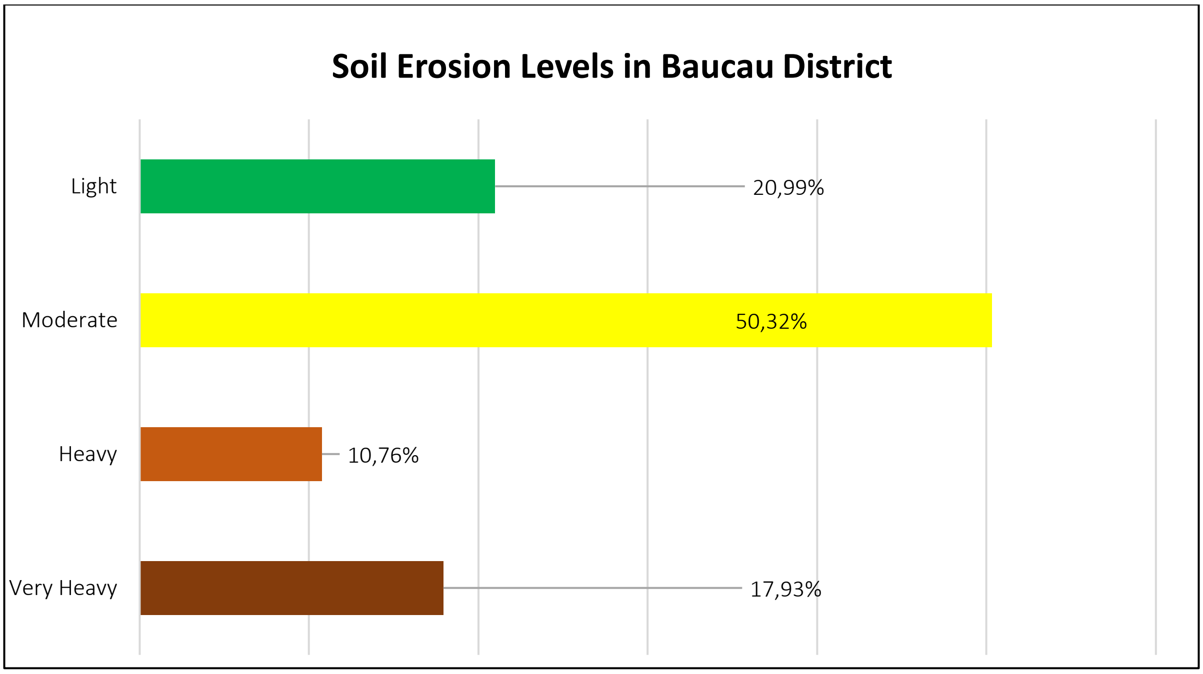


Figure 6.1 Soil Erosion Levels in Baucau District

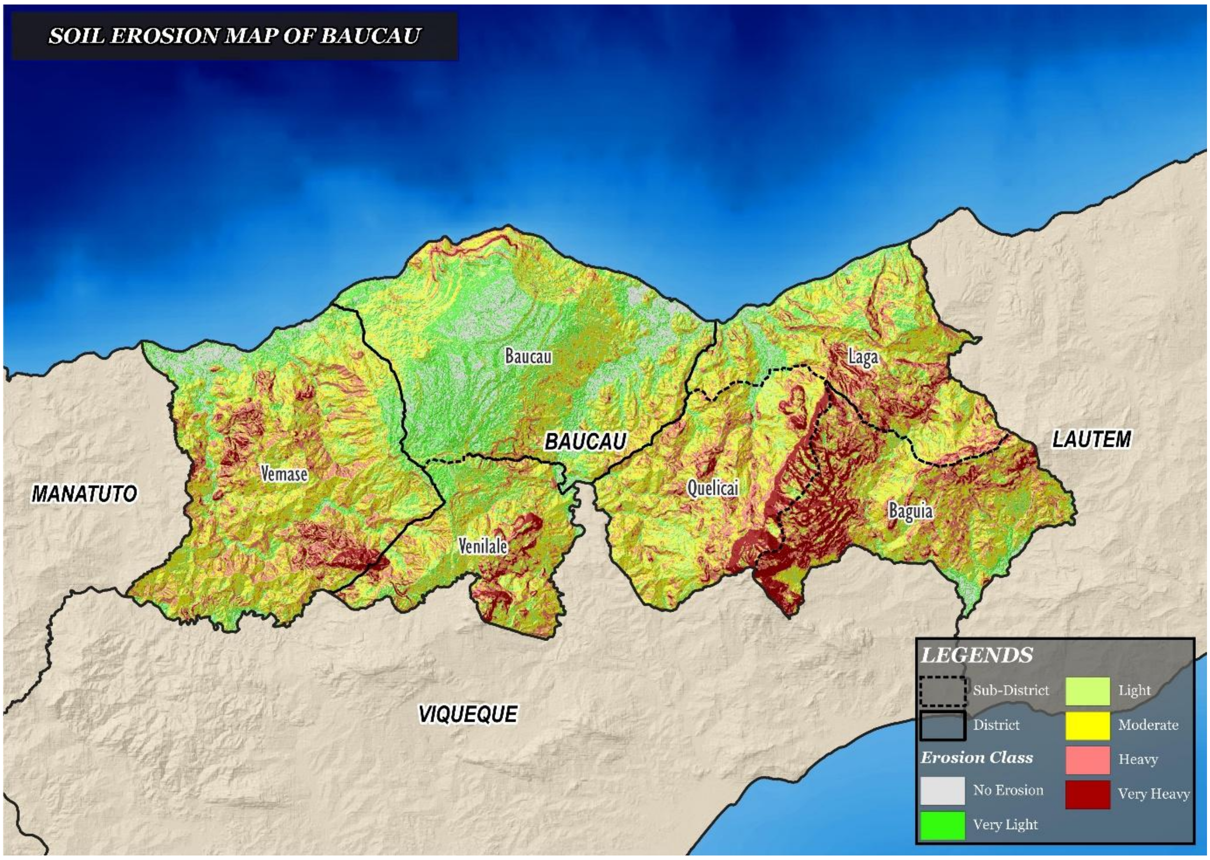


Figure 6.2 Soil Erosion Distribution Map in Baucau District

Soil type plays an important role in influencing erosion levels in Baucau District. The dominance of Vertisols and Inceptisols, which make up much of the soil in the area, provides characteristics that are prone to erosion. Additionally, the steep slope gradients in many areas accelerate surface water flow during the rainy season, increasing erosion potential. As Pimentel and Burgess (2013) explained, erosion caused by steep topography can result in the loss of up to 75% of the fertile soil layer in less than a decade if no conservation interventions are applied.

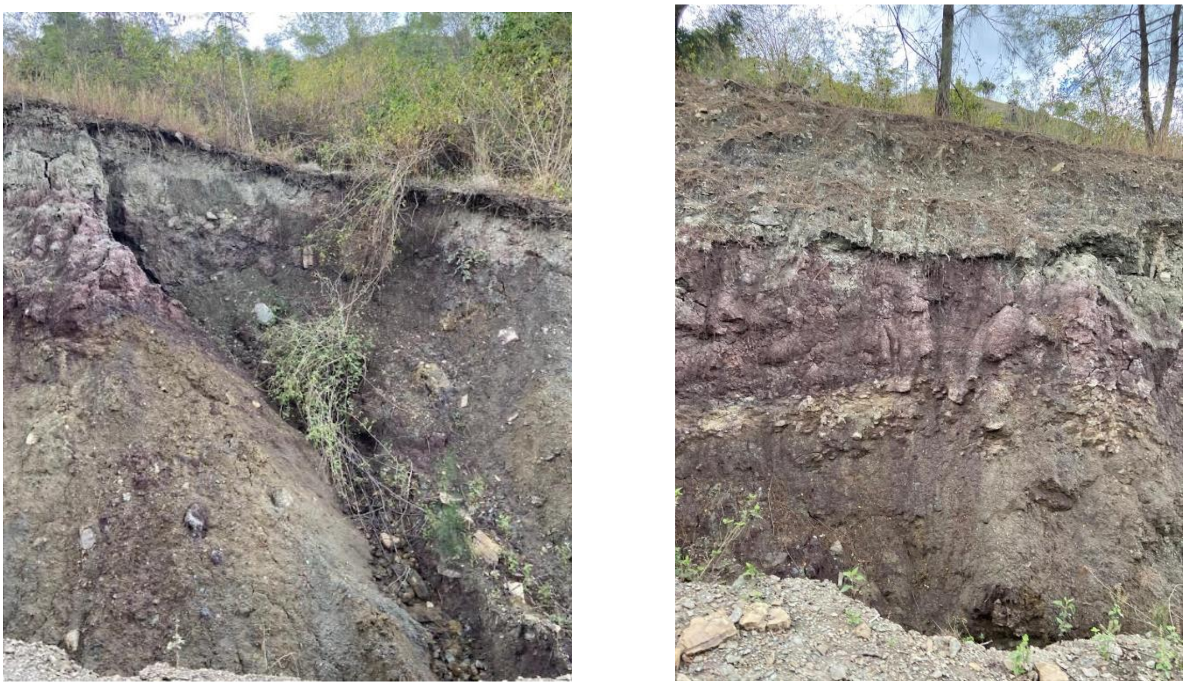


Figure 6.3 Rill Erosion Found in the Baucau Area
(Source: Researcher Documentation, 2024)

6.2 SOIL AND WATER CONSERVATION

Conservation is an effort to manage natural resources sustainably over the long term, aimed at maintaining soil quality and productivity. Conservation plays an essential role in protecting soil from degradation, rehabilitating degraded land, improving infiltration, and maintaining soil fertility.

In Baucau District, conservation efforts are based on slope gradients ranging from flat to very steep (0 to >45%). For slopes ranging from gentle to steep (8 to 25%), which are found in Laga and Quelicai Sub-Districts, optimal land use can include the development of food crops or subsystems, with staple crops such as corn and cassava being prominent in these areas. Agroforestry, combining food crops with shade trees (such as orange, jackfruit, and avocado), is a recommended practice.

For slopes ranging from steep to very steep (25 to 45%), which are highly vulnerable to soil erosion, several conservation measures can be applied. These include optimizing agroforestry by integrating subsistence crops with other perennial crops like cocoa and agarwood, creating terraces to reduce water flow speed, and using cover crops (such as vetiver grass) to stabilize soil and reduce erosion (vegetative measures). The construction of water ponds to reduce surface runoff and collect rainwater is another beneficial approach. The slope map of Baucau District is presented in **Figure 6.3**, and slope data for Baucau District is shown in **Table 6.1**.

Table 6.1 Slope Data for Baucau District

Sub-District	Slope Gradient (%)	Potential Class	Area (ha)	Area (%)
Baguia	>45	Agroforestry	7.134,57	4,74
Baguia	0-8	Highly Potential	57,16	0,04
Baguia	15-25	Moderately Potential	2.090,25	1,39
Baguia	25-45	Agroforestry	10.696,33	7,10
Baguia	8-15	Potential	614,69	0,41
Baucau	>45	Agroforestry	1.673,63	1,11
Baucau	0-8	Highly Potential	22.908,26	15,21
Baucau	15-25	Moderately Potential	6.502,38	4,32
Baucau	25-45	Agroforestry	4.520,20	3,00
Baucau	8-15	Potential	1.356,62	0,90
Laga	>45	Agroforestry	4.974,44	3,30
Laga	0-8	Highly Potential	5.342,73	3,55
Laga	15-25	Moderately Potential	5.607,17	3,72
Laga	25-45	Agroforestry	3.980,55	2,64
Quelicai	>45	Agroforestry	3.962,50	2,63
Quelicai	0-8	Highly Potential	166,93	0,11
Quelicai	15-25	Moderately Potential	5.915,03	3,93
Quelicai	25-45	Agroforestry	10.576,92	7,02
Vemasse	>45	Agroforestry	6.121,91	4,07
Vemasse	0-8	Highly Potential	6.266,22	4,16
Vemasse	15-25	Moderately Potential	8.578,96	5,70
Vemasse	25-45	Agroforestry	16.396,90	10,89
Vemasse	8-15	Potential	31,16	0,02
Venilale	>45	Agroforestry	2.996,35	1,99
Venilale	0-8	Highly Potential	1.061,69	0,71
Venilale	15-25	Moderately Potential	4.765,13	3,16
Venilale	25-45	Agroforestry	6.077,91	4,04
Venilale	8-15	Potential	212,69	0,14

The potential classes in Baucau District and their varied uses must be adapted to the land conditions, ensuring that conservation actions are taken with a focus on sustainability. This approach will help maintain the area's condition and improve the well-being of local farming communities. Given the regional conditions and existing commodities, appropriate conservation efforts and the selection of Potential plants for different slope gradients are essential.

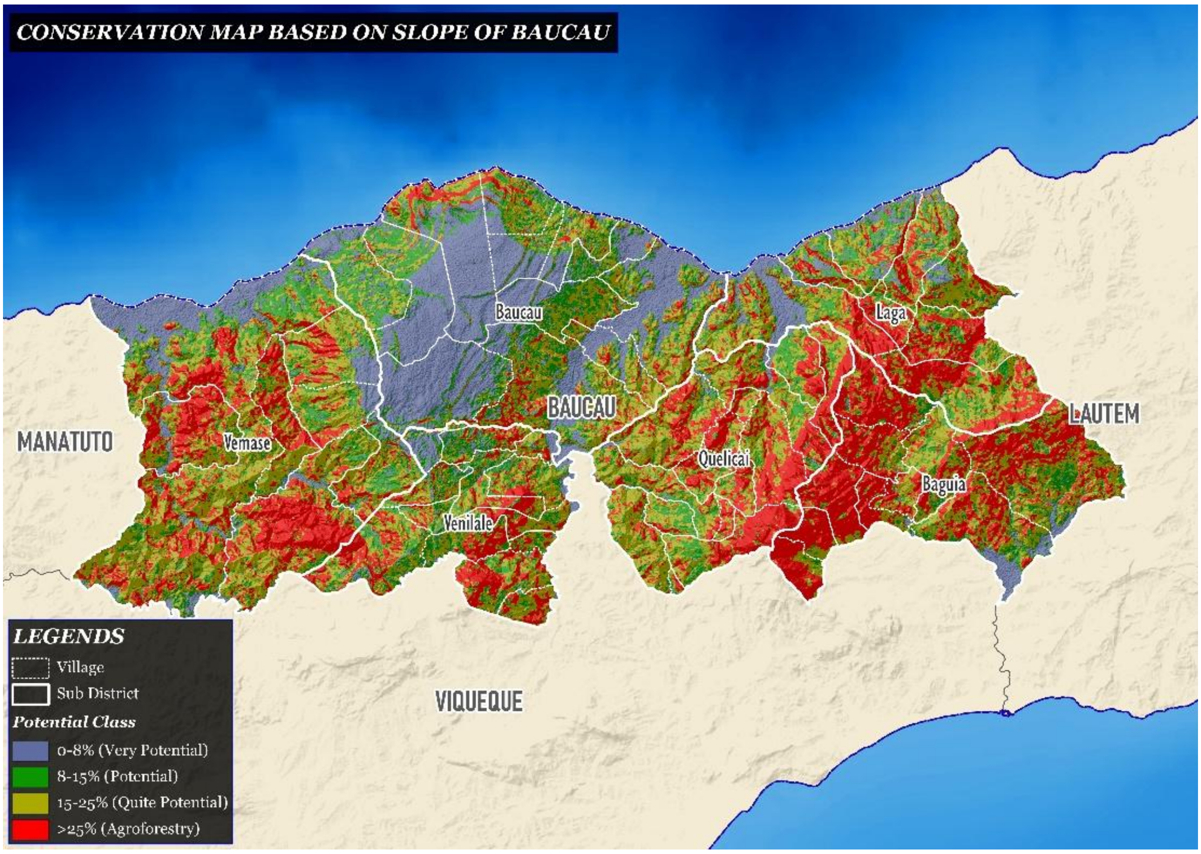


Figure 6.4 Conservation Map Based on Slope Gradient in Baucau District

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

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

1. Agro-silviculture system: the integration of trees and specific food crops on the same land.
2. Silvopastoral system: the combination of tree cultivation and forage crops to support livestock husbandry.
3. Agrosilvopastoral system: the planting of tree crops, food crops, pasture, and livestock on the same land. This system aims to optimize land

production functions but requires intensive management at the subsystem level.

4. Homegarden system: characterized by the intensive cultivation of annual and seasonal crops, typically including vegetables, cereals, fruit trees, grasses, and livestock.
5. Other systems: including the cultivation of multipurpose trees, beekeeping, and aquaculture, all of which can be utilized for various agricultural and non-agricultural purposes. The agroforestry conservation model is presented in Figure 6.5.

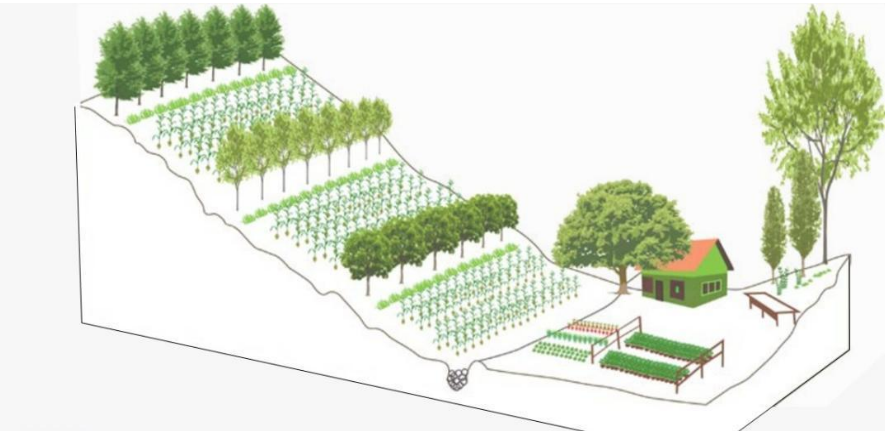


Figure 6.5 Agroforestry Conservation Model
Source: La et al., 2016

A. Importance of Agroforestry Concepts

Agroforestry plays a significant role in the production of local commodities (fuelwood, timber, fruits, and livestock feed) as well as global commodities (coffee, tea, cocoa, rubber, and latex). Agroforestry also has a strategic role in supporting countries through poverty eradication, food security, and environmental sustainability. It enhances farmer resilience and increases household income through the harvesting of a variety of products at different times of the year. The combination of trees, food crops, and livestock helps reduce environmental risks, create permanent ground cover to encounter erosion, minimize flood damage, and improve water retention, benefiting crops and pastureland.

Agroforestry has various benefits, including:

1. **Improved Food Security and Nutrient Enrichment**

Agroforestry provides a diversity of plant species to produce various types of food, contributing to food security. The integration of agroforestry components can increase agricultural productivity and diversify the nutrion available to consumers

2. **Resilient Livelihoods**

The integration of trees, food crops, and livestock can reduce vulnerability to climate disasters and market shocks. Additionally, agroforestry can help prevent pest attacks on monoculture systems by creating a better microclimate. It also influences the impacts of climate change that inhibit agricultural systems and fosters resilient livelihoods.

3. **Climate Change Mitigation and Adaptation**

The integration of various agricultural crops helps mitigate the effects of climate change on the agricultural sector. The use of trees in agroforestry plays a role in carbon sequestration, 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 crops enhance air and water quality. Tree litter can be used as organic material to reduce the use of chemical fertilizers. Deep root systems support nutrient cycling. The components of agroforestry also support biodiversity by creating habitats for flora and fauna within agricultural landscapes.

5. **Poverty Alleviation**

Agroforestry can increase income diversification through the cultivation of commercial crops, timber sales, and livestock-related earnings. This diversification can enhance sustainable agricultural productivity, boost farmers incomes, create job opportunities, and contribute to poverty alleviation and improved community welfare.

B. Agroforestry & Agro-Ecology in Baucau District

The most successful agroforestry systems in Baucau District generally involve the mixed cultivation of fruit trees and timber-producing trees along with spices. The main fruit trees selected include jackfruit, banana, mango, pineapple, and orange. Timber-producing trees commonly planted alongside the fruit trees include mahogany, sandalwood, moringa, and albizia. Agroforestry has adopted a modern approach oriented towards techniques focusing on crop rotation, intercropping, and agro-silvopasture.

Paudel *et al*. (2022) describe the agroforestry model commonly applied in Timor-Leste.

1. Alley Cropping in hilly areas along the contour to reduce landslide occurrence and improve long-term water flow. The concept of the alley cropping system is presented in **Figure 6.6**.

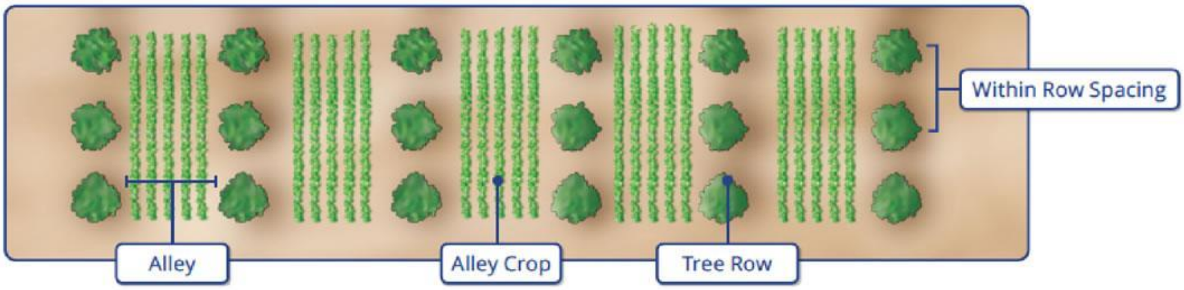


Figure 6.6 Alley Cropping Planting System Concept
(Source: https://www.fs.usda.gov/nac/practices/alley-cropping.php)

2. Hedge Planting involves creating boundaries or fences using trees or shrubs. This practice is largely applied in steep hilly areas to conserve soil. The concept of hedge planting is presented in **Figure 6.7**.

Figure 6.7 Hedge Planting Concept
(Source: https://www.flickr.com/photos/hedgerowmobile/322445711/)

3. Random Planting of both woody plants and annual crops with irregular planting distances in flat lowland areas. The concept of random planting is presented in **Figure 6.8**.

Figure 6.8 Random Planting System Concept
(Source: https://ppid.menlhk.go.id/berita_foto/browse/264)

4. Alternate Row Planting, a regular planting system with seasonal crops planted between rows on flat and large lands.

The agroforestry models that can be applied in Baucau District consist of two models. The first model is the breadfruit agroforestry (timber + fruit + spices), where the main crop managed is breadfruit, and the supporting plants include coconut, jackfruit, orange, mango, papaya, bamboo, areca nut, and pepper. This model is generally applied at elevations between 100 and 500 meters above sea level, with annual rainfall ranging from 500 to 1,500 mm.

The second model is Dragon Fruit agroforestry (timber + fruit + vegetables + others), where the main crop is dragon fruit, with a more diverse range of supporting plants, such as orange, banana, pineapple, cassava, pumpkin, corn, sandalwood, coffee, and leucaena. This model is applied at higher elevations, between 500 and 1,500 meters above sea level, with higher annual rainfall, ranging from 1,500 to 3,000 mm.

Baucau District has six agro-ecological zones (AEZ) based on agro-climatic zones. These zones have biophysical parameters such as elevation, average annual rainfall, and soil types, which are important in selecting Potential crops and agroforestry models for application in Baucau District. The table of agro-ecological zones and main crops is presented in **Table 6.2**. The agro-climatic zone map of Baucau District is presented in **Figure 6.9**.

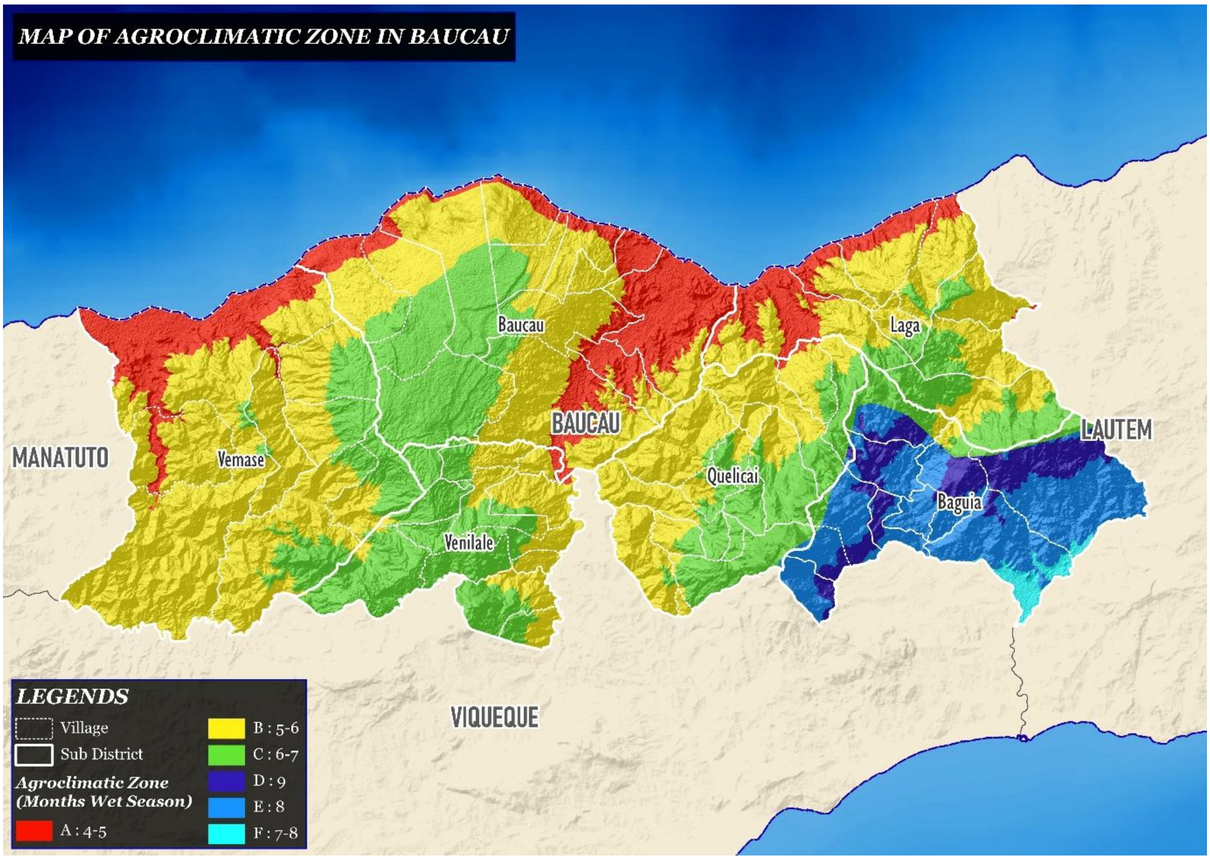


Figure 6.9 Agro-Climatic Zones Map of Baucau District

Table 6.2 Agro-Ecological Zones and Main Crops

Zone	Elevation (m)	Annual Rainfall (mm/year)	Main Crops
A	<100	500-1500	Rice, corn, cassava, coconut
B	100-500	500-1500	Corn, cassava, rice, pigeon pea
C	500-1500	1500-3000	Red beans, coffee, corn, rice, cassava
D	500-1500	500-1500	Corn, cassava, rice, sweet potato, pigeon pea
E	100-500	500-1500	Corn, cassava, rice, sweet potato, pigeon pea
F	<100	1500-3500	Rice, corn, cassava, coconut

The following are recommendations for applying agroforestry based on agro-ecological zones in Baucau District:

1. Zone A

Potential conservation practices include check dams, gabions, contour bundling, biopore holes, riverbank protection, rainwater reservoirs, and drainage systems. Potential plants include mahogany, sandalwood, teak, and timber trees with high economic value.

2. Zone B

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

4. Zone D

Potential conservation techniques include terraces with channels, bench terraces, rainwater reservoirs, drainage systems, grass planting, and check dams. Potential timber species include mahogany and sandalwood, while Potential food crops include corn, cassava, and sweet potato.

5. Zone E

Conservation practices that can be applied include channel terraces, bench terraces, rainwater reservoirs, drainage systems, grasslands, and check dams.

6. Zone F

Potential conservation techniques include check dams, gabions, contour bundling, biopore holes, riverbank protection, rainwater reservoirs, and drainage systems. Potential plants include mahogany, teak, sandalwood, corn, and cassava.

C. Soil Conservation Techniques in Baucau District

Soil conservation techniques are operational and managerial strategies aimed at maintaining and enhancing the production capacity of land vulnerable to degradation. These conservation efforts include preventing or reducing erosion, preserving, and maintaining soil quality. Various soil and water conservation techniques have been widely applied in many regions of Asia, such as converting agricultural land to forest or pastureland, terracing, mulching, and soil management (Huang *et al*., 2022). Timor-Leste's landscape has a slope gradient greater than 40%, covering 44% of its total area, with agricultural land use still being limited (Paudel *et al*., 2022). The following are some soil conservation techniques that can be applied in Timor-Leste (Godinho *et al*., 2023).

1. Check Dam

A check dam is a small, low dam built across a riverbed or other drainage channels to reduce the speed of water flow, reduce erosion, and encourage sediment deposition. Dams help preserve agricultural land and strengthen the structure of retaining dams in hilly and disaster-prone areas. Types of dams include:

a. **Brushwood**, A dam made from wood or branches, typically used for small river channels. It generally has an effective height of around 1 m above the ground, with a minimum foundation depth for the posts of 0.75 to 1 m. The brushwood conservation model is presented in **Figure 6.10**. The steps to build a brushwood dam are as follows:
   1) Dig a trench about 5 cm wide. Wooden posts (150–200 cm) are driven into the ground to a depth of about one-third to half the length of the post, with spacing between posts of 30–50 cm.
   2) The center should be made lower than the sides to create a gap that can capture the maximum water flow.
   3) Branches from trees (mahogany, rosewood, sesbania) and shrubs are woven between the wood until the desired height is reached.
   4) The ends of the woven materials should extend into the sides of the riverbed by at least 30 cm.
   5) The back portion of the dam must be filled with soil.
   6) The sides of the brushwood dam, about 1.5 to 2.0 times the dam's height, should be protected with galvanized wire to prevent erosion and should be installed securely.
   7) Side walls should be constructed to direct water flow into the dam.
   8) Correct the slope of the riverhead to prevent steep gradients that could lead to erosion

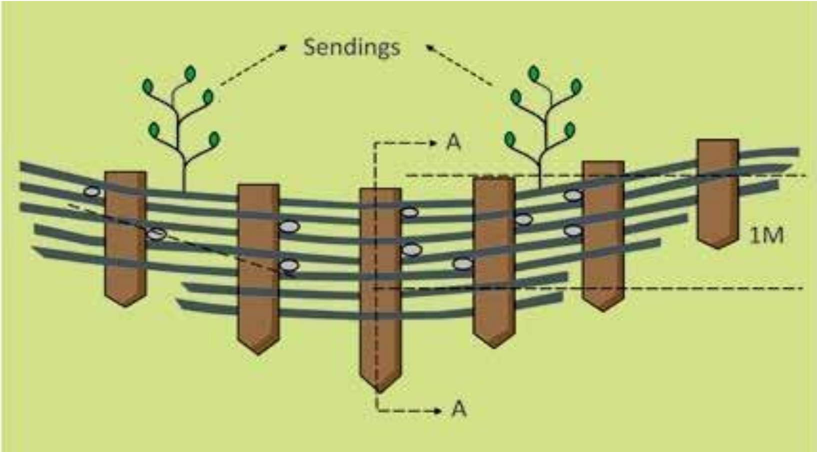


Figure 6.10 Brushwood Check Dam

Source: Godinho *et al*., 2023

b. Loose Stone: Made from loose stones to block small to medium-sized river channels. Boulder is a dam that uses large stones as barriers, based on the same principles as loose stone dams. These dams typically have a maximum effective height between 1 to 2 m, a minimum foundation depth of half the effective height, and a thickness of the discharge channel dam between 0.5 to 1 m. The loose stone model is presented in Figure 6.11. The steps for building a loose stone or boulder dam are as follows:
   1) Clean the site and mark the construction line using string.
   2) Cut the riverbank with a 1:1 slope. The foundation of the wing walls should be >0.5 m. The height of the wing walls should match the depth of the discharge channel.
   3) The dam foundation should be longer than the discharge channel.
   4) For larger dams, two wing walls should be built with appropriate foundations to direct water into the discharge channel or gap and prevent damage to the riverbank.
   5) Boulder stones are used at the gap and downstream sides of the discharge channel. The center should remain low for the discharge channel.
   6) For large volumes of water flow, concrete should be used at the gap and top of the dam, or cover the entire structure with wire mesh.
   7) An apron of stones should be built below the dam.
   8) Large stones should be placed at the bottom of the dam, and stones approximately 50 x 30 cm should be used throughout the dam.

9) The upstream side of the dam should be filled with soil to increase its stability.

Figure 6.11 Loose Stone Check Dam
Source: https://www.flickr.com/photos/mocobio/27742059100

c. **Gabion**: A dam made with hexagonal or square wire baskets filled with stones. The general specifications for a gabion dam include a maximum effective height of <5 m, a minimum foundation depth of half the effective height, and a thickness of the discharge channel dam <1 m. The conservation concept of a gabion dam is presented in **Figure 6.12**. The steps for building a gabion dam are as follows:
   1) The structure should extend at least 0.5 m into the riverbed and must be protected from floodwater with wing walls.
   2) Wing walls with appropriate foundations should be constructed on top to direct water into the discharge channel or gap and prevent damage to the riverbank. The space between the dam and the wing walls should be filled with soil.
   3) The foundation of the dam should be longer than the discharge channel.
   4) Large stones should be placed along the sides of the gabion box, while smaller stones should fill the center. The stones used for construction should be larger than the mesh size (mesh size 10 x 10 cm and 15 x 15 cm).
   5) If debris is present, a concrete layer in front of the dam is required to protect the gabion wire from damage.
   6) The dimensions of the discharge channel should be calculated based on the maximum flow from the river basin.

7) An apron should be built below the dam.
8) The back of the dam should be filled with soil to improve its strength.
9) The gabion boxes should be tied with 12-gauge wire.

Figure 6.12 Gabion Check Dam
Source: https://i.pinimg.com/originals/32/6e/5e/326e5e1d490cc5da1dd6a6ba9bdd477d.jpg

2. Terracing

Terracing is a soil and water conservation method involving the creation of a series of terraces to reduce the length and steepness of slopes. Terracing can directly control water flow and reduce large amounts of soil loss. It changes the continuity of topography and reduces slope length by intercepting runoff and increasing infiltration time. Terracing can also be combined with buffer strips to control soil erosion (Huang *et al.*, 2022). Terracing combined with agroforestry trees can help gradually increase land cover and water infiltration, reduce nutrient loss, and improve crop productivity. Terracing is not Potential for shallow soils. The conservation concept using the terracing system is presented in **Figure 6.13**, and the application of terracing is presented in **Figure 6.15**.

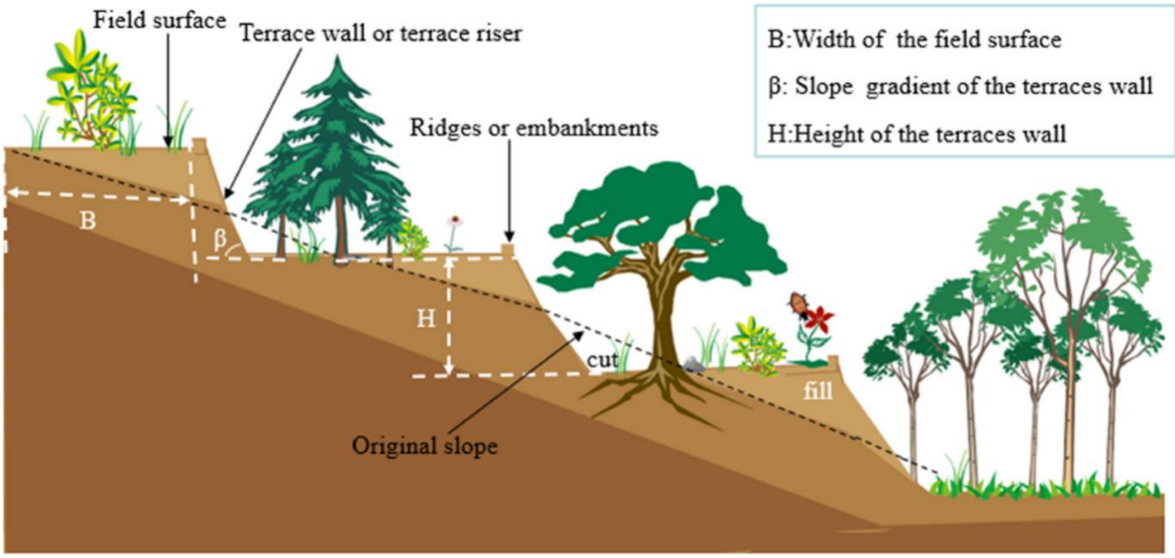
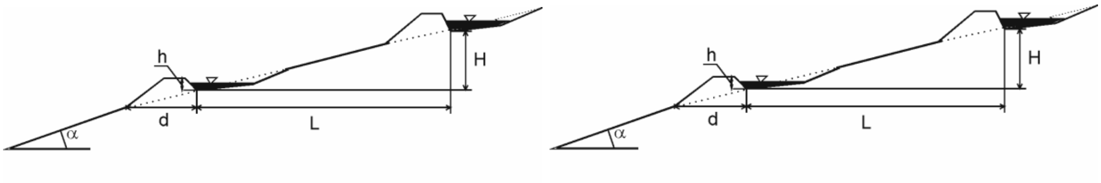


Figure 6.13 Terracing Conservation Concept
Source: (Deng *et al*., 2021)

Several types of terraces based on slope suitability include:

a. **Broad Channel Terraces**, Typically created to capture and direct excess water on fields, these terraces are Potential for wet areas and slopes of no more than 20%.

b. **Ridge Terraces**: Created to capture and hold excess water, spreading it over the land between ridge tops. These terraces are widely used on gentle slopes (<3%) because water is dispersed more evenly without requiring high ridge tops. Ridge terraces have a water channel at the back of the ridge (ridge top) to channel surface water to the discharge channel and improve water absorption into the soil. Ridge terraces divide the slope into smaller hydrological units, which can reduce water flow paths and influence water circulation on the slope and within the entire catchment area. According to Prochal (1984) in Baryła & Pierzgalski (2008), ridge terraces are divided into two types: with and without a drainage outlet. Ridge terraces without water outflow are parallel to the contours and are built on permeable soils with relatively low rainfall. Water flowing over them is retained by reservoirs and absorbed into the soil. Ridge terraces with water outflow feature surface or subsurface drainage. In terraces with subsurface drainage, water is drained through wells or underground pumps to ditches, rivers, or reservoirs. These terraces are used in areas with high precipitation and soils with low absorption capacity. The concept of dividing ridge terraces is presented in **Figure 6.14**.



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

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

Figure 6.14 Concept of Ridge Terraces: Without Outflow (Left); With Outflow (Right)

Source: Baryła & Pierzgalski (2008)

c. **Bench (Step) Terraces**, Bench terraces are used on slopes of 20 to 50% to transform the land into a series of steps separated by vertical walls, which are lined with stones or vegetation for protection. Step terraces can be made flat, inward-sloping (axial slope), or outward-sloping, and are typically constructed in rainfed Rice fields, dryland farming areas, and various agroforestry systems.
d. **Teras Individu**, teras yang dibuat pada setiap individu tanaman, terutama untuk tanaman tahunan. Jenis teras ini biasanya dibangun pada areal perkebunan atau pertanaman buah-buahan.
e. **Individual Terraces**, These terraces are created around individual plants, particularly for perennial crops. This type of terrace is usually constructed in plantation areas or orchards.
f. **Orchard Terraces**, This type of terrace is used for perennial crops, especially in plantation and fruit-growing systems. Terraces are constructed with varying intervals according to plant spacing.

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

1) Terrace length: Typically a maximum of 100 m along the drainage channel for humid tropical climates. The length of the terrace is limited by the size and shape of the land, cutting degree, and soil type.
2) Terrace width: The optimal width ranges from 2.5 to 5 m (manual construction) and 3.5 to 8 m (machine or tractor construction). The width is adjusted based on soil depth, tillage tools, plant types, and other requirements.

3) Terrace gradient: The horizontal gradient of the terrace ranges between 0.5 to 1%, depending on the climate and soil type.
4) Height and slope of the terrace steps: The terrace steps should be made from compacted soil and protected with grass or stones. The height of each step should not exceed 2 m. The Vertical Interval (VI) between consecutive terraces can be calculated using the following formula:

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

Where:
S = Slope (%)
Wb = Bench width (m)
U = Step slope (m)

Figure 6.15 Application of Terracing Conservation
Source: https://www.freepik.com/

3. Biopore Infiltration Holes

Biopore holes are cylindrical holes drilled into the soil to improve water infiltration, reduce flooding, convert organic waste into compost, reduce 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, thereby enhancing soil moisture and maximizing groundwater reserves. In addition, biopores can improve soil fertility by converting kitchen and garden waste into compost.

Biopore holes can be made by digging or using a drill to create holes with a depth of 30 to 100 cm. The spacing between holes should be around 0.5 to 1 m. Biopore holes around trees can be arranged in a triangular pattern with three holes surrounding each tree. The edges of the holes need to be reinforced with cement or short PVC pipe sections to prevent erosion. Only organic waste (kitchen waste and/or garden waste) should be placed in the holes. The waste should not be too compact, as this will hinder the water infiltration process. The compost produced usually takes 2 to 8 weeks. The concept of applying biopore infiltration holes is presented in **Figure 6.16.**

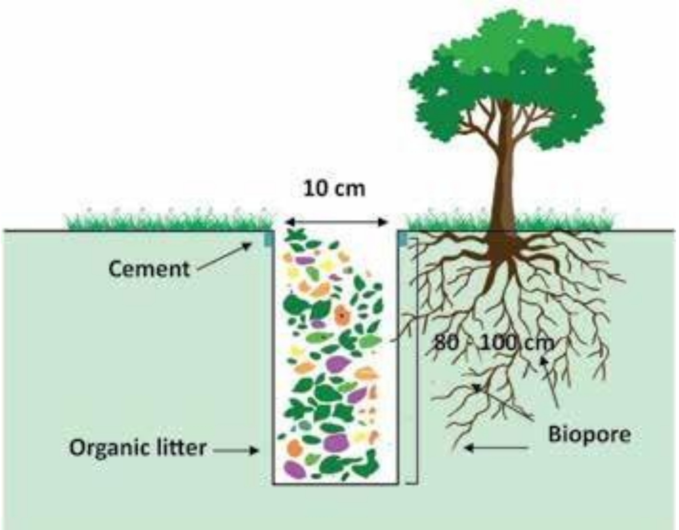


Figure 6.16 Biopore Infiltration Holes
Source: Godinho *et al*., 2023

4. Riverbank Protection

Riverbank protection is a soil and water conservation technique applied along riverbanks to prevent landslides, reduce soil erosion, improve water quality, and reduce sedimentation. Riverbank protection can be implemented in open riverbank areas susceptible to erosion and landslides, steep riverbanks, bare riverbanks, and areas with high rainfall. Riverbank management can involve planting grass, shrubs, and trees with deep roots and dense canopies or installing bamboo frames. The concept of riverbank protection with vegetation is presented in **Figure 6.17.**

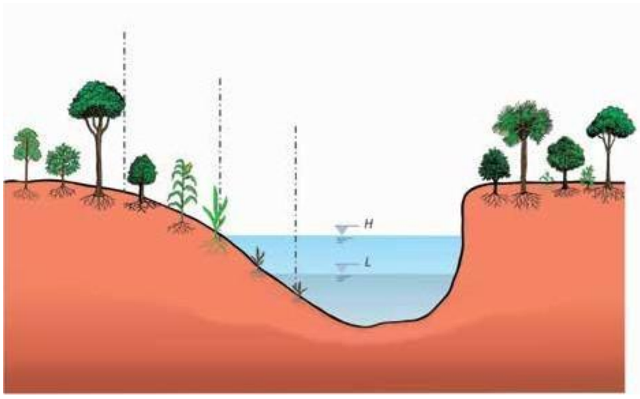


Figure 6.17 Riverbank Protection with Various Layers of Trees, Shrubs, and Grasses
Source: Godinho et al., 2023

5. Grass Planting

Grass planting is used to control soil erosion. The fibrous root system of grasses can form a dense mass of lateral roots, which interconnect to strengthen, hold, trap, and reinforce the soil. Grasses with deep, strong, dense, and fibrous root systems can penetrate and bind soil particles, thus reducing sedimentation. Grass can also be a functional component of the system, promoting the formation of terraces even on steep slopes (Do *et al.*, 2023).

Grass planting can be done in three ways:

a. Horizontal/Contour Grass Lines: This method is used on slopes <65 degrees and land prone to erosion. On slopes <30 degrees, planting distance should be 1 x 1 m with 10 x 10 cm spacing. For slopes of 30 to 45 degrees, planting distance should be 50 x 50 cm with 10 x 10 cm spacing, and for slopes >45 degrees, a planting distance of 30 x 30 cm with 10 x 10 cm spacing is recommended. The concept of horizontal/contour grass planting is presented in **Figure 6.18**.

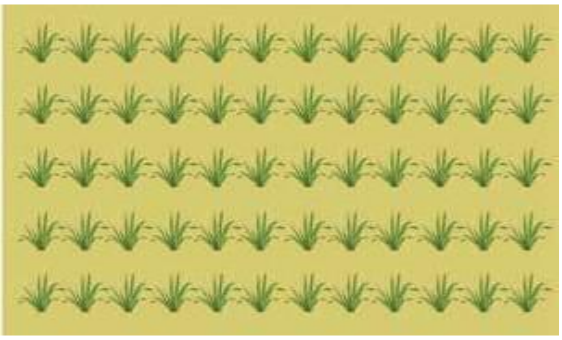


Figure 6.18 Horizontal Grass Planting
Source: Godinho et al., 2023

b. Vertical and downward Grass Planting This method can be applied on slopes <65 degrees in moist locations. The recommended planting distance is 10 cm between plants and 50 cm between rows. The concept of vertical and downward grass planting is presented in **Figure 6.19**.

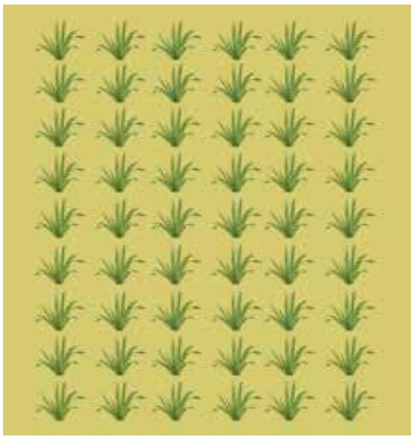


Figure 6.19 Vertical Grass Planting
Source: Godinho *et al*., 2023

c. Diagonal grass planting, 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 presented in **Figure 6.20.**

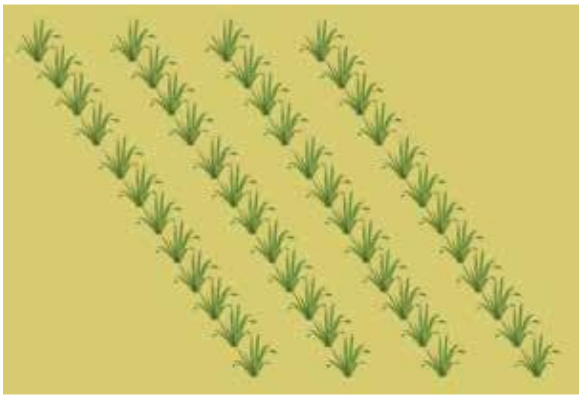


Figure 6.20 Diagonal Grass Planting
Source: Godinho *et al*., 2023

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 increase farmers' income. This conservation technique can be applied in areas with high rainfall and high surface runoff conditions on slopes of 8 to 30%.

The construction of a rainwater reservoir involves digging, clay lining, and building drainage channels. During excavation, the reservoir or edge of the reservoir must be higher than the ground surface to prevent soil from entering the reservoir. A drainage channel is created to prevent overflow from the reservoir. The distance between the drainage channel and the surface of the reservoir should be between 25 and 50 cm. The clay lining serves to reinforce the walls or reservoir of the reservoir, typically built to a thickness of 25 cm. The reservoir's walls should be sloped at an angle of 70 to 80 degrees or tiered to prevent landslides. For sandy soil, the dam walls should be lined with plastic, cement, or a mixture of lime and clay (1:1 ratio) to prevent rapid water seepage. Finally, the overflow channel should be directed toward the area to be irrigated, with a width between 15 and 25 cm and a depth between 10 and 15 cm. Additionally, the rainwater reservoir should be maintained by cleaning the drainage channels, reservoir edges, and dam walls, as well as removing sediment. The concept of constructing a rainwater reservoir is presented in **Figure 6.21**.

Figure 6.21 Construction of Rainwater Reservoir
Source: Godinho *et al.*,2023

7. Drainage Channel Construction

Drainage channels are used to direct water to areas where it can be absorbed into the soil or collected for storage. Drainage channels are usually equipped with small waterfalls to prevent erosion and landslides. The construction of a drainage channel begins by digging the soil to a minimum depth of 50 cm from the cultivation space and a base width of 50 cm. The channel floor in bench terraces is made with a slope of 0.1 to 0.5% outward. Over 1 meter of drainage, grass should be planted 20 cm across the drainage channel. Next, a waterfall is constructed using two or three split bamboo posts installed horizontally, with a depth of 0.5 m, and the outer part of the bamboo placed outside the channel. Maintenance efforts include clearing sediment, trimming weeds, and repairing damaged bamboo structures. The concept of drainage channels is presented in **Figure 6.22.**

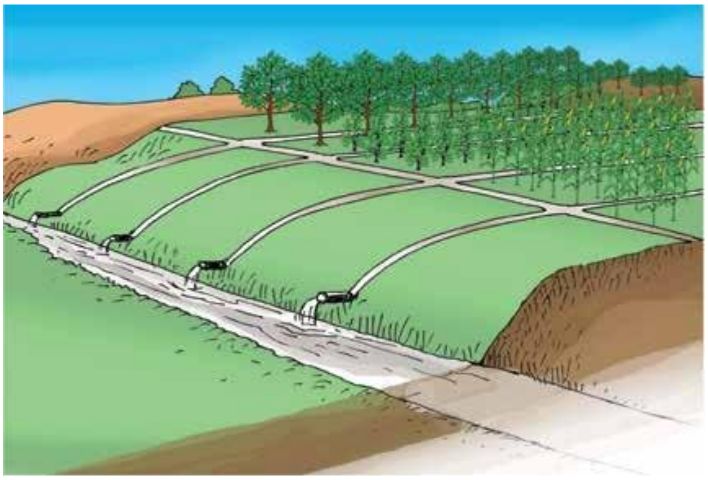


Figure 6.22 Drainage Channel
Source: Godinho *et al*.,2023

8. Wattle Fence / Live Check Dam

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

The wattle fence is constructed by clearing vegetation materials (wood or branches) to use as posts. Then, 100 cm long posts are driven into the ground at 100 cm intervals along the fence line. Two 50 cm posts are placed between the main posts and should protrude about 20 to 30 cm above the ground surface. A trench (minimum depth of 15 cm) is made along the contour between the installed posts. The bottoms of the plant cuttings are placed in the trench, then woven between the posts, and the soil is packed back into the trench. The concept of wattle fence application is presented in **Figure 6.23**.

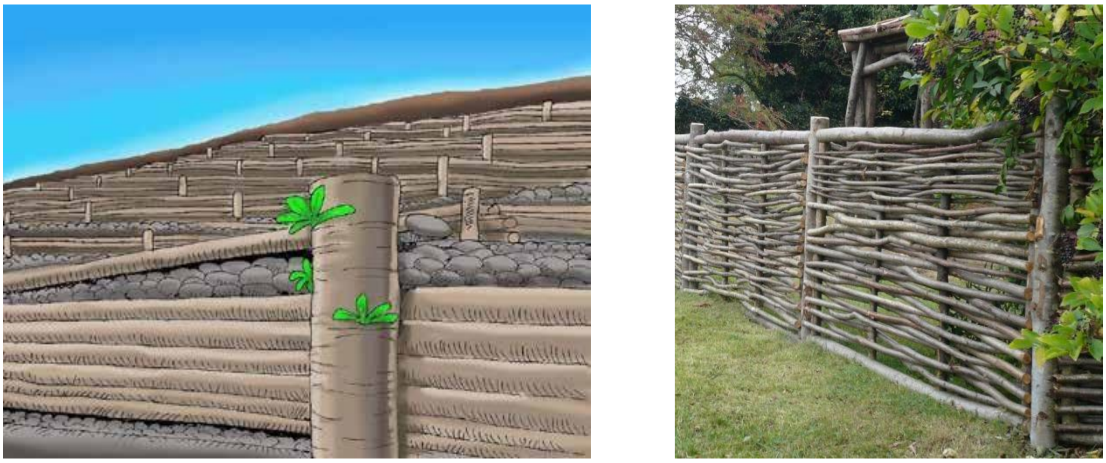


Figure 6.23 Wattle Fence

9. Vegetative Actions

Vegetative actions aim to achieve better soil and water conservation efficiency through alternating planting of fruit trees, spices, and food crops. Conservation practices should minimize soil disturbance (minimal tillage), increase ground cover, and involve crop rotation to enhance agricultural sustainability (Huang *et al*., 2022).

a. **Conservation Forests**: In soil and water conservation, these forests 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. **Plant Hedges**: The use of hedgerow plants is also effective in controlling slope soil erosion, reducing runoff, and improving soil fertility. Hedgerow plants that can be used include *Vetiveria zizanoides*, *Leucaena leucocephala*, Guinea grass, *Gamal* (*Gliricidia sepium*), *Calliandra calothyrsus*, *Pennisetum purpureum*, and others.

c. **Ground Cover**: Ground cover intensity is divided into:
   1) Total cover, especially for erosion-prone areas, mountains, near rivers, and reservoirs.
   2) Half cover, where ground cover is implemented only during certain seasons.
   3) Rotating cover, done in lightly eroded areas divided into sub-areas for rotational cover.
   4) Cover combined with planting, for areas with moderate erosion and very low vegetation cover.

Additionally, ground cover can be enhanced using mulch, consisting of leaves, compost, and manure to cover the soil surface. Mulching helps prevent soil moisture loss due to evaporation, reduces soil erosion, and controls weeds. Materials for mulch can include rice and corn straw, legume residues, vetiver grass, and plastic film (Huang *et al*., 2022).

d. **Crop Rotation**: Crops planted in rotation yield better results than those grown continuously. The yield benefit of rotation effects also depends on seasonal weather conditions and long-term practices. Long-term crop diversification enhances agroecosystem productivity compared to monoculture systems and reduces input usage. Combining legumes and brassicas tends to have a positive impact on soil due to the combination of taproots and fibrous roots, enhancing soil biodiversity (Quintarelli *et al*., 2022).

e. **Water Reservoirs**: According to Rustam (2010), an reservoir is an artificial structure used to store and retain water with a small volume capacity, smaller than a reservoir or dam. Reservoirs are usually built by damming small rivers or can be constructed outside rivers. Reservoir ponds store water during the rainy season and provide water during the dry season for a village, prioritized for the population, livestock, and crops or fields. The required volume determines the height of the reservoir and its storage capacity. The concept of conservation through the construction of an reservoir is presented in **Figure 6.24**.

Figure 6.24 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 can be rated as highly suitable for Rice fields, moderately suitable for coffee, or marginally suitable for citrus crops. Land suitability can be evaluated based on two conditions: current conditions and conditions after improvements.

7.1 AGRICULTURAL LAND SUITABILITY

Land suitability assessment based on current conditions utilizes data obtained from field surveys. This assessment reflects the capacity of the land in its existing state, without additional interventions. Current land suitability, or suitability in its natural state, does not take into account any improvement efforts or management practices that may be applied to address existing constraints or limiting factors present in each land unit or mapping unit. To determine the class of current land suitability, an evaluation of each land quality is first carried out based on the most limiting factor or the poorest land characteristic. The suitability class is then determined based on this poorest land quality or limiting factor.

Potential land suitability refers to land suitability after improvements are made. For example, land that is currently marginally suitable (S3) due to nutrient limitations may be improved to become moderately suitable (S2) or even highly suitable (S1) after interventions such as fertilization. The assessment of potential land suitability is conducted by implementing improvements on the land's limiting characteristics, with the goal of increasing its suitability. With technology, land that naturally has low suitability (current suitability) can be upgraded to a higher suitability class (potential suitability). However, not all land characteristics or qualities can be improved with existing technologies, and some may require high levels of management to enhance them. In land use planning, the primary focus is on potential land suitability because this evaluation provides a picture of the land’s maximum potential for various uses after improvements are made. Thus, potential land suitability helps in planning for effective and sustainable land use, while also identifying necessary improvements to achieve optimal outcomes.

The strategies for improving current land characteristics to reach their potential suitability, based on the level of management, are presented in **Table 7.1.**

Table 7.1 Types of Improvements for Current Land Suitability to Achieve Potential Suitability Based on Management Level

No	Land Quality/Characteristics	Types of Improvement Efforts	Management Level
1	**Radiation Regime** (Sunlight Duration)	No Improvement Possible	-
2	**Temperature Regime** - Average Annual Temperature - Average Temperature of the Coldest Month - Average Temperature of the Hottest Month	 No Improvement Possible No Improvement Possible No Improvement Possible	 - - -
3	**Air Humidity Regime** - Relative Humidity	 No Improvement Possible	 -
4	**Water Availability** - Dry Months - Rainfall	 Irrigation System Drainage System	 Moderate, High Moderate, High
5	**Rooting Medium** - Drainage - Texture - Effective Depth	 Drainage System Improvement, Construction of drainage channels Addition of organic material No Improvement Possible Generally, no improvement is possible, except for soft and thin hardpan layers, which can be broken up during soil cultivation	
6	**Nutrient Retention:** - Cation Exchange Capacity (CEC) - pH	 Liming or Addition of Organic Material	 Moderate, High
7	**Nutrient Availability:** - Total Nitrogen - P_2O_5 - K_2O	 Fertilization with Urea and ZA Fertilization with SP36 and TSP Fertilization with KCl	 Moderate, High
8	**Diversity** - Salinity	 Addition of Organic Material	 Moderate, High
9	**Erosion Hazard**	Efforts to Reduce Erosion Rates, Construction of terraces, planting along contours, planting cover crops	Moderate, High
10	**Flood Hazard**	Construction of water barriers	

	- Frequency Period	and drainage channels to facilitate water management	High
11	**Toxicity** - Aluminium Saturation - Pyrite Layer	 Lime Application Water Table Management tanah, The water table surface must be above the sulfide-bearing layers.	 Moderate, High Moderate, High
12	**Ease of Tillage**	Adjusting soil moisture to facilitate soil cultivation.	Moderate, High
13	**Terrain/Potential Mechanisms**	No Improvement Possible	-

Description:

- Moderate management level; Management that can be carried out by farmers with moderate capital or agricultural techniques.
- High management level: Management that requires relatively large capital, typically implemented by governments or large or medium-sized companies.

Table 7. 2 Assumptions on the Improvement of Current Land Quality to Achieve Potential Suitability Based on Management Level

No	Land Characteristics	Management Level Moderate	Management Level High	Types of Improvement
1	**Radiation Regime**	-	-	-
2	**Temperature Regime**	-	-	-
3	**Air Humidity Regime**	-	-	-
4	**Water Availability**			
	- Dry Months	+	++	Plant Combinations
	- Rainfall	+	++	Irigation
5	**Rooting Complex**			
	- Drainage	+	++	Drainage Channels*)
	- Soil Texture	-	+	Organic Material Addition
	- Effective Soil Depth	-	+	Planting Hole Creation with Organic Material Addition
	- Peat, Maturity	-	-	-
	- Peat Thickness	-	-	-
6	**Nutrient Retention**			
	- Cation Exchange Capacity	-	+	Organic Material Addition
	(CEC)	-	+	
	- Base Saturation (BS)	+	+	
	- pH	+	++	
	- Soil Organic Carbon (SOC)			
7	**Nutrient Availability**			
	- Total Nitrogen	+	++	Urea Fertilizer
	- Available Phosphorus	+	++	SP36 and TSP Fertilizers
	- Available Potassium	+	++	KCL Fertilizer
8	**Flood Hazard**			
	- Duration	+	++	-
	- Frequency	+	++	-
9	**Diversity**			Irrigation and Organic
	- Salinity	+	++	Material Addition
10	**Toxicity**			Lime
	- Aluminum Saturation	+	++	Groundwater Surface
	- Pyrite Depth	-	+	Control
11	**Ease of Cultivation**	-	+	Mechanization
12	**Terrain (Mechanization Potential)**	-	+	Terracing
13	**Erosion Hazard**	+	++	Soil Conservation Efforts

Description:

- No improvement can be made

\+ Improvement possible with one class upgrade (S3 to S2)

++ Improvement possible with two class upgrades (S3 to S1)

*) Poor drainage can be improved to better drainage by constructing drainage channels, but extremely rapid or excessively fast drainage is difficult to convert into moderate or good drainage.

7.2 LAND SUITABILITY CLASSIFICATION SYSTEM

The land suitability classification system based on the Framework of Land Evaluation (FAO, 1976) is widely used in Indonesia and other developing countries. This system consists of four categories: order, class, subclass, and unit (Hardjowigeno, 2015). The land suitability is systematically described as follows:

Table 7.3 Land Suitability Classification System (FAO, 1976)

Order	:	Indicates whether a piece of land is suitable or not for a particular use.
Class	:	Indicates the level of land suitability.
Sub-Class	:	Indicates the type of limitations or the kind of improvements that need to be applied within each class.
Unit	:	Indicates the differences in the degree of limiting factors that affect the management of a sub-class.

Order and class are typically used in land mapping at the reconnaissance scale, subclass at the semi-detailed scale, and unit at the detailed scale. The order is also used in land mapping at the coarse (exploratory) scale.

Order of Suitability

The order of suitability describes the general suitability of land, indicating whether a land area is suitable or not suitable for a particular land use. At the order level, land is categorized into suitable (S) or not suitable (N).

Suitable (S)

Land classified in this order can be used for a long period for a specific intended use. The benefits of land management will be satisfactory after accounting for the inputs provided, with minimal or no risk of land degradation.

Not Suitable (N)

Land classified in this order has significant physical constraints (e.g., very steep slopes, rocky areas) or economic limitations (e.g., inputs are not balanced with outputs), preventing its sustainable use for the intended purpose.

Class of Suitability

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

Highly Suitable (S1)

Land that has no significant or apparent constraints to sustainable land use or only minor limitations that do not substantially reduce land productivity.

Moderately Suitable (S2)

Land that has somewhat severe limitations that require certain management practices to maintain productivity. These limitations reduce productivity or profit and increase the required inputs.

Marginally Suitable (S3)

Land with severe limitations that significantly affect the ability to maintain the required management level. These limitations reduce productivity and profit, necessitating additional inputs to achieve expected outputs.

Permanently Not Suitable (N1)

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

Not Suitable (N2)

Land with permanent constraints that prevent any sustainable land use in the long term.

Sub-Class of Suitability

Subclasses reflect the types and intensity of limiting factors that hinder land use or the types of improvements needed. Each class may consist of one or more subclasses, depending on the nature of the limiting factors. The limiting factors are indicated by lowercase letters placed after the class symbol. For example, class S2 with a limiting factor of effective soil depth (s) can be denoted as subclass S2s. A subclass may have one, two, or at most three limiting factor symbols, with the most dominant factor listed first. For example, in the subclass S2ts, the most dominant limiting factor is topography (t), with effective soil depth (s) as the secondary limiting factor.

Unit of Suitability

At the unit level, land suitability is further subdivided into detailed units based on the intensity of the limiting factors. All units within a subclass have similar suitability levels and the same types of limiting factors at the subclass level.

Table 7.4 Land Suitability Classification Structure (FAO, 1976)

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

The differences between units typically lie in their production capacity or additional management aspects required, often providing a more detailed distinction based on the limiting factors. Detailed knowledge of these limiting factors facilitates interpretation and planning for agricultural management. Units are denoted by adding Arabic numerals separated by a hyphen after the subclass symbol. For example, S2e-1, S2e-2, and so on. The number of units in a subclass is unlimited. The symbols for units are denoted by adding Arabic numerals separated by a hyphen from the subclass symbol. For example, S2e-1, S3e-2, etc. The number of units in a subclass is not limited.

7.3 LAND SUITABILITY ASSESSMENT RESULTS

The 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 laboratories. This approach allows for the identification of both the potential and limitations of the land's biophysical characteristics for the development of various agricultural, horticultural, and forestry commodities.

Geospatial data is used to map the topography, land use distribution, and Rainfall patterns across each District, while field observations provide direct information on 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 growth requirements for each crop type in its current state, as well as its potential suitability after various land improvement efforts such as fertilization, organic material addition, or the implementation of soil conservation techniques. This process provides comprehensive information for determining the priority of commodity development, identifying limiting factors, and designing relevant technical solutions.

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

The Baucau District has significant potential as a productive area for agricultural development, especially for its flagship commodities, namely coconut and breadfruit. The advantages of relatively flat topography in some areas, abundant water resources, and favorable climatic conditions are key assets for maximizing agricultural output. However, like other areas, Baucau also faces challenges such as less-than-ideal soil texture, the presence of coarse fragments and surface rocks, poor soil drainage, and low soil fertility.

To address these constraints and improve agricultural productivity, land suitability assessment becomes a crucial step. Through this evaluation, optimal management strategies can be designed, such as the selection of appropriate soil tillage methods, the application of conservation techniques, and the use of organic fertilizers to enhance soil fertility. With a sustainable approach, the potential of coconut, breadfruit, and other commodities in Baucau can be maximized to support community welfare and regional food security.

A. Land Suitability Evaluation for Baguia Sub-District

Baguia Sub-District has marginal suitability (S3) for commodities such as irrigated Rice and rainfed Rice, and is moderately suitable for the development of various agricultural commodities such as food crops (peanuts, sorghum, corn, cassava, etc.), horticultural vegetables (shallots, chilies, paprika, caisim, green beans, cucumbers, cabbage, etc.), horticultural fruits (rambutan, mango, guava, jackfruit, etc.), ornamental flowers (roses, asters, sunflowers), spices and medicinal plants (vanilla, candlenut, cinnamon, etc.), industrial crops (coconut, robusta coffee, tobacco, etc.), and forage crops such as elephant grass, setaria, legumes, and grazing areas, all of which fall under marginal suitability and can be developed in this region.

Baguia Sub-District has significant biophysical potential for agricultural commodity development, although its utilization is constrained by several limiting factors. These factors include climatic conditions such as Temperature, Rainfall intensity, and the duration of the dry period; morphological land conditions, including steep slopes, erosion levels, surface rock outcrops, and coarse fragments; and soil characteristics such as shallow effective soil depth and suboptimal drainage systems. Furthermore, soil chemical limitations, such as texture, cation exchange capacity (CEC), base saturation (BS), and the content of primary nutrients like nitrogen (N), phosphorus (P), and potassium (K), also affect the suitability of the land for various agricultural commodities.

Most of these limiting factors can be mitigated through the application of technical and land conservation management approaches. These efforts may include optimizing the irrigation system, planting vegetation for slope stabilization, constructing terraces, land clearing, digging planting holes, developing water recharge zones, adding organic material, and applying fertilization techniques based on specific nutrient needs. However, Temperature is a permanent constraint that cannot be modified through technical interventions. Therefore, appropriate adaptation strategies are required, particularly by selecting agricultural commodities suited to the local environmental conditions.

Commodities such as **wheat, potatoes, carrots, garlic, arabica coffee, cashew, and melinjo** are generally not recommended for development due to the Temperature constraints. In addition to the commodities mentioned, **Table 7.5** presents alternative crops considered suitable for agricultural development in Baguia Sub-District.

B. Land Suitability Evaluation for Baucau Sub-District

Baucau Sub-District has marginal suitability (S3) for commodities such as irrigated Rice and rainfed Rice, and is moderately suitable (S2) for the development of various agricultural commodities such as food crops (soybeans, green beans, cowpea, etc.), horticultural vegetables (caisim, green beans, broccoli, etc.), horticultural fruits (watermelon, melon, bananas, etc.), ornamental flowers (roses, asters, sunflowers), spices and medicinal plants (Jatropha, galangal, cardamom, etc.), industrial crops (sugarcane, kapok, etc.), and forage crops such as elephant grass, setaria, legumes, and grazing areas, which are all included in marginal suitability and can be developed in this area.

Baucau Sub-District has considerable biophysical potential for agricultural commodity development, though its utilization faces various limiting factors. These include climatic conditions such as Temperature, Rainfall intensity, and the length of the dry period; morphological land conditions, such as steep slopes, erosion levels, surface rock outcrops, and coarse fragments; and soil characteristics, including shallow effective depth and suboptimal drainage systems. Additionally, soil chemical constraints, such as texture, cation exchange capacity (CEC), base saturation (BS), and the content of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K), play a significant role in determining land suitability for different agricultural commodities.

Most of these limiting factors can still be addressed through the application of technical and land conservation management approaches. Efforts may include optimizing irrigation systems, planting slope-stabilizing vegetation, constructing terraces, land clearing, digging planting holes, developing water recharge zones, adding organic material, and applying fertilization techniques based on specific nutrient needs. However, Temperature remains a permanent factor that cannot be improved through technical interventions. Therefore, appropriate adaptation strategies are necessary, particularly in selecting agricultural commodities suitable for local environmental conditions.

Commodities such as **wheat, potatoes, carrots, garlic, arabica coffee, cashew, and melinjo** are generally not recommended for development due to Temperature limitations. In addition to the commodities mentioned, Table 7.5 presents alternative crops considered suitable for agricultural development in Baucau Sub-District.

C. Land Suitability Evaluation for Laga Sub-District

Laga Sub-District has marginal suitability (S3) for commodities such as irrigated Rice and rainfed Rice, and is moderately suitable (S2) for the development of various agricultural commodities such as food crops (soybeans, green beans, cowpea, etc.), horticultural vegetables (cucumbers, cabbage, eggplant, etc.), horticultural fruits (papaya, oranges, avocados, etc.), ornamental flowers (roses, asters, sunflowers), spices and medicinal plants (turmeric, candlenut, Jatropha, etc.), industrial crops (cotton, robusta coffee, coconut, etc.), and forage crops such as elephant grass, setaria, legumes, and grazing areas, all of which fall under marginal suitability and can be developed in this area.

Laga Sub-District has significant biophysical potential for agricultural commodity development, but its utilization is limited by several constraints. These factors include climatic conditions, such as Temperature, Rainfall intensity, and the duration of the dry period; morphological land conditions, including steep slopes, erosion levels, surface rock outcrops, and coarse fragments; and soil characteristics, such as shallow effective depth and suboptimal drainage systems. Additionally, soil chemical limitations, such as texture, cation exchange capacity (CEC), base saturation (BS), and the content of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K), also affect land suitability for various agricultural commodities.

Most of these limiting factors can still be managed through technical and land conservation approaches. Efforts may include optimizing irrigation systems, planting slope-stabilizing vegetation, constructing terraces, land clearing, digging planting holes, developing water recharge zones, adding organic material, and applying fertilization techniques based on specific nutrient needs. However, Temperature remains a permanent constraint and cannot be improved through technical interventions. Therefore, appropriate adaptation strategies are necessary, especially by selecting agricultural commodities that are compatible with local environmental conditions.

Commodities such **as wheat, potatoes, carrots, garlic, arabica coffee, cashew, and melinjo are** generally not recommended for development due to the permanent Temperature limitations. In addition to the commodities mentioned, **Table 7.5** presents alternative crops considered suitable for agricultural development in Laga Sub-District.

D. Land Suitability Evaluation for Quelicai Sub-District

Quelicai Sub-District has marginal suitability (S3) for commodities such as irrigated Rice and rainfed Rice, and is moderately suitable (S2) for the development of various agricultural commodities such as food crops (soybeans, green beans, cowpea, etc.), horticultural vegetables (bitter melon, tomato, long beans, etc.), horticultural fruits (soursop, breadfruit, snakefruit, etc.), ornamental flowers (roses, asters, sunflowers), spices and medicinal plants (vanilla, candlenut, Jatropha, etc.), industrial crops (tobacco, sugarcane, kapok, etc.), and forage crops such as elephant grass, setaria, legumes, and grazing areas, all of which fall under marginal suitability and can be developed in this region.

Quelicai Sub-District has considerable biophysical potential for agricultural commodity development, although its utilization is limited by several constraints. These limiting factors include climatic conditions such as Temperature, Rainfall intensity, and the length of the dry period; morphological land characteristics, including steep slopes, erosion levels, surface rock outcrops, and coarse fragments; and soil characteristics, such as shallow effective depth and suboptimal drainage systems. Additionally, soil chemical limitations, such as texture, cation exchange capacity (CEC), base saturation (BS), and the content of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K), also affect the suitability of the land for various agricultural commodities.

Most of these limiting factors can be addressed through technical approaches and land conservation management. Efforts may include optimizing the irrigation system, planting vegetation for slope stabilization, constructing terraces, land clearing, digging planting holes, developing water recharge zones, adding organic material, and applying fertilization techniques based on specific nutrient needs. However, Temperature remains a permanent constraint that cannot be modified through technical interventions. Therefore, appropriate adaptation strategies are required, particularly through the selection of agricultural commodities that are suitable for the local environmental conditions.

Commodities such **as wheat, potatoes, carrots, garlic, arabica coffee, cashew, and melinjo** are generally not recommended for development due to the permanent Temperature limitations. In addition to the commodities mentioned, **Table 7.5** presents alternative crops considered suitable for agricultural development in Quelicai Sub-District.

E. Land Suitability Evaluation for Vemasse Sub-District

Vemasse Sub-District has marginal suitability (S3) for commodities such as irrigated Rice and rainfed Rice, and is moderately suitable (S2) for the development of various agricultural commodities such as food crops (soybeans, green beans, cowpea, etc.), horticultural vegetables (shallots, chilies, paprika, caisim, green beans, cucumbers, cabbage, etc.), horticultural fruits (rambutan, mango, guava, jackfruit, etc.), ornamental flowers (roses, asters, sunflowers), spices and medicinal plants (vanilla, candlenut, cinnamon, etc.), industrial crops (coconut, robusta coffee, tobacco, etc.), and forage crops such as elephant grass, setaria, legumes, and grazing areas, all of which fall under marginal suitability and can be developed in this region.

Vemasse Sub-District has considerable biophysical potential for agricultural commodity development, but its utilization is constrained by several limiting factors. These factors include climatic conditions such as Temperature, Rainfall intensity, and the duration of the dry period; morphological land characteristics such as steep slopes, erosion levels, surface rock outcrops, and coarse fragments; and soil characteristics including shallow effective depth and suboptimal drainage systems. Additionally, soil chemical constraints such as texture, cation exchange capacity (CEC), base saturation (BS), and the content of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K) play a significant role in determining land suitability for various agricultural commodities.

Most of these limiting factors can still be managed through technical and land conservation approaches. Efforts may include optimizing irrigation systems, planting vegetation for slope stabilization, constructing terraces, land clearing, digging planting holes, developing water recharge zones, adding organic material, and applying fertilization techniques based on specific nutrient needs. However, Temperature remains a permanent factor that cannot be improved through technical interventions. Therefore, appropriate adaptation strategies are necessary, especially through selecting agricultural commodities that are suited to local environmental conditions.

Commodities such as **wheat, potatoes, carrots, garlic, arabica coffee, cashew, and melinjo** are generally not recommended for development due to the permanent Temperature limitations. In addition to the commodities mentioned, **Table 7.5** presents alternative crops considered suitable for agricultural development in Vemasse Sub-District.

F. Land Suitability Evaluation for Venilale Sub-District

Venilale Sub-District has marginal suitability (S3) for commodities such as irrigated Rice and rainfed Rice, and is moderately suitable (S2) for the development of various agricultural commodities such as food crops (soybeans, green beans, cowpea, etc.), horticultural vegetables (cucumbers, cabbage, eggplant, etc.), horticultural fruits (papaya, oranges, avocado, etc.), ornamental flowers (roses, asters, sunflowers), spices and medicinal plants (turmeric, candlenut, Jatropha, etc.), industrial crops (cotton, robusta coffee, coconut, etc.), and forage crops such as elephant grass, setaria, legumes, and grazing areas, all of which fall under marginal suitability and can be developed in this region.

Venilale Sub-District has significant biophysical potential for agricultural commodity development, although its utilization is limited by several constraints. These include climatic conditions such as Temperature, Rainfall intensity, and the length of the dry period; morphological land conditions, such as steep slopes, erosion levels, surface rock outcrops, and coarse fragments; and soil characteristics, including shallow effective depth and suboptimal drainage systems. Additionally, soil chemical limitations, such as texture, cation exchange capacity (CEC), base saturation (BS), and the content of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K), also affect land suitability for various agricultural commodities.

Most of these limiting factors can still be addressed through technical and land conservation management approaches. Efforts may include optimizing the irrigation system, planting vegetation for slope stabilization, constructing terraces, land clearing, digging planting holes, developing water recharge zones, adding organic material, and applying fertilization techniques based on specific nutrient needs. However, Temperature remains a permanent constraint that cannot be modified through technical interventions. Therefore, appropriate adaptation strategies are necessary, particularly by selecting agricultural commodities that are compatible with local environmental conditions.

Commodities such as **wheat, potatoes, carrots, garlic, arabica coffee, cashew, and melinjo** are generally not recommended for development due to the permanent Temperature limitations. In addition to the commodities mentioned, **Table 7.5** presents alternative crops considered suitable for agricultural development in Venilale Sub-District.

Table 7.5 Land Suitability Evaluation Matrix in Baucau District

Commodities	Sub-District	Limiting Factors	Potential Land Suitability
FOOD COMMODITY			
Irrigated Rice	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	N: Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops S3: Temperature, Texture, Coarse Fragments, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium	S3: Temperature S2: Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
DRYLAND FOOD COMMODITIES			
Upland Rice	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	N: Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops S3: Temperature, Drainage, Texture, Coarse Fragments, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium	S3: Temperature S2: Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Peanut	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	N: Slope Gradient, Erosion Hazard S3: Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium S2: Temperature, Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	S2: Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Sorghum	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	N: Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops S3: Texture, Coarse Fragments, Total Nitrogen, Available Phosphorus, Available Potassium S2: Temperature, Effective Soil Depth	S2: Temperature, Rainfall, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Corn	• Baguia • Baucau • Laga • Quelicai	N: Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops	S2: Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope

	• Vemasse • Venilale	**S3:** Drainage, Texture, Coarse Fragments, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Effective Soil Depth	Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Cassava	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops **S3:** Temperature, Drainage, Coarse Fragments, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Dry Months, Texture	**S3:** Temperature **S2:** Dry Months, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Effective Soil Depth, Surface Rocks, Rock Outcrops
Soybean	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Texture, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Coarse Fragments, Effective Soil Depth, Surface Rocks, Rock Outcrops	**S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Mung Bean	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Texture, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Coarse Fragments, Surface Rocks, Rock Outcrops	**S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Cowpea	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Drainage, Texture, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium	**S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops

		S2: Coarse Fragments, Surface Rocks, Rock Outcrops	
Taro	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Texture, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Coarse Fragments, Surface Rocks, Rock Outcrops	**S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Wheat	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Temperature, Rainfall, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops **S3:** Texture, Coarse Fragments, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium	**N:** Temperature **S2:** Rainfall, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Sweet Potato	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops **S3:** Temperature, Drainage, Coarse Fragments, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Dry Months, Texture	**S3:** Temperature **S2:** Dry Months, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Effective Soil Depth, Surface Rocks, Rock Outcrops
		VEGETABLE COMMODITY	
Potato	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Temperature, Slope Gradient, Erosion Hazard **S3:** Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Texture, Coarse Fragments, Effective Soil Depth, Surface Rocks, Rock Outcrops	**N:** Temperature **S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Carrot	• Baguia • Baucau • Laga • Quelicai • Vemasse	**N:** Temperature, Slope Gradient, Erosion Hazard **S3:** Effective Soil Depth, Total Nitrogen, Available	**N:** Temperature **S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope

	• Venilale	Phosphorus, Available Potassium **S2:** Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Garlic	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Temperature, Rainfall, Slope Gradient, Erosion Hazard **S3:** Texture, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Coarse Fragments, Effective Soil Depth, Surface Rocks, Rock Outcrops	**N:** Temperature **S2:** Rainfall, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Shallot	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Rainfall, Slope Gradient, Erosion Hazard **S3:** Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Surface Rocks, Rock Outcrops	**S2:** Temperature, Rainfall, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Chili	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Drainage, Texture **S2:** Coarse Fragments, Effective Soil Depth, Surface Rocks, Rock Outcrops, Total Nitrogen, Available Phosphorus, Available Potassium	**S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Bell Pepper	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Texture, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Coarse Fragments, Effective Soil Depth, Surface Rocks, Rock Outcrops	**S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops

Caisim	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Rainfall, Slope Gradient, Erosion Hazard **S3:** Texture, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Coarse Fragments, Effective Soil Depth, Surface Rocks, Rock Outcrops	**S2:** Temperature, Rainfall, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient Erosion Hazard, Surface Rocks, Rock Outcrops
Green Bean Broccoli	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Texture, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Coarse Fragments, Surface Rocks, Rock Outcrops	**S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient Erosion Hazard, Surface Rocks, Rock Outcrops
Snow Pea	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Temperature, Texture, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Coarse Fragments, Surface Rocks, Rock Outcrops	**S3:** Temperature **S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Cucumber	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Texture, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Coarse Fragments, Surface Rocks, Rock Outcrops	**S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Cabbage	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Texture, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium	**S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops

		S2: Coarse Fragments, Surface Rocks, Rock Outcrops	
Eggplant	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Drainage, Texture, Effective Soil Depth **S2:** Coarse Fragments, Surface Rocks, Rock Outcrops, Total Nitrogen, Available Phosphorus, Available Potassium	**S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Bitter Melon	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Texture, Effective Soil Depth **S2:** Temperature, Coarse Fragments, Surface Rocks, Rock Outcrops, Total Nitrogen, Available Phosphorus, Available Potassium	**S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Vegetable Tomato	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Drainage, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	**S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Long Bean	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Texture, Effective Soil Depth **S2:** Temperature, Coarse Fragments, Surface Rocks, Rock Outcrops, Total Nitrogen, Available Phosphorus, Available Potassium	**S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
		FRUIT COMMODITY	
Rambutan Manggo	• Baguia • Baucau • Laga • Quelicai	**N:** Effective Soil Depth, Slope Gradient, Erosion Hazard	**S2:** Temperature, Coarse Fragments, Erosion Hazard, Surface Rocks, Rock

	• Vemasse • Venilale	**S2:** Temperature, Coarse Fragments, Total Nitrogen, Surface Rocks, Rock Outcrops	Outcrops, Effective Soil Depth, Slope Gradient
Guava	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Slope Gradient, Erosion Hazard **S3:** Drainage, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Coarse Fragments, Surface Rocks, Rock Outcrops	**S2:** Temperature, Coarse Fragments, Surface Rocks, Rock Outcrops, Effective Soil Depth, Slope Gradient
Jackfruit	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Slope Gradient, Erosion Hazard, Rock Outcrops **S2:** Temperature, Coarse Fragments, Surface Rocks **S3:** Drainage, Texture, Total Nitrogen, Available Phosphorus, Available Potassium	**S2:** Temperature, Texture, Coarse Fragments, Erosion Hazard, Surface Rocks, Effective Soil Depth, Slope Gradient, Rock Outcrops
Watermelon Melon	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Drainage, Texture, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Coarse Fragments, Surface Rocks, Rock Outcrops	**S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Banana	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Slope Gradient, Erosion Hazard, Rock Outcrops **S3:** Dry Months, Texture, Total Nitrogen **S2:** Temperature, Coarse Fragments, Base Saturation, Surface Rocks	**S2:** Temperature, Dry Months, Texture, Coarse Fragments, Erosion Hazard, Surface Rocks, Effective Soil Depth, Slope Gradient, Rock Outcrops
Papaya	• Baguia • Baucau • Laga • Quelicai • Vemasse	**N:** Effective Soil Depth, Slope Gradient, Erosion Hazard **S3:** Drainage, Total Nitrogen, Available	**S2:** Temperature, Texture, Coarse Fragments, Erosion Hazard, Surface Rocks, Rock Outcrops,

	• Venilale	Phosphorus, Available Potassium **S2:** Temperature, Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	Effective Soil Depth, Slope Gradient
Orange	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Slope Gradient, Erosion Hazard, Rock Outcrops **S3:** Dry Months, Drainage, Texture, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Texture, Coarse Fragments, Surface Rocks	**S2:** Temperature, Dry Months, Texture, Coarse Fragments, Erosion Hazard, Surface Rocks, Effective Soil Depth, Slope Gradient, Rock Outcrops
Avocado	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Slope Gradient, Erosion Hazard, Rock Outcrops **S3:** Dry Months, Drainage, Texture, Total Nitrogen, Available Potassium **S2:** Temperature, Coarse Fragments, Surface Rocks	**S2:** Temperature, Dry Months, Texture, Coarse Fragments, Erosion Hazard, Surface Rocks, Effective Soil Depth, Slope Gradient, Rock Outcrops
Soursop Breadfruit Snake Fruit Longan Custard Apple	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Slope Gradient, Erosion Hazard, Rock Outcrops **S3:** Drainage, Texture, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Coarse Fragments, Surface Rocks	**S2:** Temperature, Texture, Coarse Fragments, Erosion Hazard, Surface Rocks, Effective Soil Depth, Slope Gradient, Rock Outcrops
Durian	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Drainage, Texture, Effective Soil Depth **S2:** Temperature, Coarse Fragments, Surface Rocks, Rock Outcrops	**S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Erosion Hazard, Surface Rocks, Rock Outcrops, Slope Gradient
Pineapple	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard, Rock Outcrops **S3:** Drainage, Total Nitrogen, Available	**S2:** Texture, Coarse Fragments, Effective Soil Depth, Erosion Hazard, Surface Rocks,

		Phosphorus, Available Potassium **S2**: Texture, Coarse Fragments, Effective Soil Depth, Surface Rocks	Slope Gradient, Rock Outcrops
Strawberry	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N**: Effective Soil Depth, Slope Gradient, Erosion Hazard, Rock Outcrops **S3**: Drainage, Texture, Total Nitrogen, Available Phosphorus, Available Potassium **S2**: Temperature, Coarse Fragments, Surface Rocks	**S2**: Temperature, Texture, Coarse Fragments, Erosion Hazard, Surface Rocks, Effective Soil Depth, Slope Gradient, Rock Outcrops
Grape	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N**: Effective Soil Depth, Slope Gradient, Erosion Hazard **S2**: Temperature, Dry Months, Texture, Coarse Fragments, Total Nitrogen, Available Phosphorus, Available Potassium, Surface Rocks, Rock Outcrops	**S2**: Temperature, Dry Months, Texture, Coarse Fragments, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth, Slope Gradient
Passion Fruit	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N**: Dry Months, Effective Soil Depth, Slope Gradient, Erosion Hazard **S3**: Temperature, Total Nitrogen, Available Phosphorus, Available Potassium **S2**: Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	**S3**: Temperature, Dry Months **S2**: Texture, Coarse Fragments, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth, Slope Gradient
FLOWER COMMODITY			
Rose	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N**: Slope Gradient **S3**: Drainage, Effective Soil Depth, Erosion Hazard, Available Phosphorus, Available Potassium **S2**: Temperature	**S2**: Temperature, Effective Soil Depth, Slope Gradient, Erosion Hazard

Aster Sunflower	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient **S3:** Drainage, Erosion Hazard, Available Phosphorus, Available Potassium **S2:** Temperature, Effective Soil Depth	**S2:** Temperature, Effective Soil Depth, Slope Gradient, Erosion Hazard
SPICES AND MEDICINAL COMMODITY			
Ginger	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Rainfall, Dry Months, Slope Gradient, Erosion Hazard **S3:** Temperature, Drainage, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	**S3:** Temperature, Dry Months **S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Batuan
Vetiver Root **Lemongrass**	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Dry Months, Slope Gradient, Erosion Hazard **S3:** Drainage, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Texture, Coarse Fragments, Base Saturation, Effective Soil Depth, Surface Rocks, Rock Outcrops	**S3:** Dry Months **S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Vanilla	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Drainage, Texture, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Coarse Fragments, Effective Soil Depth, Surface Rocks, Rock Outcrops	**S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Candlenut	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Erosion Hazard **S3:** Drainage, Total Nitrogen, Available	**S2:** Temperature, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks,

		Phosphorus, Available Potassium **S2:** Temperature, Texture, Coarse Fragments, Slope Gradient, Surface Rocks, Rock Outcrops	Rock Outcrops, Effective Soil Depth
Cinnamon	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Dry Months, Erosion Hazard **S3:** Drainage, pH, Total Nitrogen, Available Potassium, Slope Gradient **S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Surface Rocks, Rock Outcrops	**S3:** Dry Months **S2:** Temperature, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Nutmeg Pepper	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Erosion Hazard **S3:** Drainage, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Texture, Coarse Fragments, Slope Gradient, Surface Rocks, Rock Outcrops	**S3:** Dry Months **S2:** Temperature, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth
Jatropha	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Drainage, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Texture, Coarse Fragments, Effective Soil Depth, Surface Rocks, Rock Outcrops	**S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Aromatic Ginger Galangal Cardamom	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Dry Months, Drainage, Effective Soil Depth, Total Nitrogen, Available Potassium **S2:** Coarse Fragments, Surface Rocks, Rock Outcrops	**S2:** Dry Months, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops

Turmeric	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Drainage, Texture, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Coarse Fragments, Surface Rocks, Rock Outcrops	**S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
INDUSTRIAL COMMODITY			
Rubber	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Slope Gradient, Erosion Hazard **S3:** Base Saturation, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Texture, Coarse Fragments, Salinitas, Surface Rocks, Rock Outcrops	**S3:** Dry Months **S2:** Temperature, Texture, Coarse Fragments, Salinitas, Erosion Hazard, Surface Rocks, Rock Outcrops, Slope Gradient, Effective Soil Depth
Coconut	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Erosion Hazard **S3:** Dry Months, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Texture, Coarse Fragments, Slope Gradient, Surface Rocks, Rock Outcrops	**S2:** Temperature, Dry Months, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth
Oil Palm	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Erosion Hazard **S3:** Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Texture, Coarse Fragments, Slope Gradient, Surface Rocks, Rock Outcrops	**S3:** Dry Months **S2:** Temperature, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth

Arabica Coffee	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Temperature, Effective Soil Depth, Erosion Hazard **S3:** Dry Months, Texture, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Coarse Fragments, Slope Gradient, Surface Rocks, Rock Outcrops	**N:** Temperature **S2:** Dry Months, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth
Robusta Coffee	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Slope Gradient, Erosion Hazard **S3:** Dry Months, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	**S2:** Temperature, Dry Months, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth
Cocoa	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Slope Gradient, Erosion Hazard **S3:** Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Temperature, Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	**S3:** Dry Months **S2:** Temperature, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth
Clove Tea	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Slope Gradient, Erosion Hazard **S2:** Temperature, Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	**S3:** Dry Months **S2:** Temperature, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth
Tobacco	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Slope Gradient, Erosion Hazard **S3:** Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium	**S2:** Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops

		S2: Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	
Sugar Cane Kapok	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	N: Effective Soil Depth, Slope Gradient, Erosion Hazard S3: Texture, Total Nitrogen, Available Phosphorus, Available Potassium S2: Temperature, Coarse Fragments, Surface Rocks, Rock Outcrops	S2: Temperature, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth
Cashew	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	N: Temperature, Effective Soil Depth, Slope Gradient, Erosion Hazard S3: Dry Months, Total Nitrogen, Available Phosphorus, Available Potassium S2: Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	N: Temperature S2: Dry Months, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth
Melinjo	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	N: Temperature, Effective Soil Depth, Slope Gradient, Erosion Hazard S2: Dry Months, Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	N: Temperature S2: Dry Months, Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops, Effective Soil Depth
Cotton	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	N: Rainfall, Slope Gradient, Erosion Hazard S3: Texture, Effective Soil Depth, Total Nitrogen, Available Phosphorus, Available Potassium S2: Temperature, Dry Months, Coarse Fragments, Surface Rocks, Rock Outcrops	S2: Temperature, Rainfall, Dry Months, Texture, Coarse Fragments, Effective Soil Depth, Slope Gradient, Erosion Hazard, Surface Rocks, Rock Outcrops
Quinine	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	N: Effective Soil Depth, Slope Gradient, Erosion Hazard S3: Temperature, Total Nitrogen, Available	S3: Temperature S2: Texture, Coarse Fragments, Slope Gradient, Erosion Hazard, Surface Rocks,

		Phosphorus, Available Potassium **S2:** Texture, Coarse Fragments, Surface Rocks, Rock Outcrops	Rock Outcrops, Effective Soil Depth
LIVESTOCK GRAZING AND FORAGE AREA			
Elephant Grass Setaria	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**S3:** Rock Outcrops, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Surface Rocks, Drainage, Rainfall, pH, Base Saturation	**S3:** Rock Outcrops **S2:** Surface Rocks
Legumes	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**S3:** Rock Outcrops, Total Nitrogen, Available Phosphorus, Available Potassium **S2:** Surface Rocks, Drainage, Rainfall, Erosion Hazard, Slope Gradient, Base Saturation	**S3:** Rock Outcrops **S2:** Surface Rocks
Grazing	• Baguia • Baucau • Laga • Quelicai • Vemasse • Venilale	**N:** Erosion Hazard, Surface Rocks **S3:** Dry Months **S2:** Surface Rocks, Rock Outcrops	**S3:** Dry Months **S2:** Slope Gradient, Erosion Hazard, Surface Rocks Rock Outcrops

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

VIII. FORESTRY POTENTIAL

8.1 LAND SUITABILITY ASSESSMENT RESULTS

Land suitability analysis is a fundamental step in formulating strategies for the sustainable management of forest land resources. This evaluation is carried out through an integrated approach that combines the use of geospatial data, field observations, and physical and chemical soil analysis in the laboratory. This approach allows for the identification of both the potential and limitations of the land's biophysical characteristics relevant to the development of various forestry crops.

Geospatial data are used to map topography, land use distribution, and rainfall patterns in each area. This information provides an initial overview of spatial conditions that influence tree growth. Field observations are then conducted to gather direct data on slope gradients and ground vegetation, which are important factors in determining land support for forestry crops. Laboratory analysis complements this process by measuring macro-nutrient content (N, P, K), organic matter, Cation Exchange Capacity (CEC), Base Saturation (BS), pH, and soil texture, thereby providing a comprehensive understanding of soil fertility and characteristics.

The collected data are then analyzed based on the actual growth requirements of each forestry species and the potential suitability after land improvements. The land improvements considered include fertilization, organic matter addition, and the application of soil conservation techniques such as terracing or planting cover crops. Therefore, the evaluation not only assesses the existing conditions but also considers the potential for productivity improvement through appropriate technical interventions.

This scientific approach forms the basis for the land suitability evaluation in Baucau District, providing strategic guidance for determining the priorities for forestry commodity development. The analysis also identifies limiting factors that may hinder plant growth, while designing relevant technical solutions.

A. Land Suitability Evaluation of Baguia Sub-District

Baguia Sub-District has potential for the development of forestry crops with a land suitability level of S3 (marginally suitable). Species such as teak (*Tectona grandis*), mahogany (*Swietenia macrophylla*), and Agathis (*Agathis dammara*) have opportunities for development if supported by the application of proper technical improvements.

However, the development of forestry crops in this area faces several limiting factors, both biophysical and chemical in nature. These limiting factors include Temperature conditions, long dry season periods, steep slope gradients, high erosion levels, the presence of surface rock outcrops, shallow effective soil depth, and low nutrient content, particularly nitrogen (N) and potassium (K). In addition to the primary commodities mentioned, **Table 8.1** presents alternative plant species that are considered suitable to support forestry development in Baguia Sub-District.

B. Land Suitability Evaluation of Baucau Sub-District

Baucau Sub-District has potential for the development of forestry crops with a land suitability level of S3 (marginally suitable). Species such as altingia (*Altingia excelsa*), sengon (*Falcataria moluccana*), and acacia (*Acacia mangium*) have opportunities for development if supported by the application of proper technical improvements.

However, the development of forestry crops in this area faces several limiting factors, both biophysical and chemical in nature. These limiting factors include Temperature conditions, long dry season periods, steep slope gradients, high erosion levels, the presence of surface rock outcrops, shallow effective soil depth, and low nutrient content, particularly nitrogen (N) and potassium (K). In addition to the primary commodities mentioned, **Table 8.1** presents alternative plant species that are considered suitable to support forestry development in Baucau Sub-District.

C. Land Suitability Evaluation of Quelicai Sub-District

Quelicai Sub-District has potential for the development of forestry crops with a land suitability level of S3 (marginally suitable). Species such as altingia (*Altingia excelsa*), albizia (*Falcataria moluccana*), and acacia (*Acacia mangium*) have opportunities for development if supported by the application of proper technical improvements.

However, the development of forestry crops in this area faces several limiting factors, both biophysical and chemical in nature. These limiting factors include Temperature conditions, long dry season periods, steep slope gradients, high erosion levels, the presence of surface rock outcrops, shallow effective soil depth, and low nutrient content, particularly nitrogen (N) and potassium (K). In addition to the primary commodities mentioned, **Table 8.1** presents alternative plant species that are considered suitable to support forestry development in Quelicai Sub-District.

D. Land Suitability Evaluation of Vemasse Sub-District

Vemasse Sub-District has potential for the development of forestry crops with a land suitability level of S3 (marginally suitable). Species such as leucaena (*Leucaena leucocephala*), eucalyptus (*Eucalyptus spp.*), and gelam (*Melaleuca cajuputi*) have opportunities for development if supported by the application of proper technical improvements.

However, the development of forestry crops in this area faces several limiting factors, both biophysical and chemical in nature. These limiting factors include Temperature conditions, long dry season periods, steep slope gradients, high erosion levels, the presence of surface rock outcrops, shallow effective soil depth, and low nutrient content, particularly nitrogen (N) and potassium (K). In addition to the primary commodities mentioned, **Table 8.1** presents alternative plant species that are considered suitable to support forestry development in Vemasse Sub-District.

E. Land Suitability Evaluation of Venilale Sub-District

Venilale Sub-District has potential for the development of forestry crops with a land suitability level of S3 (marginally suitable). Species such as teak (*Tectona grandis*), pine (*Pinus merkusii*), and sandalwood (*Santalum album*) have opportunities for development if supported by the application of proper technical improvements.

However, the development of forestry crops in this area faces several limiting factors, both biophysical and chemical in nature. These limiting factors include Temperature conditions, long dry season periods, steep slope gradients, high erosion levels, the presence of surface rock outcrops, shallow effective soil depth, and low nutrient content, particularly nitrogen (N) and potassium (K). In addition to the primary commodities mentioned, **Table 8.1** presents alternative plant species that are considered suitable to support forestry development in Vemasse Sub-District.

Table 8.1 Land Suitability Evaluation Matrix for Forestry Crops in Baucau District

Commodities	Sub-District	Limiting Factors	Potential Land Suitability
Teak	• Baguia • Baucau • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Erosion Hazard **S3**: Total Nitrogen, Available Potassium, Slope Gradient **S2**: Temperature	**S3:** Dry Months, Effective Soil Depth **S2:** Temperature, Slope Gradient, Erosion Hazard
Mahogany	• Baguia • Baucau • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Erosion Hazard, Surface Rocks **S3**: Total Nitrogen, Available Potassium, Slope Gradient **S2**: Temperature, Rock Outcrops	**S3:** Dry Months, Effective Soil Depth **S2:** Temperature, Slope Gradient, Erosion Hazard
Agathis	• Baguia • Baucau • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Erosion Hazard, Surface Rocks **S3**: Total Nitrogen, Available Potassium, Slope Gradient **S2**: Temperature, Rock Outcrops	**S3:** Dry Months, Effective Soil Depth, Surface Rocks **S2:** Temperature, Slope Gradient, Erosion Hazard, Rock Outcrops
Altingia	• Baguia • Baucau • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Erosion Hazard, Surface Rocks **S3**: Temperature, Total Nitrogen, Available Potassium, Slope Gradient **S2**: Rock Outcrops	**S3**: Temperature, Dry Months, Effective Soil Depth, Surface Rocks **S2:** Slope Gradient, Erosion Hazard, Rock Outcrops
albizia	• Baguia • Baucau • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Erosion Hazard, Surface Rocks **S3**: Total Nitrogen, Available Potassium, Slope Gradient **S2** : Rock Outcrops	**S3**: Dry Months, Effective Soil Depth, Surface Rocks **S2:** Slope Gradient, Erosion Hazard, Rock Outcrops

Leucaena	• Baguia • Baucau • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Erosion Hazard, Surface Rocks **S3**: Total Nitrogen, Available Potassium, Slope Gradient **S2**: Rock Outcrops	**S3:** Dry Months, Effective Soil Depth, Surface Rocks **S2:** Slope Gradient, Erosion Hazard, Rock Outcrops
Acacia	• Baguia • Baucau • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Erosion Hazard, Surface Rocks **S3**: Total Nitrogen, Available Potassium, Slope Gradient **S2**: Rock Outcrops	**S3**: Dry Months, Effective Soil Depth, Surface Rocks **S2:** Slope Gradient, Erosion Hazard, Rock Outcrops
Eucalyptus	• Baguia • Baucau • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Erosion Hazard, Surface Rocks **S3**: Total Nitrogen, Available Potassium, Slope Gradient **S2**: Rock Outcrops	**S3:** Dry Months, Effective Soil Depth, Surface Rocks **S2:** Slope Gradient, Erosion Hazard, Rock Outcrops
Melaleuca	• Baguia • Baucau • Quelicai • Vemasse • Venilale	**N:** Effective Soil Depth, Erosion Hazard, Surface Rocks **S3:** Total Nitrogen, Available Potassium, Slope Gradient **S2**: Rock Outcrops	**S3:** Effective Soil Depth, Surface Rocks **S2:** Slope Gradient, Erosion Hazard, Rock Outcrops
Pine	• Baguia • Baucau • Quelicai • Vemasse • Venilale	**N:** Dry Months, Effective Soil Depth, Erosion Hazard, Surface Rocks **S3**: Total Nitrogen, Available Potassium, Slope Gradient **S2**: Rock Outcrops	**S3:** Dry Months, Effective Soil Depth, Surface Rocks **S2:** Slope Gradient, Erosion Hazard, Rock Outcrops
Sandalwood	• Baguia • Baucau • Quelicai • Vemasse • Venilale	**N:** Rock Outcrops **S3**: Total Nitrogen, P-Tersedia, Available Potassium **S2**: Temperature, bahan kasar, Erosi, Surface Rocks, pH, C-organik	**S3:** Rock Outcrops **S2:** Temperature, bahan kasar, Surface Rocks

8.2 LAND IMPROVEMENT EFFORTS

Land improvement efforts in forest crop management are strategic steps to maintain the ecological functions of forests while also enhancing the productivity of both timber and non-timber forest products. Forest land generally faces several limiting factors that can reduce productivity potential, including extreme Temperatures, long dry seasons, steep slopes, high erosion levels, the presence of surface rock outcrops, shallow effective soil depth, and limitations in macro-nutrient elements such as nitrogen (N), phosphorus (P), and potassium (K).

Most of these constraints can be overcome through integrated conservation and appropriate technical interventions. For instance, the impact of long dry periods can be minimized by scheduling planting at the beginning of the rainy season to optimize plant growth. On land with steep slopes and high erosion levels, rehabilitation can be carried out through reforestation with endemic tree species that have strong root systems, combined with the planting of cover crops such as legumes or grass for soil stabilization to reduce topsoil loss. Meanwhile, shallow soil depth can be addressed by creating planting holes tailored to the biophysical conditions, and surface rock outcrops can be utilized by creating planting holes between them.

Additionally, nutrient limitations can be addressed through fertilization based on soil needs, where nitrogen accelerates early seedling growth, phosphorus supports root development, and potassium enhances plant resilience against environmental stress. In areas with long dry periods, water availability can be maintained through the development of simple irrigation systems, construction of soil and water conservation dams, and rainwater harvesting techniques. Thus, planned, adaptive, and conservation-based land improvement efforts are key to enhancing the sustainability of forest management in areas with diverse biophysical conditions.

8.3 FORESTRY CROP DEVELOPMENT ZONE

The zoning for forestry crop development in Baucau District reflects a systematic effort to manage forest resources sustainably. The division of the area into three main categories agroforestry, protected and conservation forests, and mangrove forests is based on biophysical characteristics, geological conditions, soil types, and the prevailing agro-climatic regimes. This zoning serves not only as a spatial planning tool but also as a strategic framework for optimizing the ecological, economic, and social potential of each area.

The zoning division allows for the identification of specific potential areas: agroforestry as the basis for integrating production and conservation with diversified high-value crops; protected and conservation forests as buffers for terrestrial ecosystems that manage water resources and biodiversity; and mangrove forests as natural coastal defenses protecting the area from abrasion and saltwater intrusion.

A. Agroforestry

Agroforestry is a land-use system that plays a strategic role in supporting ecological sustainability while improving community welfare. The agroforestry zone in Baucau District covers approximately 347.21 km^2 or 23.05% of the total area, located at elevations of 500 to 1,000 m above sea level with slope gradients of 25 to 45%. The agroforestry system developed in this region combines food crops and shade trees (such as citrus, jackfruit, and avocado). The largest areas of this system are found in Vemasse Sub-District (11.67%), Quelicai Sub-District (5.30%), and Baguia Sub-District (3.20%).

One of the flagship commodities developed in the agroforestry system in this region is coffee. Coffee cultivation is typically carried out using a multistrata system, where coffee plants grow under the shade of hardwood trees. This system provides significant ecological benefits, including reducing erosion rates through the root systems of the shade trees, increasing soil moisture, and enriching organic matter content through leaf litter. Additionally, the multistrata system creates a more complex habitat, thus supporting biodiversity conservation. Economically, coffee has a high market value both domestically and internationally. This potential is further enhanced if managed with environmentally friendly principles, as coffee produced through sustainable practices can command a premium price in global markets.

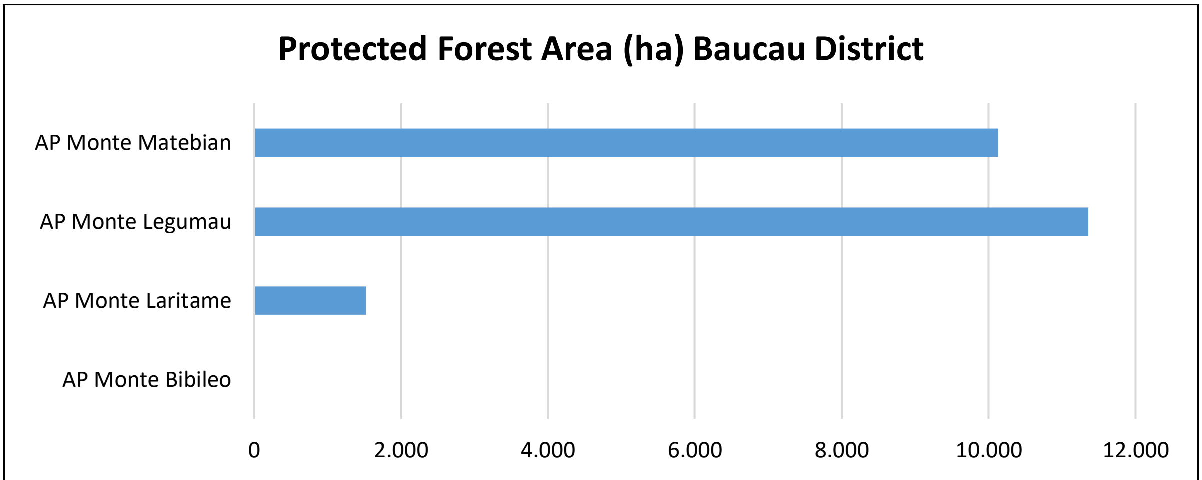
The land suitability evaluation results indicate that Arabica coffee is not recommended for development in most of Baucau District. This is due to the limiting factor of relatively high Temperatures, which are permanent and cannot be mitigated through technical interventions. Arabica coffee typically requires cooler highland conditions for optimal growth, whereas most of Baucau District lies within zones with unsuitable Temperatures. In contrast, Robusta coffee is more recommended for development because it has higher tolerance to heat, is more adaptable to local agro-climatic conditions, and is relatively more resistant to pests and diseases. With the proper cultivation practices, the development of Robusta coffee in the agroforestry system has the potential to produce more stable yields, strengthening the competitiveness of Baucau coffee in both domestic and international markets.

B. Protected and Conservation Forests

Protected forests and conservation areas in Baucau District cover approximately 188.30 km² or 12.50% of the total area. The largest distribution of these areas is found in Baguia Sub-District (4.13%), Vemasse Sub-District (2.24%), and Quelicai Sub-District (2.16%). These areas are typically located at elevations of over 1,000 m above sea level with slope gradients greater than 45%. Agro-climatically, these areas fall within zones B, C, D, and E, which are characterized by wet seasons lasting 5 to 9 months. These biophysical conditions give this area significant ecological functions, especially in soil and water conservation, biodiversity preservation, and mitigation of land degradation and erosion. Therefore, reforestation and ecosystem restoration programs are set as the main priorities to maintain environmental stability.

The zoning-based management approach provides an integrated framework that allows for scientific, systematic, and sustainable land management. This strategy not only focuses on forest ecosystem protection but also supports national food security, environmental quality, and the well-being of local communities. Thus, protected and conservation forests in Baucau play a critical role as ecological buffers and as strategic assets in sustainable development.

Administratively, the protected forest areas in Baucau District include several Protected Areas (AP) that have been designated as conservation areas, such as AP Monte Matebian, AP Monte Legumau, AP Monte Lanitame, and AP Monte Bibileo. Each of these areas has distinct biophysical characteristics but collectively functions to manage water resources, reduce the risk of erosion and landslides, and preserve biodiversity. These areas also provide extensive ecosystem services, including environmental regulation, microclimate control, and habitat protection for endemic flora and fauna of high ecological value.



	AP Monte Bibileo	AP Monte Laritame	AP Monte Legumau	AP Monte Matebian
Hutan Lindung (ha)	0,35	1520,37	11357,12	10129,12

Figure 8.1 Protected Forest Area (ha) in Baucau District

C. Mangrove Forest

The mangrove forest zone in Baucau District covers approximately 0.11% of the total land area, making it relatively small in quantitative terms compared to other terrestrial ecosystems. However, the mangrove forest plays a crucial ecological role, including protecting the coastline from abrasion, damping wave energy, reducing the risk of saltwater intrusion, and maintaining water quality by filtering sediments. Additionally, the mangrove ecosystem serves as an important habitat for various aquatic species with economic value, such as fish, shrimp, and crabs, while also contributing to significant blue carbon reserves that support climate change mitigation efforts.

From a socio-economic perspective, the presence of mangrove forests provides direct and indirect benefits to coastal communities, both through the utilization of non-timber forest products and ecosystem services that support sustainable livelihoods. Therefore, the management of the mangrove zone in Baucau District should focus on community-based conservation approaches, ecosystem restoration, and integration with coastal development policies. This will ensure that the ecological, economic, and social functions of the mangrove forests are maintained, while also strengthening environmental resilience and local community welfare.

8.4 POTENTIAL FOR SANDALWOOD CULTIVATION

Sandalwood (*Santalum album* L.) is a high-value tree species with ecological, economic, and cultural significance. Its wood produces high-quality essential oil used in the perfume, cosmetics, and pharmaceutical industries, and it holds symbolic value in the traditions and cultures of the Asia-Pacific region, including Timor-Leste. In addition, sandalwood is utilized for crafts, carvings, and artistic products, making it a commodity with broad and sustainable market appeal.

Sandalwood has long been a part of the local vegetation landscape in Baucau District and shows adaptability to marginal land conditions, such as rocky soils, limited rainfall, and varied topography. Its ecological role not only maintains ecosystem balance but also provides economic potential for the community. However, to date, its management and utilization have not been optimized, meaning its full economic value has not yet been realized by local communities.

Based on the land suitability evaluation results, the potential for sandalwood cultivation in Baucau falls within the S3 category (marginally suitable). This category indicates that the land can still be used for sandalwood cultivation, although there are several limiting factors to consider, including surface rock outcrops, temperature, coarse material content, and surface rocks. These factors may hinder optimal growth but can be addressed through technical interventions, such as selecting appropriate planting sites, maintaining host trees, and applying suitable silvicultural techniques.

In line with this, the Government of Timor-Leste has initiated a sandalwood tree inventory program as a strategic step to secure this resource and ensure its sustainability. The program aims to catalog the number, distribution, and condition of sandalwood trees in various regions, including Baucau, forming the basis for more targeted and data-driven development planning. With government policy support, high economic value, and sandalwood's ability to adapt to marginal lands, its development in Baucau District has significant prospects. If managed sustainably, sandalwood will not only provide a source of income for the community but also serve as a symbol of cultural identity and success in conserving local resources.

IX. LIVESTOCK POTENTIAL

9.1 INTRODUCTION

Timor-Leste is a country predominantly composed of mountainous and highland regions. Administratively, Timor-Leste is divided into 14 districts: Ainaro, Aileu, Ataúro, Bobonaro, Baucau, Covalima, Dili, Ermera, Lautém, Liquiçá, Manufahi, Manatuto, Região Administrativa Especial de Oe-Cusse Ambeno (RAEOA), and Viqueque. The country experiences two seasons: the dry season, which lasts from June to November, and the rainy season, which occurs from December to May. The topography, dominated by hills, and its proximity to the Australian continent subject Timor-Leste to the influence of the dry easterly monsoon winds, leading to drought conditions in many areas. Furthermore, the low rainfall also limits the growth of vegetation in various parts of the country.

The hilly topography and low rainfall not only affect vegetation growth and agriculture but also limit the availability of forage for the livestock sector. The development of the livestock sector depends heavily on the potential of land resources, proper land use, and management methods. These factors play a crucial role in providing animal feed, which primarily consists of grasses and legumes.

Forage can come from both natural sources and cultivation, including from grazing lands (Priyanto, 2016). Optimal use of land for livestock depends on both anthropogenic factors and the biophysical conditions of the land. Therefore, the application of various technological and institutional innovations is necessary to ensure that land resources are used effectively and efficiently (Suryana and Rahman, 2006).

In general, the livestock sector in Timor-Leste faces several challenges. One of the main causes is the traditional and extensive livestock management system, which results in suboptimal production. Low awareness, limited knowledge, and lack of technological expertise among farmers are also key obstacles, especially regarding the provision of animal feed in terms of both type and quality. Livestock is generally kept as a household asset that can be sold in times of need. Additionally, some communities still use livestock as draft animals for land cultivation, employing traditional management systems.

The success of livestock enterprises depends on three key factors: breeding stock, feed, and management (Aman *et al*., 2019). These three factors form an interconnected system: if one is neglected or not adequately addressed, even well-managed aspects will not result in optimal outcomes. Livestock productivity, especially for ruminants, is highly dependent on effective feed management, including the quantity, quality, and sustainability of feed availability (Rokhayati and Evadewi, 2023). According to Winarni and Sukaesih (2015), feed plays a vital role in supporting livestock development, as it directly impacts production, productivity, and animal health. The quality of forage is influenced by the variety of forage, genotype, harvest maturity, season, and management practices (Adesogan *et al*., 2015).

The success of livestock enterprises depends on three key factors: breeding stock, feed, and management (Aman *et al*., 2019). These three factors form an interconnected system: if one is neglected or not adequately addressed, even well-managed aspects will not result in optimal outcomes. Livestock productivity, especially for ruminants, is highly dependent on effective feed management, including the quantity, quality, and sustainability of feed availability (Rokhayati and Evadewi, 2023). According to Winarni and Sukaesih (2015), feed plays a vital role in supporting livestock development, as it directly impacts production, productivity, and animal health. The quality of forage is influenced by the variety of forage, genotype, harvest maturity, season, and management practices (Adesogan *et al*., 2015).

An initial step in the development of the livestock sector in Timor-Leste is the optimization of land use for the sustainable provision of forage. To achieve this, there must be compatibility between land characteristics and the types of forage crops 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 management level applied (Nugroho *et al*., 2014). Land suitability evaluation requires environmental data and soil quality for a specific area. This assessment is carried out by identifying various land characteristics, such as topography, climate, soil conditions and quality, and other physical environmental factors (Iswan *et al*., 2019). Through this evaluation process, information about the biophysical resources of the land, including climate and soil, is obtained, allowing for the determination of land suitability classes and the identification of limiting factors that need to be addressed (Jawang *et al*., 2018).

9.2 RESEARCH METHODS

The research was conducted using survey methods and descriptive analysis on areas selected purposively, 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 include interview results on livestock production and socio-economic conditions, as well as field observations regarding biophysical land conditions and soil characteristics for forage land suitability. The biophysical and soil properties were further analyzed according to laboratory standards. Secondary data used include the 2019 Timor-Leste agricultural census.

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

A. Research Procedure

1. Production and Socio-Economic Aspects of Livestock

Observations were conducted through interviews with parameters such as: types of livestock, livestock population, land area, maintenance/caging systems, feed and nutrition management systems, water sources, breeding systems, animal health management, livestock products, marketing, infrastructure, farmer characteristics, and cultural traditions.

2. Forage Land Suitability

The procedure for evaluating forage land suitability has been detailed in **Chapter III (Methodology).**

9.3 GENERAL OVERVIEW

A. General Existing Conditions

The livestock sector plays a crucial role in supporting the livelihoods of many households in Baucau District. The distribution of households engaged in livestock farming shows significant variation across Sub-Districts. Baucau Sub-

District has the highest number of households involved in livestock farming, with 434 households (54.87%). In contrast, Baguia Sub-District has the fewest livestock farming households, with only 21 households (2.65%).

Nevertheless, their contribution remains important in meeting local needs while preserving the traditional livestock farming practices that have been an integral part of local life. With these differences, each Sub-District contributes to the sustainability of the livestock sector in Baucau. The number of agricultural households engaged in livestock farming is presented in **Figure 9.1.**

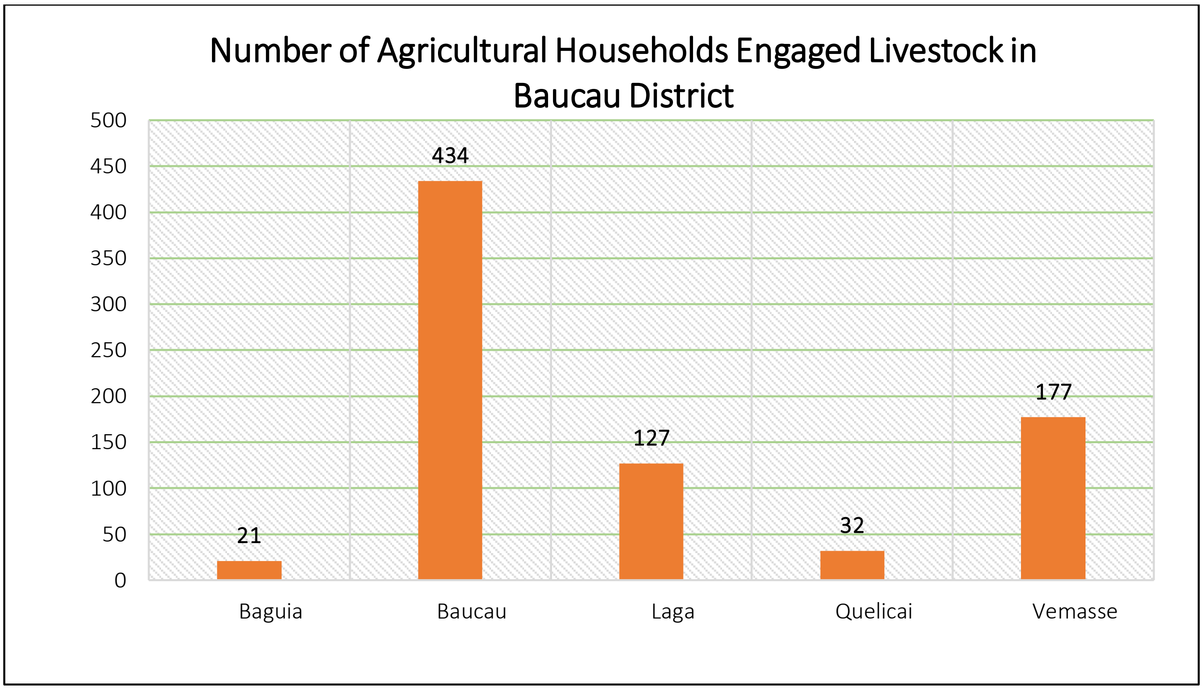


Figure 9.1 Number of Households Engaged in Livestock Farming
(Source: Agriculture Timor-Leste Census, 2019)

Venilale Sub-District has the highest number of cattle-keeping households, with 964 households (38.19%) and a total cattle population of 3,956. Meanwhile, Vemasse Sub-District has the smallest number of cattle-keeping households, with 55 households (2.18%) and a total of 258 cattle **(Figure 9.2** and **Figure 9.3).**

The highest number of horse-keeping households is found in Venilale Sub-District, with 1,078 households (28.06%) and a population of 2,231 horses. In contrast, the smallest number of horse-keeping households is found in Baguia Sub-District, with 311 households (8.09%) and a population of 861 horses **(Figure 9.2** and **Figure 9.3)**.

For buffaloes, Laga Sub-District dominates with 696 households (20.21%) and a population of 4,500 buffaloes. The smallest number of buffalo-keeping households is found in Baguia Sub-District, with 311 households (8.09%) and a total of 3,012 buffaloes **(Figure 9.2** and **Figure 9.3)**. Meanwhile, dairy cattle are only kept by households in Baguia Sub-District and Baucau, though in very small numbers, with only 1 household in total.

In Baucau District, small livestock, such as pigs, are the most commonly kept. Baucau Sub-District has the highest number of pig-keeping households, with 5,314 households (33.25%) and a total of 17,041 pigs. The lowest number is in Vemasse Sub-District, with 1,258 households (7.87%) and 4,714 pigs **(Figure 9.4** and **Figure 9.5)**.

The number of households keeping goats shows considerable variation. Baucau Sub-District has the highest number of goat-keeping households, with 1,885 households (28.27%) and a total of 13,762 goats, while the lowest number of goat-keeping households is found in Baguia Sub-District, with 456 households (6.84%) and 1,864 goats **(Figure 9.4** and **Figure 9.5).**

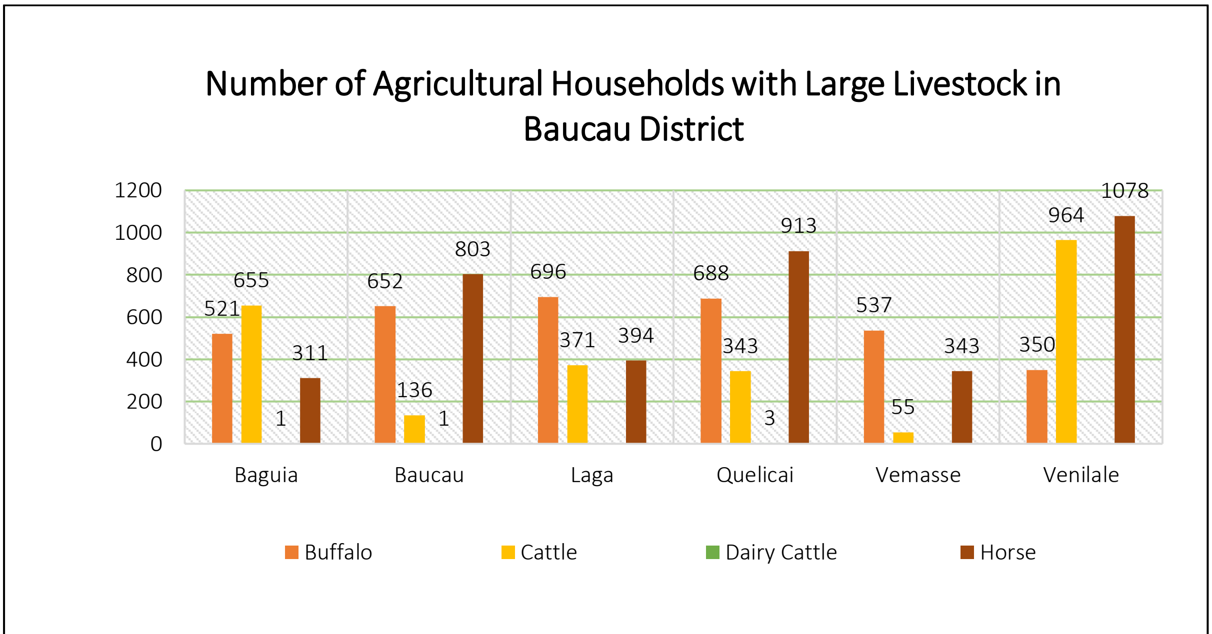


Figure 9.2 Number of Households with Large Livestock
(Source: Agriculture Timor-Leste Census, 2019)

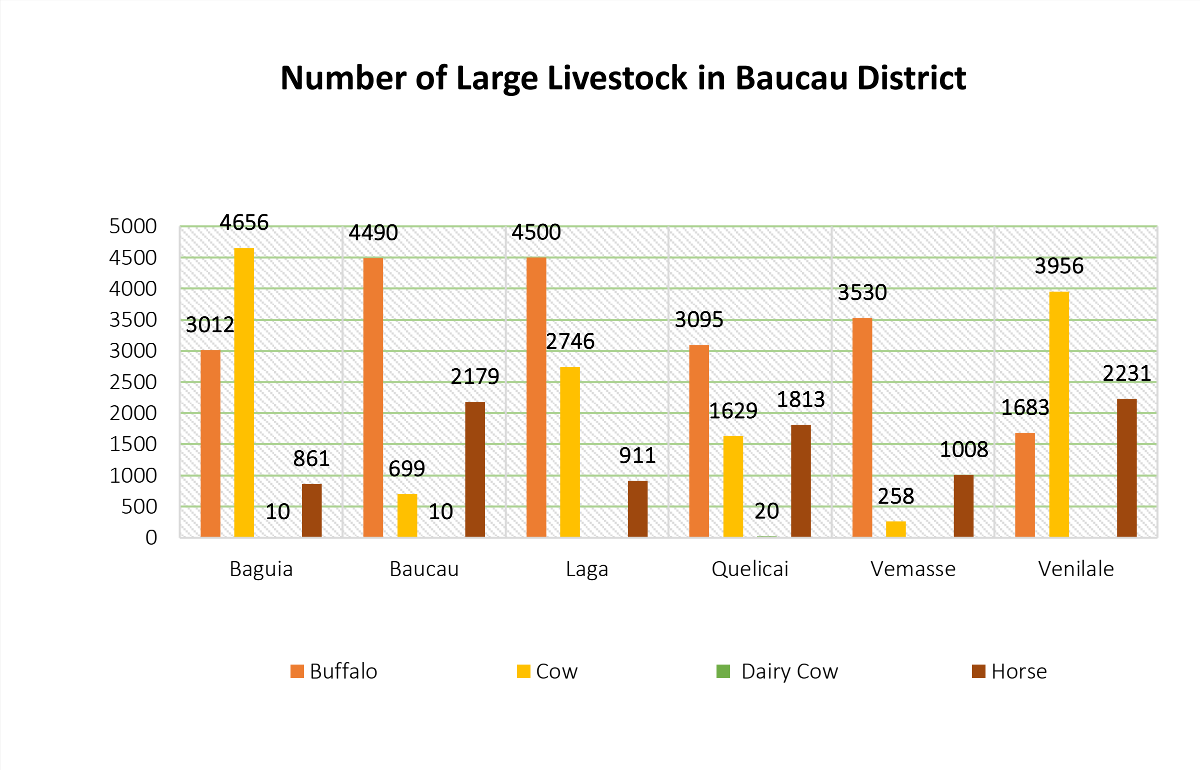


Figure 9.3 Number of Large Livestock
(Source: Agriculture Timor-Leste Census, 2019)

Sheep are kept by some households in Baucau District, although in limited numbers. Baucau Sub-District has the highest number of sheep-keeping households, with 720 households (40.40%). The smallest number of sheep-keeping households is found in Baguia Sub-District, with only seven households (0.39%). Dairy sheep are only kept in Baucau Sub-District, with just one household. Although there is only one household, this has the potential to stimulate the development of the livestock subsector in Baucau. The number of households keeping small livestock is shown in **Figure 9.4** and **Figure 9.5**

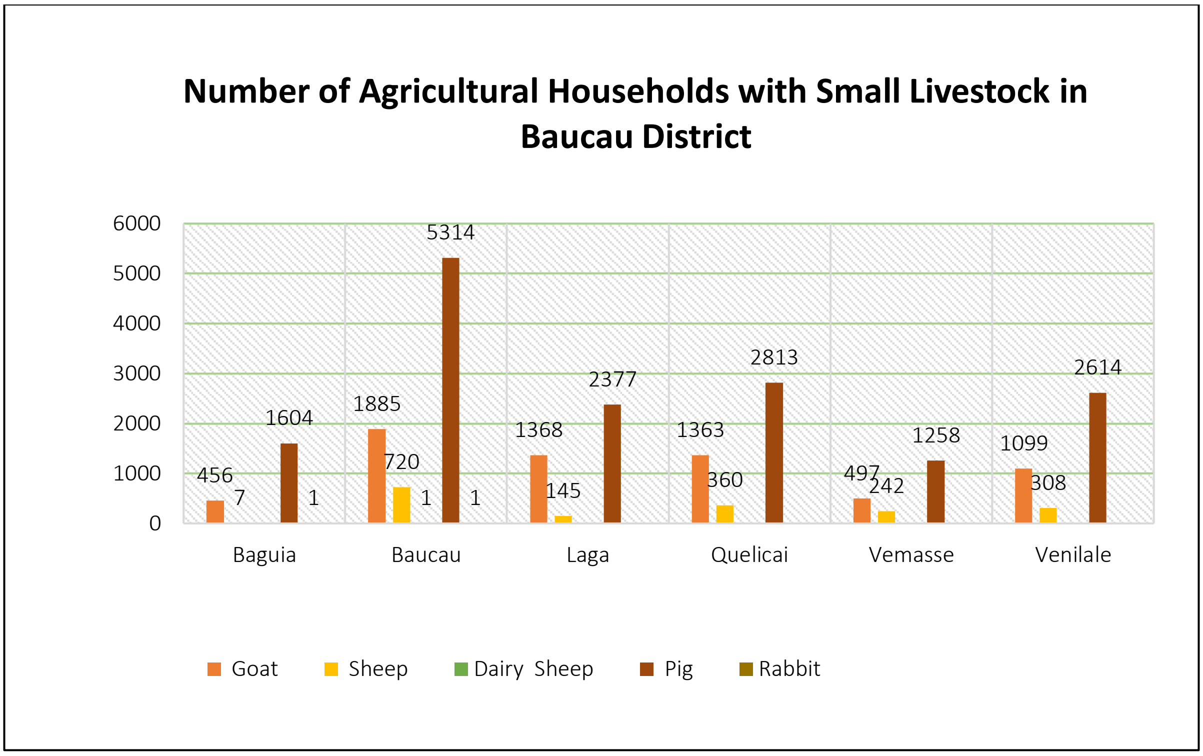


Figure 9.4 Number of Households with Small Livestock
(Source: Agriculture Timor-Leste Census, 2019)

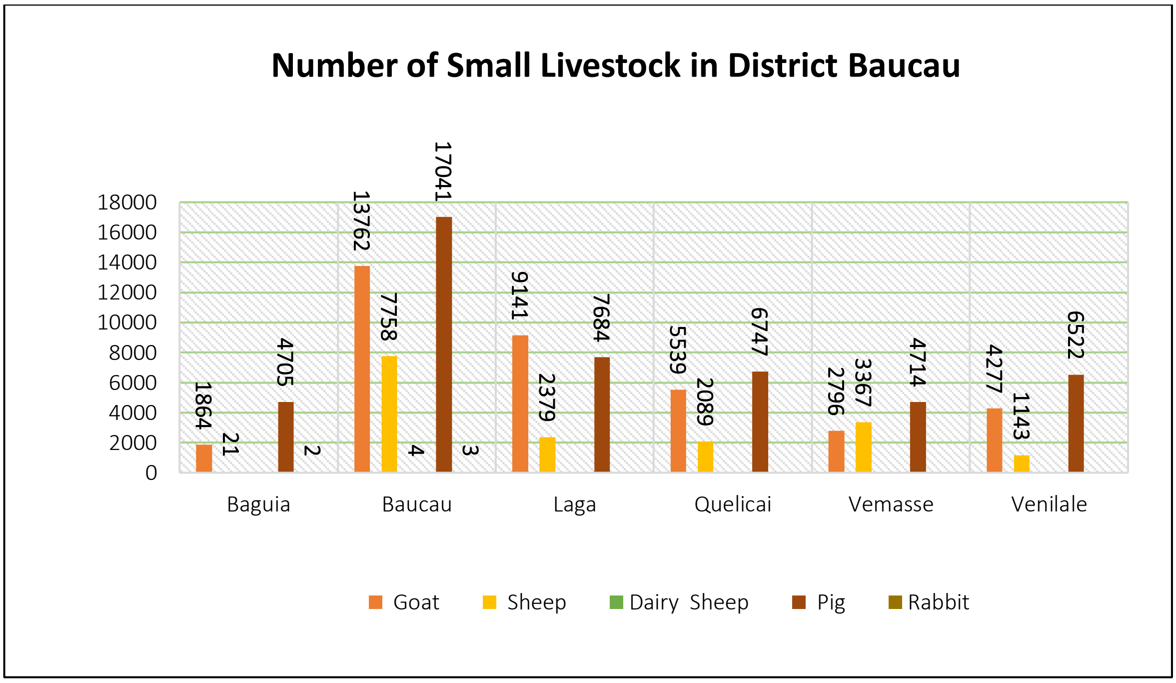


Figure 9.5 Number of Small Livestock
(Source: Agriculture Timor-Leste Census, 2019)

The number of households keeping poultry in Baucau District shows significant differences between Sub-Districts, with chickens being the most commonly kept poultry species (**Figure 9.6**). Baucau Sub-District the largest number of chicken-keeping households, with 4,985 households (31.09%) and a total of 55,418 chickens. In contrast, Vemasse Sub-District has the smallest number of chicken-keeping households, with 1,209 households (7.54%) and 12,665 chickens (**Figure 9.6** and **Figure 9.7**).

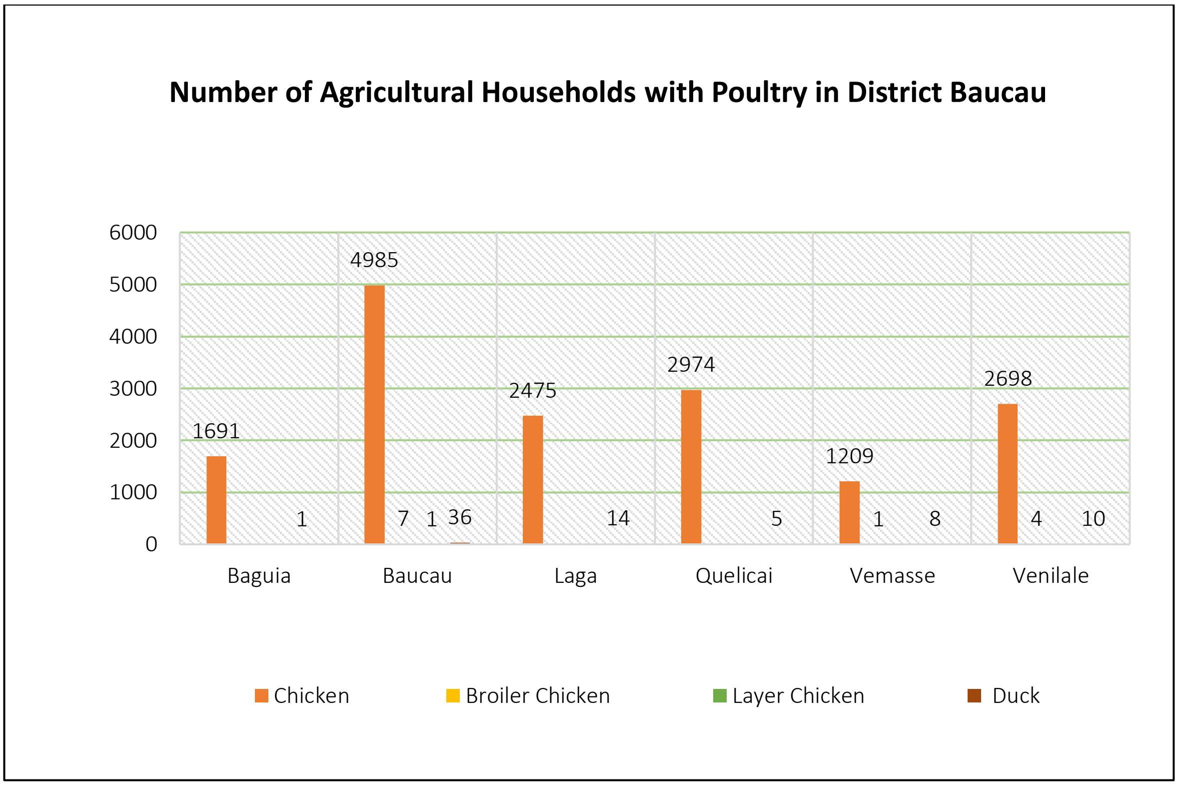


Figure 9.6 Number of Households with Poultry
(Source: Agriculture Timor-Leste Census, 2019)

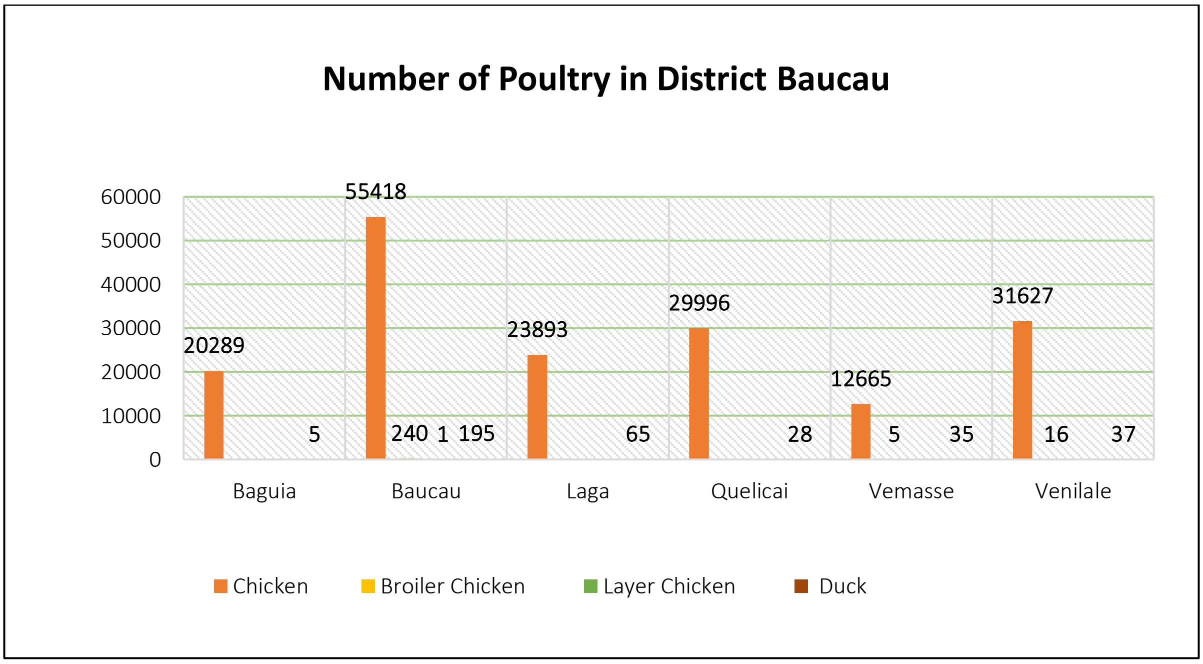


Figure 9.7 Number of Poultry
(Source: Agriculture Timor-Leste Census, 2019)

Grazing land potential is one of the important assets in sustainable livestock management. Grazing land can be a major source of livestock feed, particularly for species such as cattle, goats, and sheep, which require high-quality grass to support growth and production. Baucau District has two types of grazing lands: temporary and permanent. Baucau Sub-District has the largest areas of both permanent and temporary grazing lands compared to other Sub-Districts. The area of permanent grazing land reaches 107.51 ha, or about 42.55% of the total available land, while temporary grazing land covers 94.39 ha, or 45.75%

The presence of these grazing lands plays a strategic role in supporting the livestock sector, particularly in providing natural feed resources for livestock. The large areas of grazing land not only help meet the feed requirements but also serve as important assets for more efficient and sustainable livestock management. Based on this data, Baucau Sub-District has a comparative advantage with the largest dominance of grassland area among other Sub-Districts. This indicates significant potential for grazing in the area. Meanwhile, Venilale Sub-District has the smallest area of temporary grazing land, at 4.37 ha (2.12%). The Sub-District with the smallest area of permanent grazing land is Baguia Sub-District, with 2 ha (0.79%). The proportion of grazing land is presented in **Figure 9.8.**

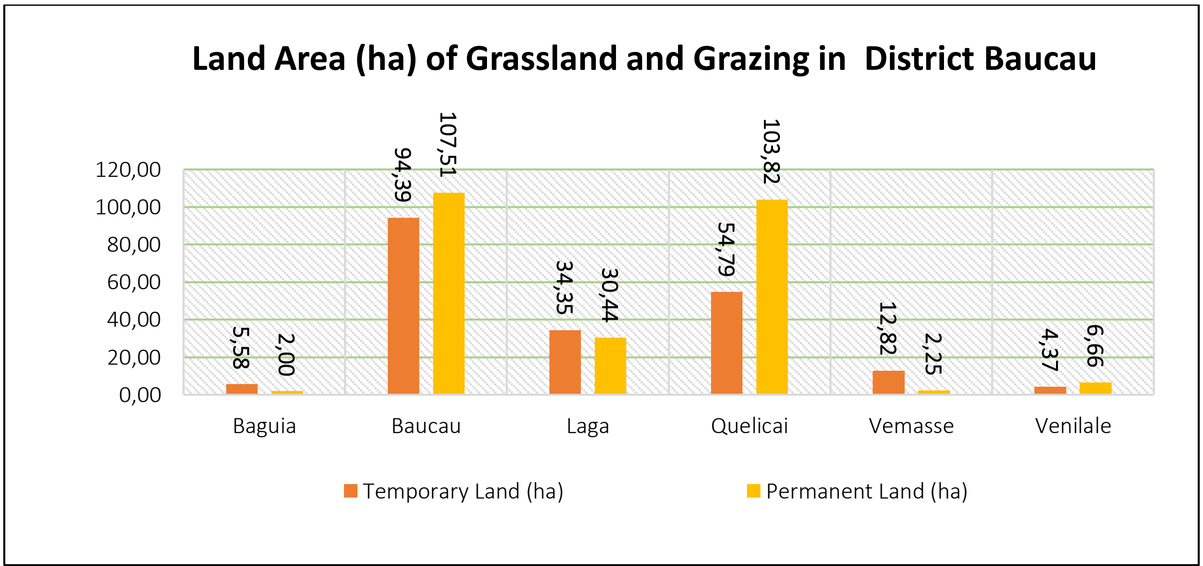


Figure 9.8 Grazing Land Area
(Source: Agriculture Timor-Leste Census, 2019)

B. Existing Conditions of Survey Locations

Observations in Baucau District were conducted on a farm belonging to a community member in Triloka. Based on the observation results, it was found that the area used for livestock farming is approximately 4.7 ha, with a population of 10 Bali cattle. Of this number, three cattle were a donation from the Ministry. The land has been planted with various types of forage crops such as kinggrass, lamtoro, gamal, and turi. This area holds great potential as a model for developing community-based livestock farming with a focus on the local economy. The land is strategically located near the main highway, providing easy and accessible transportation. The development is expected to focus on increasing livestock numbers, expanding forage crop areas, and empowering farmers through technical training and strengthening institutional capacity. Given its potential, this land is highly suitable for development into an economically oriented livestock farm with increased livestock populations and diversified forage crops.

Figure 9.9 Existing Condition of the Survey Location in Baucau District
(Source: Research Documentation, 2025)

9.4 DISCUSSION

A. Evaluation of Forage Land Suitability

Land suitability analysis for forage crops in Baucau District is a method used to assess the suitability for the growth of various forage species and grasses in grazing areas of a specific region. This analysis aims to facilitate the development of livestock feed sources and ensure their optimal availability. According to Djaenudin *et al*. (2003), land suitability is defined as the degree to which land is suitable for a particular use. Land suitability can be assessed based on current conditions (actual land suitability) or after improvements (potential land suitability). The land suitability evaluation in Timor-Leste uses a matching method, which compares the data on land characteristics and quality with suitability criteria based on the growth requirements of the evaluated crops. Some of the forage crops identified based on the land resource potential include elephant grass (Pennisetum purpureum), leguminous plants, and field grasses.

The results of the land suitability evaluation in the Sub-Districts of Baguia, Baucau, Laga, Quelicai, Vemasse, and Venilale indicate that these areas have potential for developing forage crops such as elephant grass, setaria, legumes, and grazing lands, as detailed in **Table 7.3 of Chapter 7 in this report**. Based on the table, the actual land suitability for grazing varies from S2 (Moderately Suitable) to N (Not Suitable). The main limiting factors affecting land suitability include total nitrogen (N-total), available phosphorus (P), available potassium (K), slope, erosion, rainfall, surface rocks, rock outcrops, and dry months. However, these constraints can still be addressed through technical interventions, such as the application of fertilizers containing nitrogen, phosphorus, and potassium, such as urea, KCl, and SP-36; addition of organic materials; planting of terrace-strengthening crops such as elephant grass, vetiver, and setaria; creating terraces; and installing irrigation systems like sprinklers.

The suitability evaluation results for Aldeia Aubaca, Village Triloca, Baucau Sub-District, Baucau District, as the survey location, indicate that forage crops such as elephant grass, setaria, legumes, and grazing lands have suitability criteria of S2 (moderately suitable). Limiting factors such as rainfall, slope, total phosphorus, available phosphorus, available potassium, pH, base saturation (KB), organic carbon (C-organic), and total nitrogen (N-total) can still be improved technically by creating irrigation systems and terraces in the forage land, selecting forage crops with strong root systems, applying fertilizers containing N, P, K, and adding organic materials such as compost and manure. With these improvements, land suitability can be enhanced so that forage crops can produce optimally.

To improve livestock development locations, particularly in the development of forage crops (HPT) in Timor-Leste, several important steps need to be taken to enhance both the quantity and quality of forage, including:

1. **Planting Leguminous Forage Crops**

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

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

Increasing the diversity of forage species, both leguminous and grass species, is essential for the development of livestock feed. The greater the diversity of forage species consumed by livestock, especially ruminants, the more likely it is that their nutritional needs will be met. Some leguminous species with high nutritional content that have potential for development include Indigofera, Calliandra, Turi, and Stylo. A commonly found local legume species is Lamtoro taramba. It is important to be cautious when feeding Lamtoro to pregnant livestock, as its leaves contain anti-nutritional substances like mimosine and cyanide acid, which are toxic if consumed in excess. This can be mitigated by feeding Lamtoro in moderation, mixing it with other feed, and ensuring that it is wilted (air-dried) to reduce the levels of anti-nutritional substances.

B. Livestock Ecological Potential and Suitability

Baucau District has a total area of 150,165.90 ha, with 54,637.94 ha allocated for livestock sector development. This potential needs to be optimally utilized through human resource empowerment and effective land management. One important factor in determining the potential of a region for livestock development is the ecological suitability or environmental condition of the area. Regions that do not meet the ecological suitability indicators are considered less potential for livestock development. Therefore, livestock development in Baucau District must take ecological suitability into account.

Once the measurements for each parameter in the field, such as rainfall, temperature, and soil chemical parameters like organic carbon (C-organic), cation exchange capacity (CEC), base saturation (BS), total phosphorus (P-total), available phosphorus (P-available), etc., are obtained, they are analyzed using Geographic Information System (GIS) applications to determine the ecological suitability of five livestock species: sheep, beef cattle, dairy cattle, pigs, and buffalo. The ecological suitability map for livestock is presented in Figure 9.10.

Available land for livestock development in Baucau District includes areas designated as mixed gardens and grazing land. These lands are categorized as available because they are assumed to be able to produce forage for livestock in the form of grass, legumes, or crop residues. Lands that are categorized as not available for livestock development include those designated as forests and rice fields. Technically, this issue can be addressed by improving barns with proper air circulation and ventilation systems. However, for dairy cattle, temperature is a critical factor that must be met for their development.

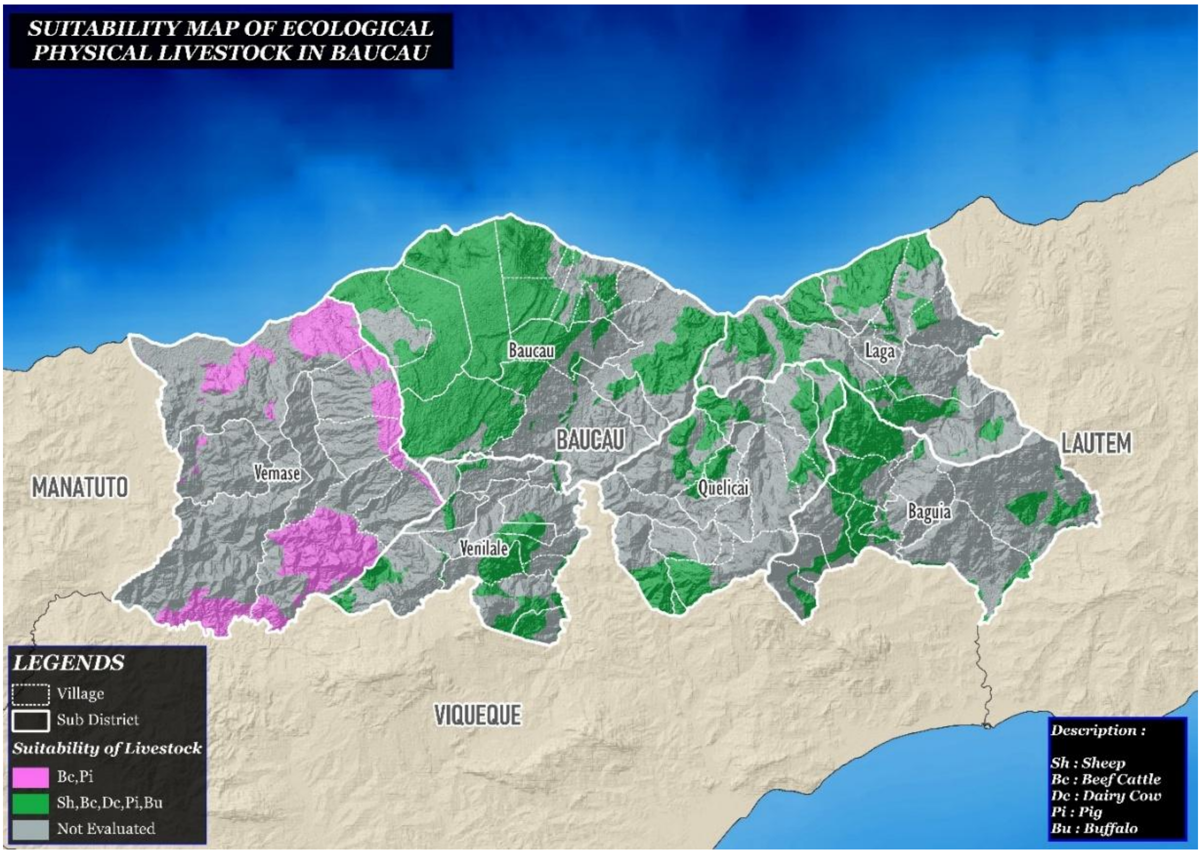


Figure 9.10 Ecological Suitability Map for Livestock in Baucau District

Table 9.1 Livestock Development Area in Baucau District

Sub-Distict	Results of Large Livestock Development Suitability					Area (ha)
	Sheep	Beef Cattle	Dairy Cattle	Pigs	Buffalo	
Baguia	S	S	S	S	S	5.812,24
Baucau	S	S	S	S	S	22.573,96
Laga	S	S	S	S	S	7.318,36
Quelicai	S	S	S	S	S	5.665,85
Vemasse	N	S	S	S	N	9.466,91
Venilale	S	S	S	S	S	3.800,62

Based on **Table 9.1,** the ecological suitability of land for large livestock development, including sheep, beef cattle, dairy cattle, pigs, and buffalo, shows a spatial distribution that varies across the study area. Baucau Sub-District stands out as the most suitable area for large livestock development, while the Sub-Districts of Vemasse, Laga, Baguia, Quelicai, and Venilale also show suitability for large livestock farming. However, sheep and buffalo are less suitable for development in Vemasse due to temperature limitations. Meanwhile, for poultry, the ecological suitability of land can be categorized as very high and uniform, covering 100% of the area analyzed. This is due to the biological characteristics of poultry, which have a high adaptability to various environmental conditions, enabling them to be raised on almost all types of land available.

To support the livestock sector development program, it is essential to identify and map regions that primarily function as livestock farming locations and forage crop cultivation areas. Baucau District has an average environmental temperature of about 23.31°C, with an average annual rainfall of 1,333.94 mm, providing ecological potential conducive to sustaining livestock farming optimally. This condition also supports the sustainable availability of forage crops throughout the year. Environmental temperature plays a crucial role in determining the thermal comfort and productivity of livestock. Extremely low temperatures can cause cold stress in livestock, which leads to increased body heat production and basal metabolic rate. If this condition persists without adequate feed support, the metabolic energy of livestock decreases, and their resistance to extreme temperatures weakens. This results in disrupted growth, decreased productivity, and a significantly higher risk of disease outbreaks.

On the other hand, excessively high environmental temperatures cause livestock to decrease feed intake and prefer to increase water consumption. The reduced nutrient intake directly impacts livestock performance and production. Therefore, optimal environmental management, particularly regulating temperature and humidity, is essential for sustainable livestock farming systems. These efforts aim to create conditions that support the physiological balance of livestock, thus maintaining maximal productivity.

C. Socio-Economic Aspects of Livestock Farming

For the people of Baucau District, livestock plays a crucial and multifunctional role, far beyond merely being a source of food. Livestock is an integral part of the subsistence agricultural system and developing civilization. It is still common to find people using livestock such as cattle, buffalo, and horses as draft animals for plowing rice fields and farmland. The use of livestock for labor enables farmers to cultivate larger areas and significantly increase agricultural productivity. Additionally, in some cultures, livestock also holds social, economic, or ritual significance. For example, in some cultures, livestock is used as dowry or offerings in traditional ceremonies. Moreover, the number of livestock a person owns often serves as a measure of wealth and social status in the community.

One endemic species of livestock in Timor-Leste is the Timor buffalo (*Karaw Timor*). The Timor buffalo holds an important position in the social life of Timor-Leste's people, especially as an offering in ceremonies such as death, birth, and weddings. Timor buffalo is also used in traditional transactions, such as land sales, its manure is used as fertilizer, and historically, the local people consumed buffalo milk for protein intake, making the Timor buffalo highly valued.

Buffalo milk has been consumed by the local population for centuries and is one of the more popular milk types, alongside cow and goat milk. Buffalo milk is thicker and has a distinctive smell compared to cow milk. In the past, people commonly consumed Timor buffalo milk directly without further processing, making it an important part of the cultural identity.

Livestock farming is generally still conducted using traditional free-range grazing methods, known as the extensive system. According to Williamson and Payne (1993), in the extensive management system, livestock are kept freely and graze natural vegetation. In this system, livestock are left with a composition of males and several females in one population. The key feature of extensive management is that no shelters are provided and no supplemental feeding is given (Jamili, M. A. 2022). The advantages of the extensive system include minimal labor, short working hours, and livestock can find feed in grazing fields and former agricultural lands. However, the drawbacks include difficulty in controlling the nutritional feed intake, and livestock are more susceptible to diseases and death. Unsupervised and free-roaming livestock also contribute to social problems, such as livestock theft and damage to farmers' crops.

The farming practices rely heavily on traditional knowledge passed down through generations. The absence of large-scale livestock industries results in low production levels, as there are still many areas in need of improvement. Livestock distribution within the community is relatively low due to limited capital and poor breeding practices. This is because increasing livestock populations requires significant investment and time. Therefore, livestock is not viewed as a primary income source, which leads to low livestock production in the region (Serey *et al.*, 2014).

From interviews, it was revealed that the community received cattle and buffalo assistance in 2014 from the MAPPF. However, over time, due to low supervision and lack of education, the assistance has not developed as initially intended. The community used the assistance to meet household needs or as dowry payments. As a result, attention to the sustainability of livestock breeding has been neglected, which could hinder long-term development.

Other challenges in livestock farming are complex, ranging from production to post-production, including infrastructure and facilities that also need development. In terms of breeding, the community still applies natural mating without knowing artificial insemination (AI) technology, making it difficult to breed livestock for sustainability. The community is still not well-educated on proper livestock management. They are not informed about good feed practices for livestock productivity. Moreover, in terms of marketing, farmers can only sell live animals, making it difficult to increase the market price of livestock products. Despite better access from Dili to other districts, inadequate road infrastructure remains a challenge for the community in marketing their livestock products to a wider market.

Given the various challenges faced in both pre-production and post-production stages, attention is needed to address these issues, which could serve as a foundation for designing a master plan for livestock farming development. Improvement recommendations could start with educating the community on breeding practices and introducing AI technology. Furthermore, education on the importance of proper livestock management is crucial. This aims to motivate the community to adopt a more economically-oriented approach to livestock farming rather than viewing it merely as a family asset. The government should not only focus on education but also provide financial support in the form of credit loans to facilitate livestock farming. Increasing the marketability of products could be achieved by educating farmers and opening new marketing channels that extend beyond just selling live animals.

X. FRESHWATER FISHERIES POTENTIAL

10.1 INTRODUCTION

Timor-Leste, as an archipelagic country, holds vast natural resource potential, particularly in the marine and fisheries sectors. Baucau District, as one of the administrative regions, offers diverse topographical, soil, water quality, and climatic conditions that present significant potential for the development of both freshwater and brackish water aquaculture. Aquaculture not only contributes to local food security but also creates sustainable economic opportunities for surrounding communities.

However, the development of aquaculture ventures requires an in-depth study of land suitability. Selecting the right location is crucial to the success of this venture, as each fish species has different tolerances to environmental factors such as topography, hydrology, soil conditions, water quality, and climate. Therefore, land suitability analysis is an essential first step in aquaculture planning.

The study specifically focused on freshwater aquaculture practiced by communities in the lowland and coastal areas of Baucau District. These regions possess biophysical characteristics that are relatively more favorable for aquaculture development compared to mountainous areas, with more stable water availability and land conditions that allow the construction of fish ponds at lower erosion risk. The objective of the study was to evaluate land suitability in Baucau District based on a set of biophysical parameters identified in the assessment matrix, encompassing four main groups of factors: topography and hydrology, soil conditions, water quality, and climate. Each factor was assigned a specific weight reflecting its level of importance in determining land suitability for aquaculture, so that the evaluation results could provide an objective overview of aquaculture development potential in the area.

Utilizing the evaluation matrix is key to determining whether the land in Baucau District can support sustainable and efficient aquaculture production systems. This evaluation not only focuses on technical analysis but also incorporates local policies, community participation, and customary practices in water resource management, ensuring that the results can be optimally applied in Baucau 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**.

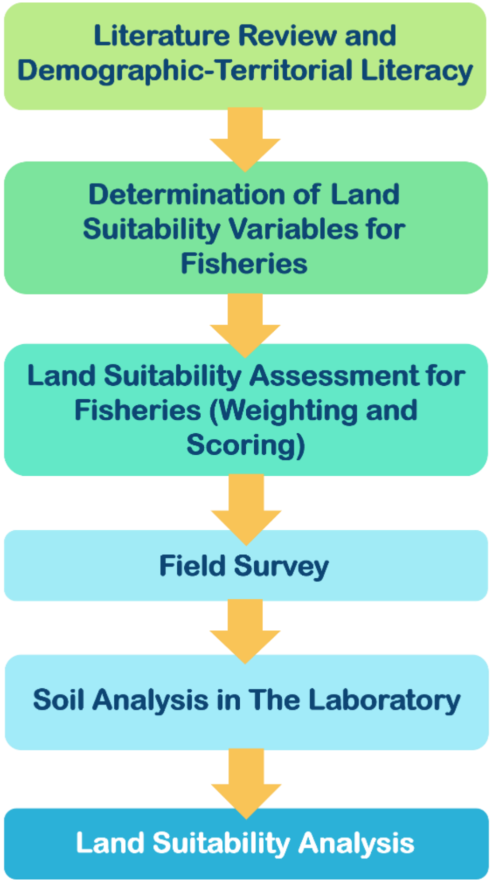


Figure 10.1 Flowchart of the research process for land suitability in the aquaculture sector

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

a. Topography

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

b. Soil Conditions

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

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

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

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

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

c. Water Quality

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

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

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

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

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

d. Climate

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

D. Land Suitability Evaluation for Aquaculture

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

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

Table 10.3 Land Suitability for Pond Aquaculture Parameters

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

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

Table 10.4 Land Suitability Scoring Calculation

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

E. Field Survey

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

Table 10.5 Field Survey Activities by Area in Baucau District

No.	Schedule	Sub-District	Village	Purpose (Ownership)
1	08 May 2025	Baucau	Caibada Makasai	Business (Individual)
2	08 May 2025	Baucau	Gariuai	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	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)	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

Baucau District holds great potential in the fisheries sector, which can support local economic growth and food security. Based on data from the Timor-Leste Population Census of 2022, in 2019, aquaculture production in Baucau District reached a total of 16,525 kilograms. Although it slightly decreased to 16,411 kilograms in 2020, production volume began to increase gradually in the following years. In 2021, production was recorded at 16,740 kilograms, which then rose to 17,074 kilograms in 2022. By 2023, production is expected to reach 17,416 kilograms. This indicates the sustainability potential of the aquaculture sector in the Baucau region, where the gradual increase in production shows good resource management and continuous optimization efforts. With the application of modern technology and proper management, aquaculture production in Baucau has the opportunity to further develop as a sector contributing to both local and national economies.

A. Capture Fisheries

According to official reports from the Ministry of Agriculture and Fisheries of Timor-Leste, the development of the fisheries sector in Baucau District has shown a positive trend in recent years, driven by efforts to improve infrastructure, train fishermen, and adopt modern technology. The abundant natural resources, combined with government support and community participation, create significant opportunities to strengthen this sector.

1. Number of Fishing Households

In terms of the number of fishing households in Baucau District, Baucau Sub-District has the highest number of fishing households, with 199 households (40.20%). In contrast, Baguia Sub-District has the fewest fishing households, with only 3 households (0.61%). This could indicate limited community involvement in fisheries activities in this area.

This distribution shows varying potentials and challenges in managing the fisheries sector across each Sub-District. Baucau Sub-District, with the highest number of fishing households, has great potential for further development through improved fishing technology, training programs for fishermen, and better access to markets. Meanwhile, Baguia Sub-District represents an area with initial potential that can be strengthened through empowerment programs and infrastructure support to encourage community participation in fisheries. Through a strategic approach, the fisheries potential in these two Sub-Districts can be maximized to support sustainable local economic development. Graphs showing the number of fishing households are presented in **Figures 10.2** and **10.3.**

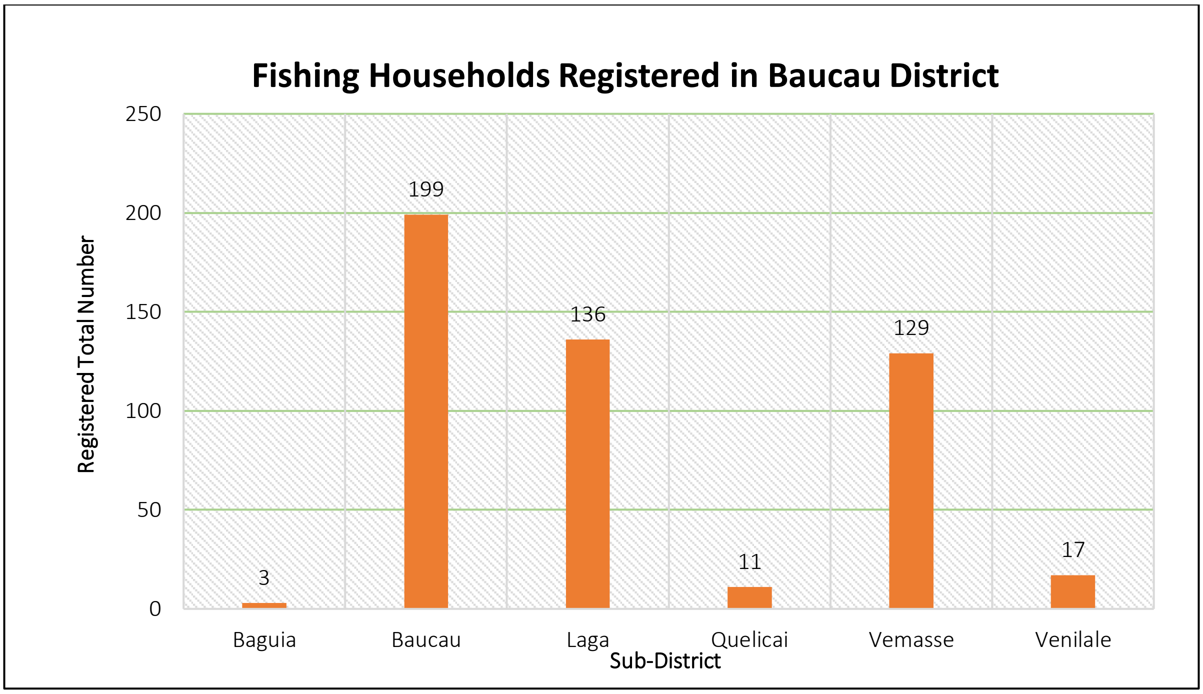


Figure 10.2 Fishing Households in Baucau District
(Source: Timor-Leste Agriculture Census, 2019)

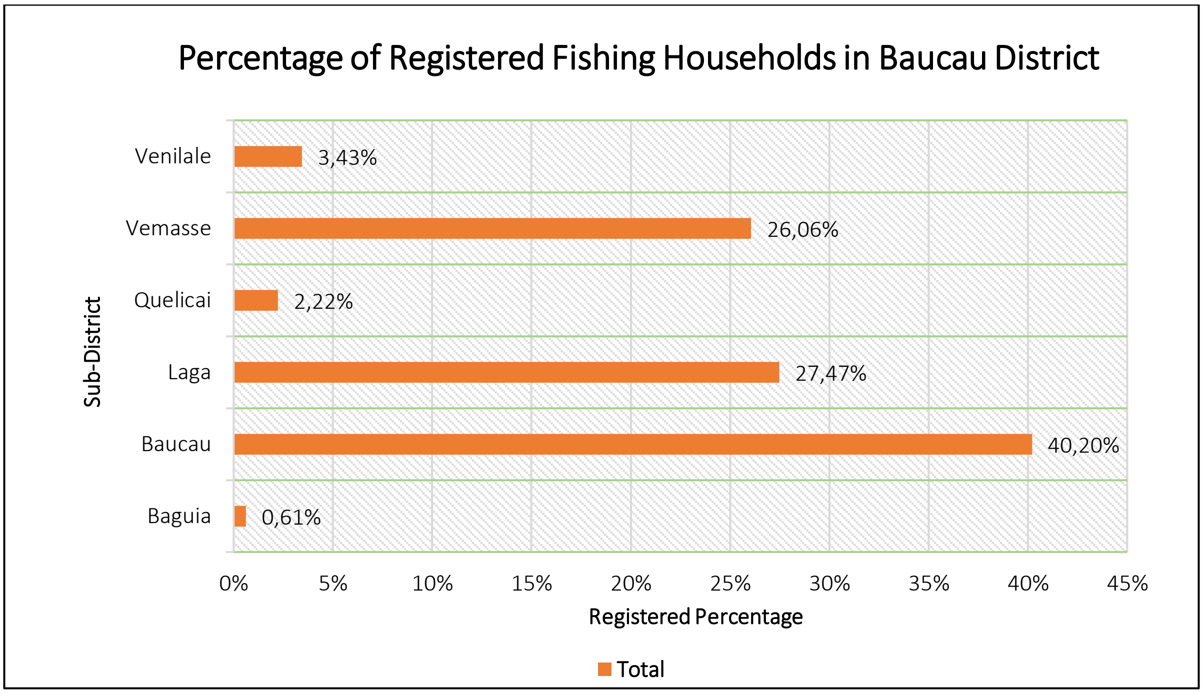


Figure 10.3 Percentage of Fishing Households in Baucau District
(Source: Timor-Leste Agriculture Census, 2019)

2. Households Involved in Fishing Activities

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

Baucau Sub-District has the highest number of households involved in fishing for consumption and occasional sales, totaling 136 households or 46.26%. On the other hand, Quelicai Sub-District has the fewest households in this category, with only 1 household or 0.34%, reflecting a significant difference in the scale of fisheries activities between these areas. Meanwhile, Baucau Sub-District has the highest number of households involved in fishing for consumption and social obligations, with 29 households or 42.65%. Baguia Sub-District has two households engaged in fishing activities aimed at both consumption and fulfilling social needs. This makes Baguia Sub-District the area with the smallest number of households involved in these activities. The Sub-District with the highest number of households involved in fishing for direct sales is Laga Sub-District, with 76 households (51.35%), while the lowest is Venilale Sub-District, with 1 household (0.68%). The number of households involved in fishing activities is presented in **Figures 10.4** and **10.5.**

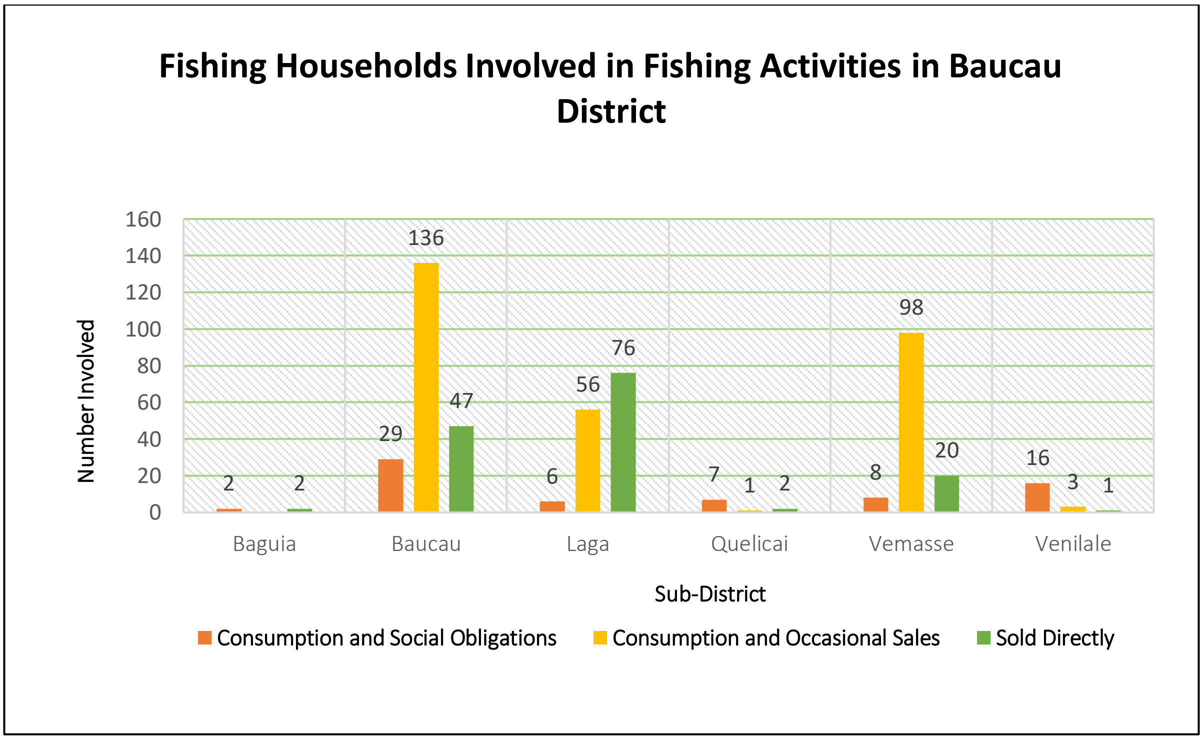


Figure 10.4 Number of Households Involved in Fishing Activities
(Source: Timor-Leste Agriculture Census, 2019)

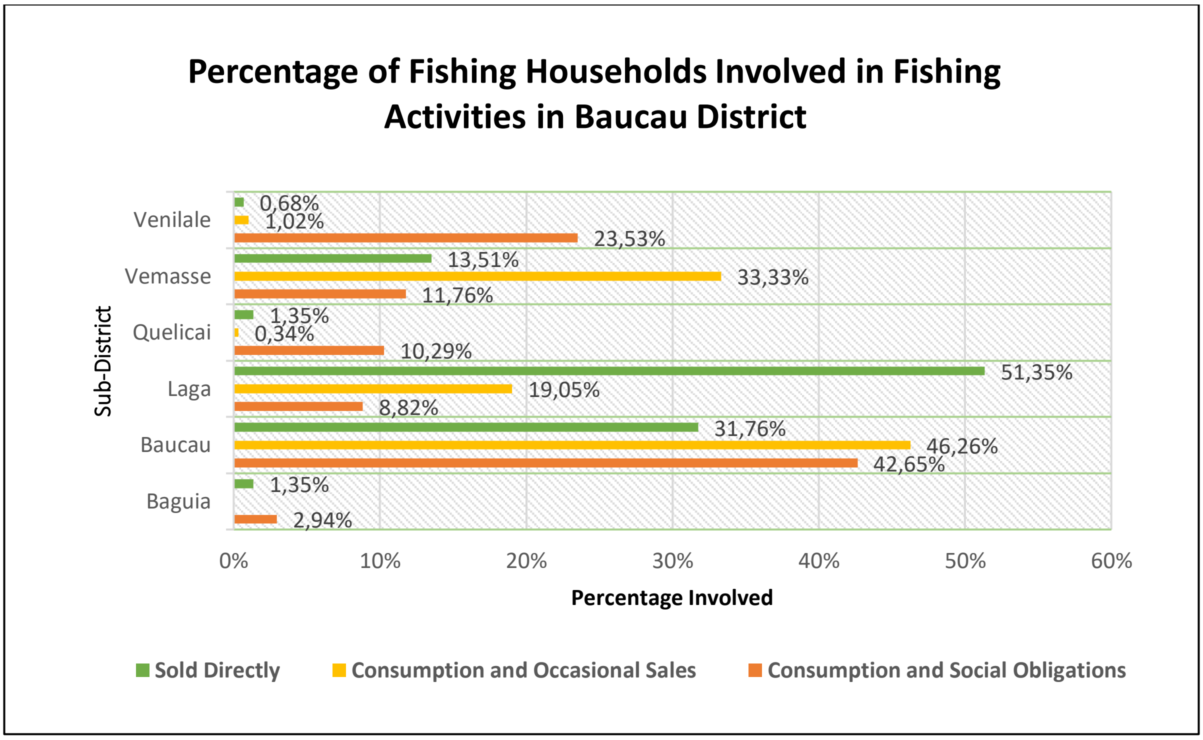


Figure 10.5 Number of Households Involved in Fishing Activities
(Source: Timor-Leste Agriculture Census, 2019)

B. Aquaculture

Aquaculture in Baucau District has great potential to support food security, increase income for local communities, and maintain sustainable natural resources, particularly through the sustainable management of freshwater fisheries resources. Based on data da Fonseca *et al*.(2023), the production of aquaculture fish consumed by people in Baucau District was recorded at 0.12 kg per person per year in 2019. However, from 2020 to 2023, this figure slightly decreased and stabilized at around 0.11 kg per person per year.

1. Proportion of Land for Aquaculture

The distribution of land for aquaculture in Baucau District shows significant variation across each Sub-District. Venilale Sub-District dominates with the largest area for aquaculture land, totaling 45.98 ha (78.22%). In contrast, Laga Sub-District has only about 0.48 ha (0.81%) of aquaculture land, indicating limited potential for aquaculture development compared to Venilale Sub-District. The proportion of land allocated for aquaculture is shown in **Figures 10.6** and **10.7.**

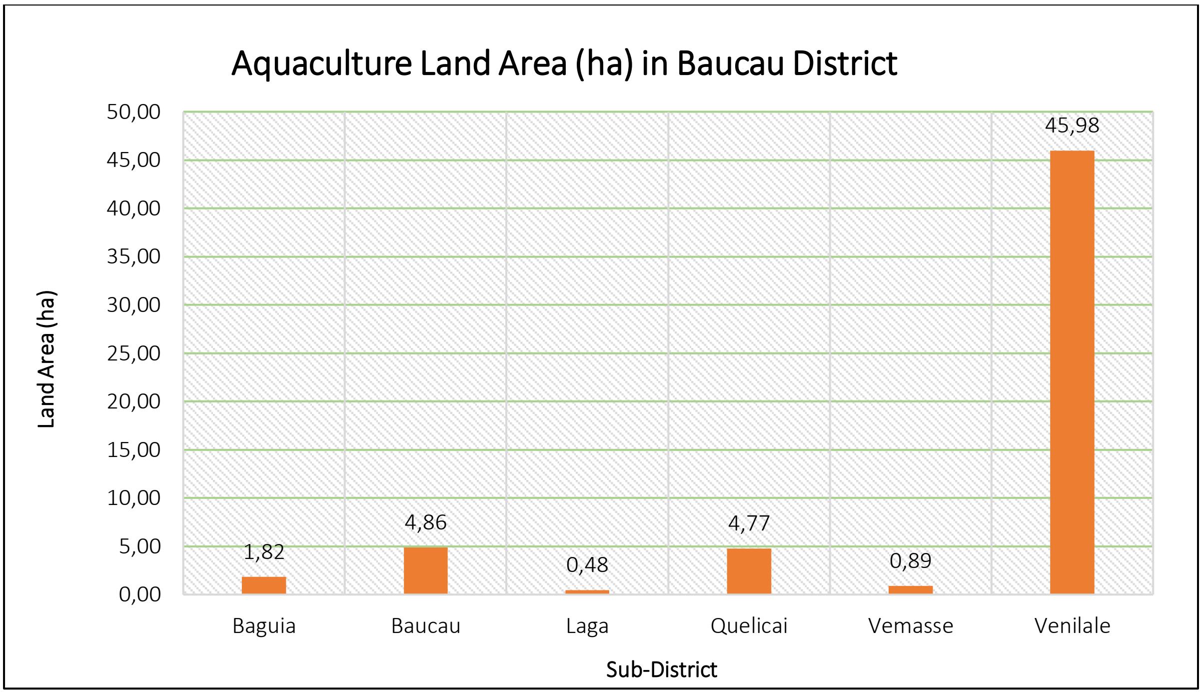


Figure 10.6 Aquaculture Land Area in Baucau District
(Source: Timor-Leste Agriculture Census, 2019)

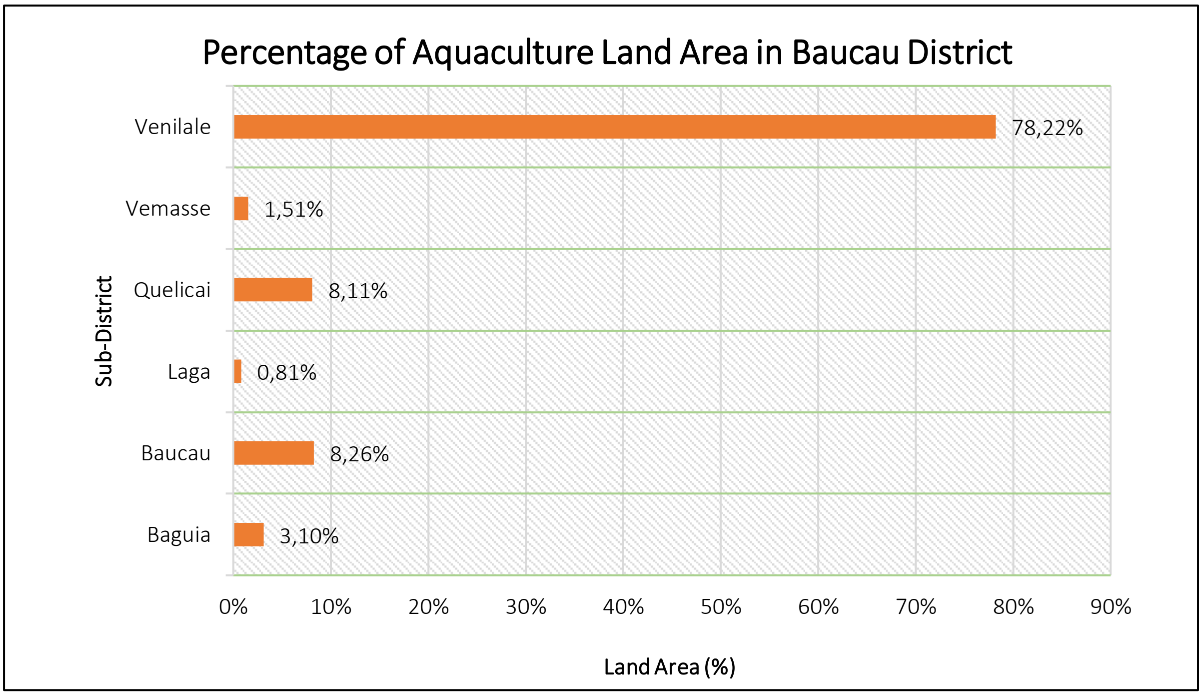


Figure 10.7 Percentage of Aquaculture Land in Baucau District
(Source: Timor-Leste Agriculture Census, 2019)

2. Aquaculture Households

Households involved in aquaculture play a crucial role in driving the growth of the local fisheries sector, supporting food security, and strengthening the local economy. Each household engaged in aquaculture reflects the sustainability of aquaculture practices and their adaptation to water resource-based economic opportunities.

The number of households involved in aquaculture in Baucau District shows significant variation. Venilale Sub-District has the highest number of households engaged in aquaculture, with 234 households (58.65%), while Baguia Sub-District has only 13 households (3.26%) involved in aquaculture.

A strategic approach is needed to increase community participation in Sub-Districts with lower engagement in aquaculture. By strengthening local capacity and optimizing existing aquaculture potential in each Sub-District, Baucau District can increase the contribution of this sector to local economic growth. The number of households engaged in aquaculture in Baucau District is presented in **Figures 10.8** and **10.9**.

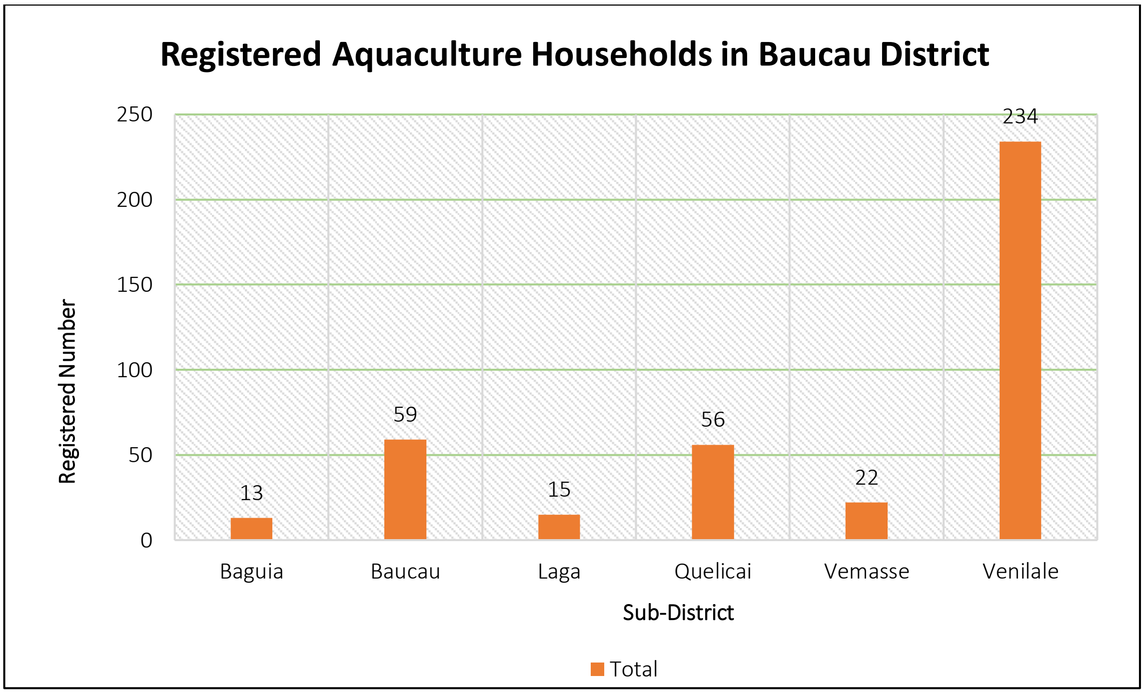


Figure 10.8 Aquaculture Households in Baucau District
(Source: Timor-Leste Agriculture Census, 2019)

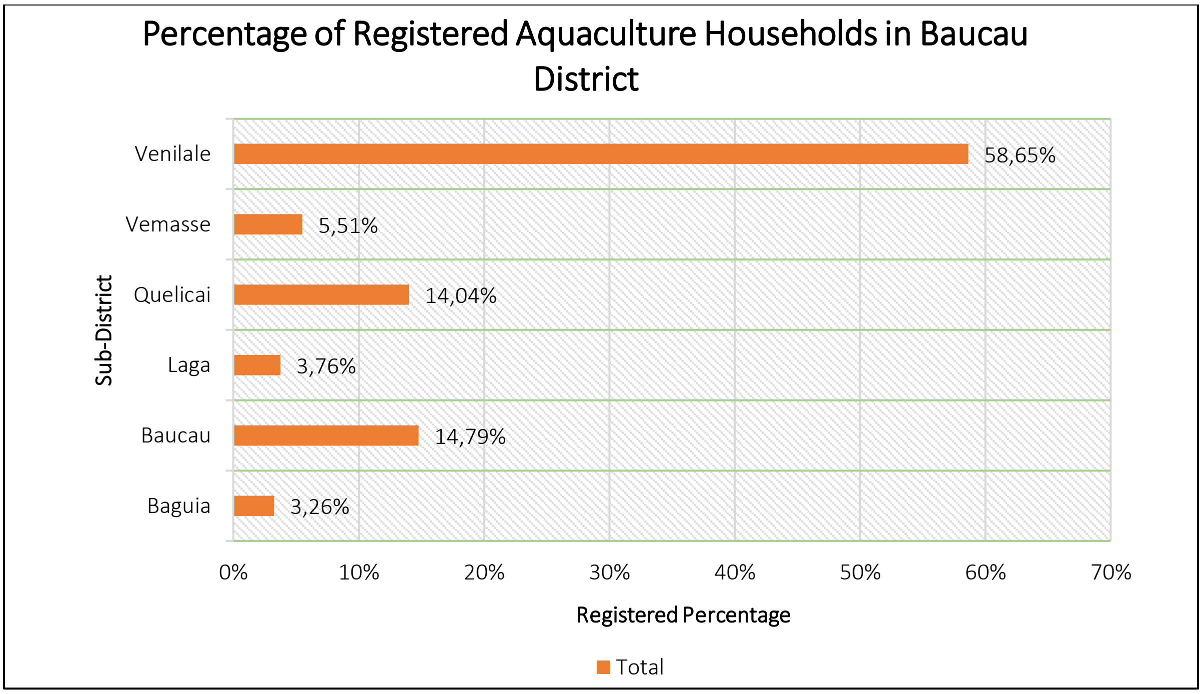


Figure 10.9 Percentage of Aquaculture Households in Baucau District
(Source: Timor-Leste Agriculture Census, 2019)

3. Aquaculture Systems

The aquaculture systems in Baucau District show a diverse distribution across each Sub-District, with a dominant number of pond-based farming systems spread throughout the region. Venilale Sub-District has the highest number of ponds, totaling 226 units or about 45.56%. The pond-based aquaculture system is most dominant in Venilale Sub-District, which has the highest number of units, 91 units, representing 72.80% of the total. On the other hand, fish ponds, although contributing on a small scale, are also found in Venilale Sub-District, with 3 units, representing 50% of the total fish ponds. Fish cage systems are scattered across several regions, namely Baucau, Quelicai, and Venilale. Quelicai Sub-District has the highest number of fish cages, with 2 units, accounting for 50% of the total fish cages. Meanwhile, Baucau Sub-District and Venilale Sub-District each have 1 unit of fish cage, demonstrating a variety of farming methods, though still on a limited scale. The facilities used for aquaculture in Baucau District are shown in **Figures 10.10** and **10.11.**

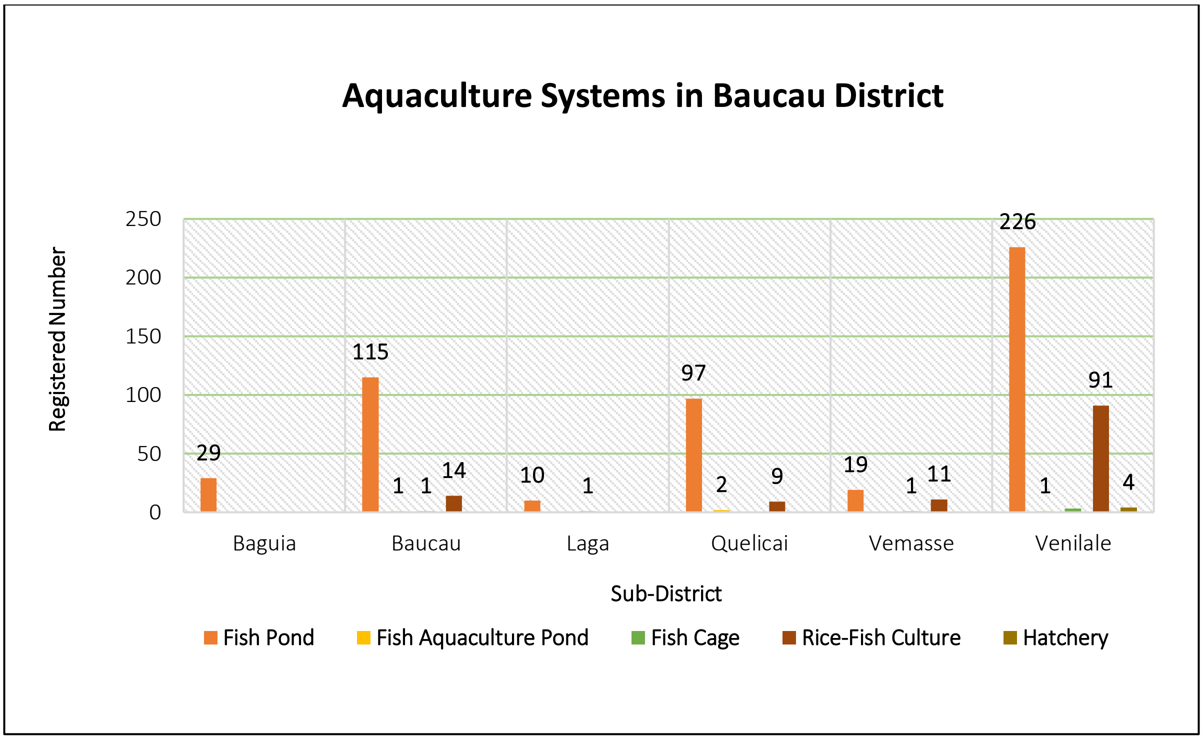


Figure 10.10 Aquaculture Systems in Baucau District
(Source: Timor-Leste Agriculture Census, 2019)

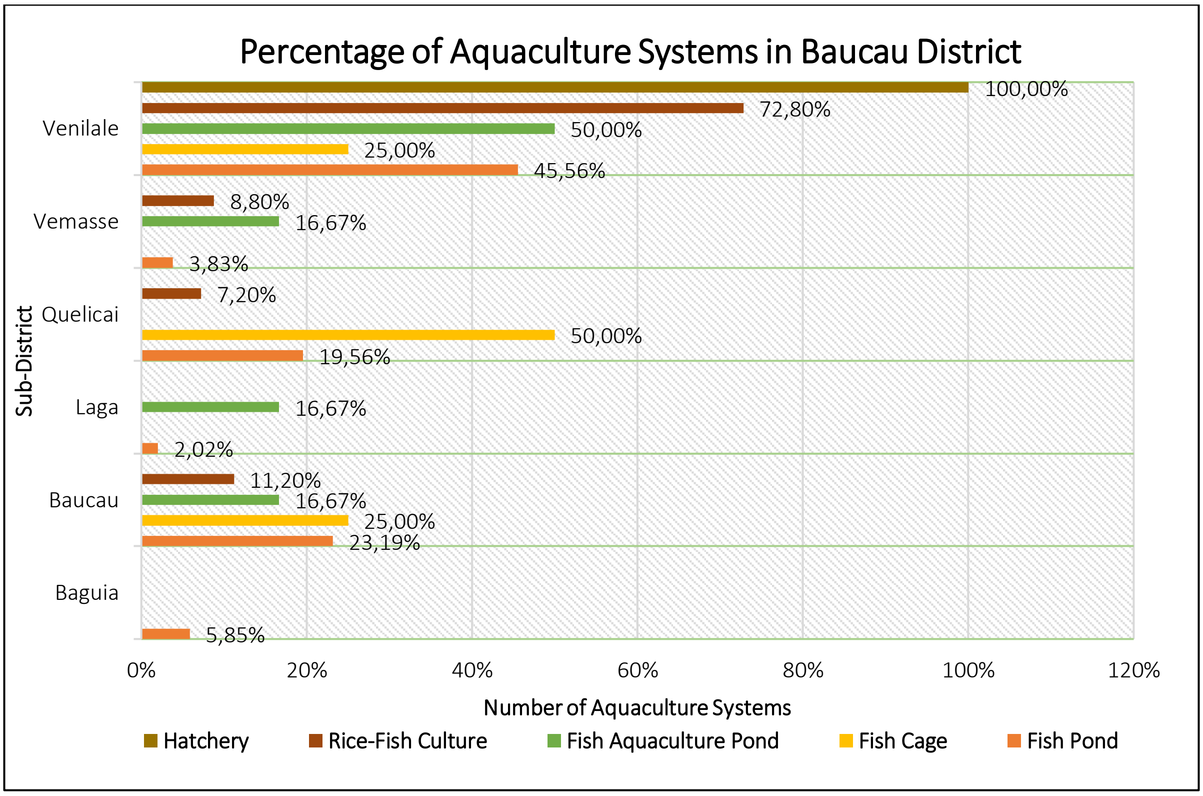


Figure 10.11 Percentage of Aquaculture Systems in Baucau District
(Source: Timor-Leste Agriculture Census, 2019)

C. Field Observation Results

Baucau District has various fisheries systems that reflect differences in function and management levels, ranging from temporary fish holding ponds to more modern farming facilities. In Caibada Village, the available ponds serve as temporary holding areas for fish distributors before being distributed to consumers. This location has two concrete ponds and one earthen pond, utilizing spring water as the main source, but without aeration systems or special treatments, as their function is only to hold fish temporarily before they are sold.

Figure 10.12 Temporary Fish Holding Ponds in Caibada Village
(Source: Researcher Documentation, 2025)

In Gari Uai, the farming system is more developed with private ownership and better infrastructure. There are 12 concrete ponds, some of which are equipped with aeration systems using aerator pumps. The pond owner, a teacher by profession, focuses on tilapia farming with a production cycle of three times per year. Each pond is stocked with 500 fingerlings and produces 250-280 fish per cycle, with an average weight of 200-300 grams per fish. High-quality pellets are used for feeding, with a consumption of 6-7 sacks per pond during the cultivation period.

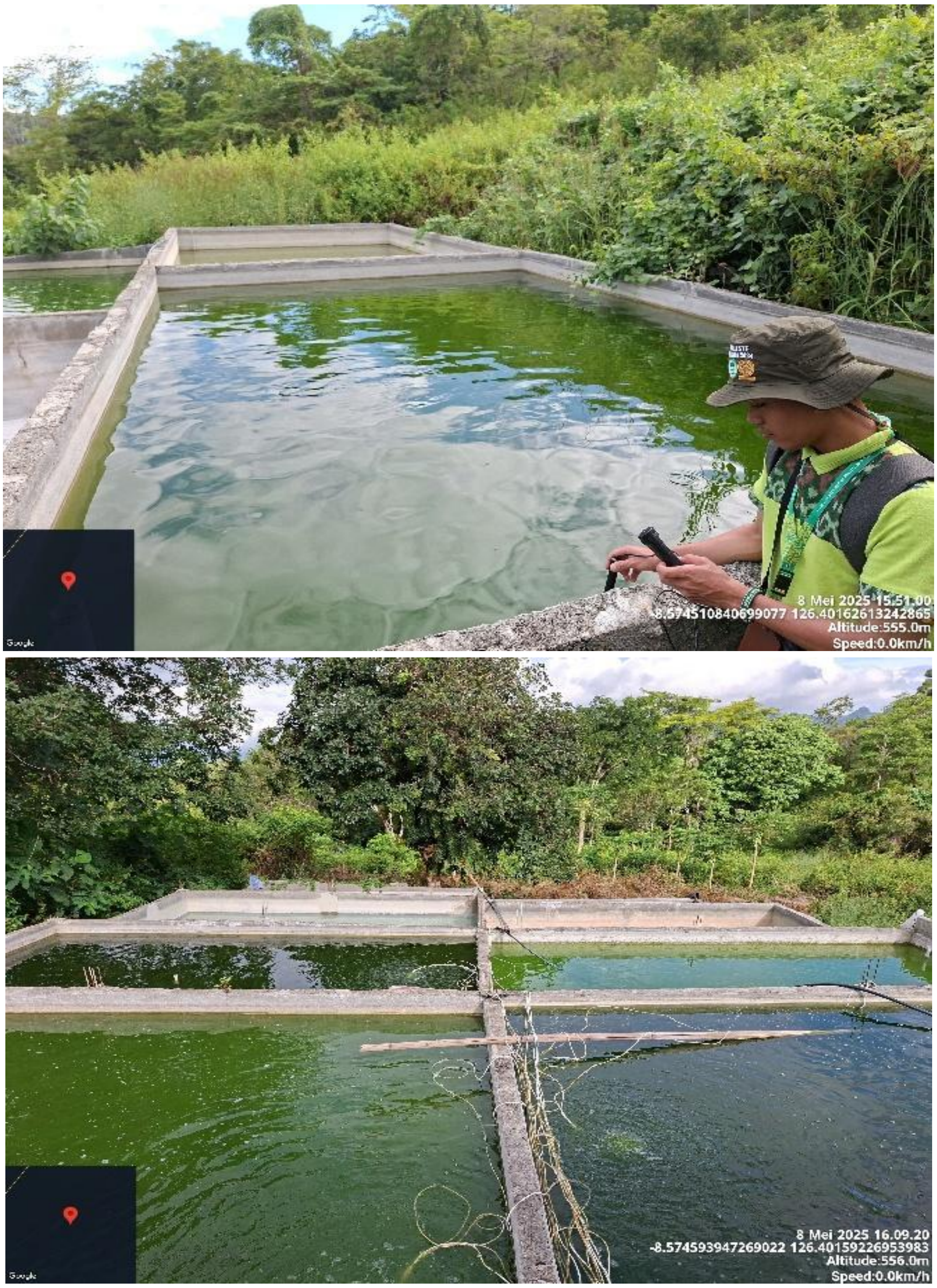


Figure 10.13 Tilapia Ponds in Gari Uai Village
(Source: Researcher Documentation, 2025)

In Triloca, the farming system focuses on catfish seed production with private assets. The farm owner, with a background in biology, manages concrete ponds with water sourced from natural springs. The main activity at this location is catfish breeding, with a breeder population of 30 females and 60 males, almost two years old. Each breeding cycle produces around 100-300 fingerlings, using commercial feed (PSP) during the early growth phase.

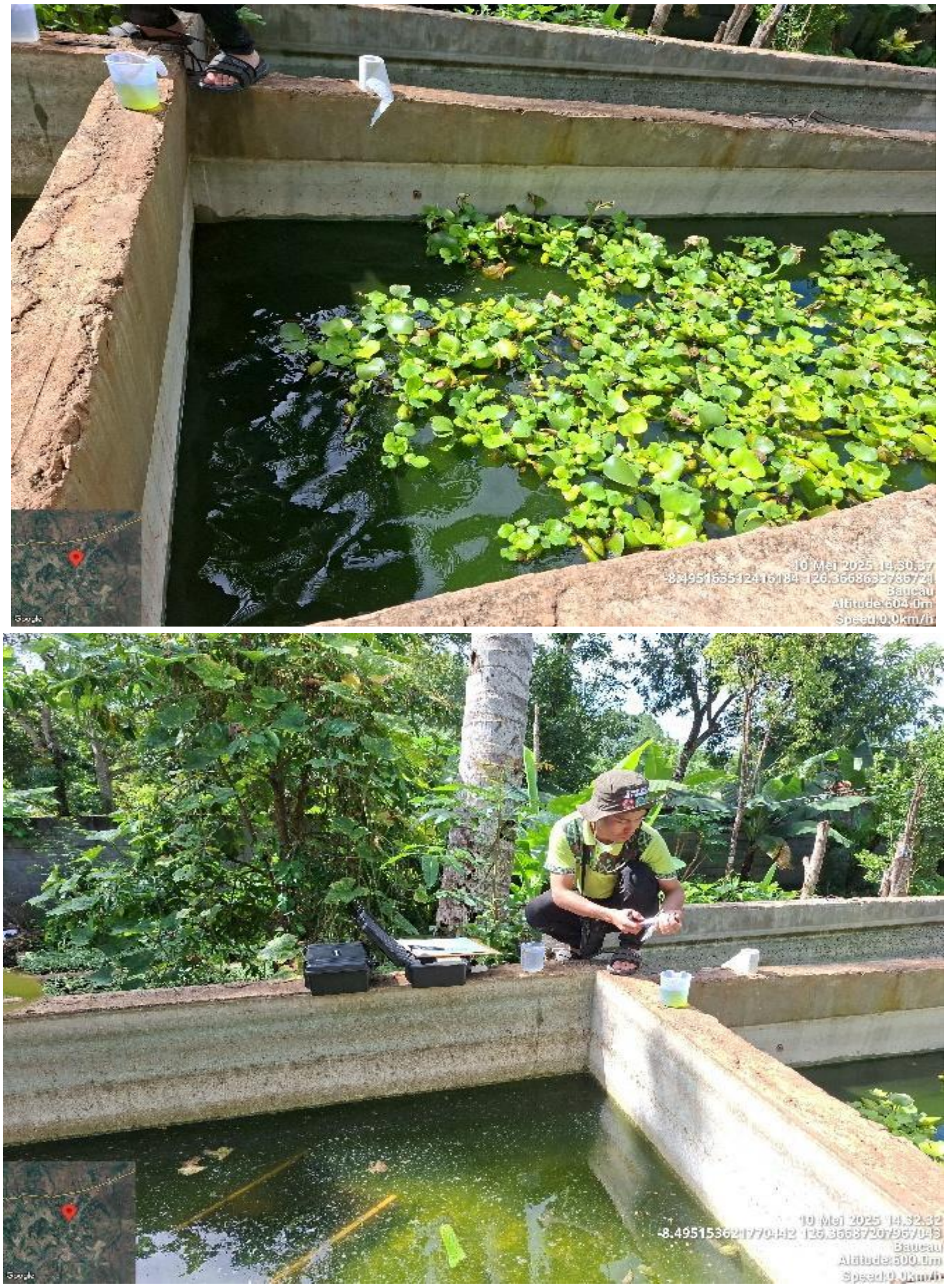


Figure 10.14 Catfish Breeding Ponds in Triloca Village
(Source: Researcher Documentation, 2025)

Meanwhile, the farming facility in Vemasse is managed by the national government through the Department of Aquaculture. This facility is comprehensive, including laboratories, pump houses, water filters, and breeding, nursery, and grow-out blocks. The farming system uses three types of ponds: earthen, concrete, and fiber round ponds, with water sourced from seawater via pumps and boreholes for freshwater supply. The main commodities farmed include tilapia, milkfish, and crabs, with a survival rate of 85%. In 2023, 2,000 tilapia fingerlings were stocked, with an estimated Feeding Conversion Ratio (FCR) of 3.9. Harvesting is done when the fish reach a size of around 300 grams per fish after undergoing the grow-out phase with high-quality pellet feed.

Figure 10.15 Brackish Water Fisheries Facility in Vemasse
(Source: Researcher Documentation, 2025)

Overall, the fisheries systems in Baucau District show a variety of goals and management methods, ranging from fish transit to breeding and grow-out on a larger scale. The fisheries potential in this region can be enhanced by optimizing aeration systems, improving infrastructure, and increasing feed efficiency to support higher productivity.

10.4 COMPREHENSIVE LAND SUITABILITY ANALYSIS FOR AQUACULTURE

A. Aquaculture Land Suitability in Baucau District

Land suitability is an indicator of how appropriate a region is for specific uses, particularly for aquaculture. The assessment aims to determine whether the physical, chemical, and climatic characteristics of the land support the optimal and sustainable growth of aquatic commodities.

The evaluation is carried out using two approaches: actual suitability and potential suitability. Actual suitability reflects the land's condition without any intervention, based on field survey data. This assessment identifies limiting factors, evaluates land quality, and generates an overall score indicating the land's natural capacity to support aquaculture commodities.

In contrast, potential suitability refers to the condition of the land after improvements are made to address limiting factors. Marginal land (S3) can be improved to become moderately suitable (S2) or highly suitable (S1) through technical interventions such as topographic modification or water quality improvement. This evaluation considers the possible technical and economic improvements that could be implemented.

The improvement of land suitability from actual to potential largely depends on the effectiveness of management and available technology. However, not all land characteristics can be improved, and some may require high levels of management or are not yet addressable with current technology. Therefore, land use planning for aquaculture should focus primarily on potential suitability. This evaluation provides the maximum projection of land capacity and serves as the foundation for formulating management strategies and the necessary interventions to achieve optimal ecological and productive outcomes.

B. Results of Aquaculture Land Suitability Evaluation

Land suitability analysis is a crucial step in formulating sustainable land management strategies for aquaculture development. This evaluation is conducted using an integrated approach that combines topographic data, field observations, and laboratory analysis of soil and water physical and chemical properties. This approach enables the identification of potential and biophysical constraints of land in supporting various types of aquaculture commodities.

Each commodity is analyzed based on its actual growth requirements and the potential land suitability after improvements, such as water quality management, topographic engineering, or the application of adaptive farming techniques. The results of this evaluation provide targeted information for setting development priorities, identifying limiting factors, and formulating appropriate technical solutions based on local conditions.

This approach is applied in the land suitability study in Baucau District, providing the scientific basis for productive and sustainable land use planning. All data supporting the evaluation process, both from the field and laboratory, are systematically documented in the relevant technical documents. A map showing the distribution of soils on aquaculture land in Baucau is presented in **Figure 10.16.**

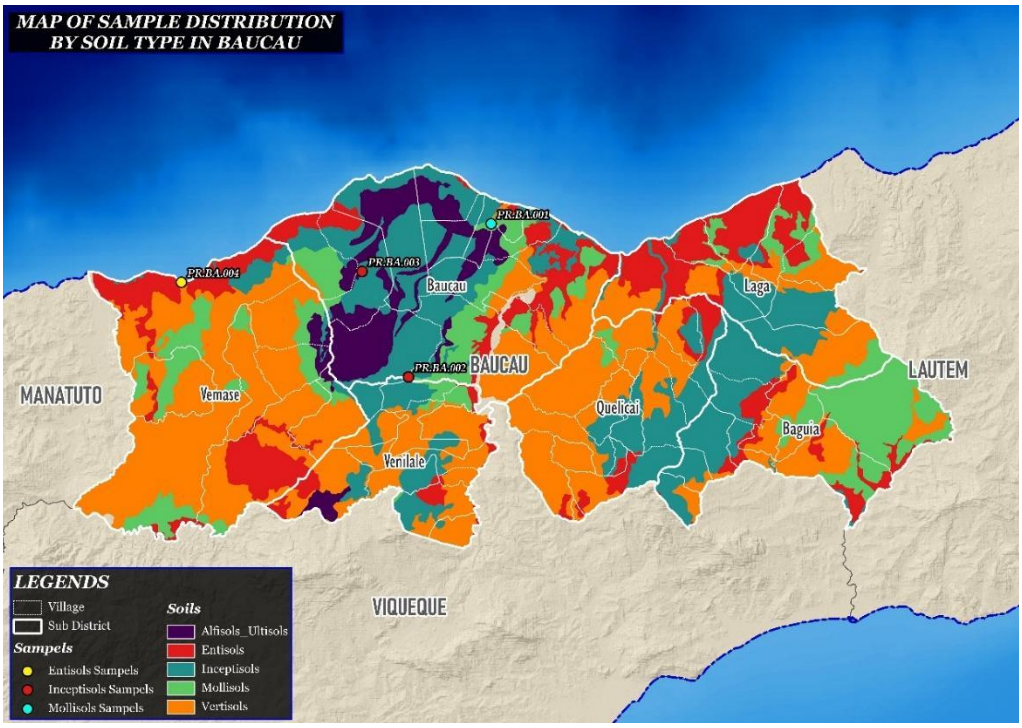


Figure 10.16 Map of Soil Distribution on Aquaculture Land in Baucau

a. Land Suitability Evaluation in Baucau Sub-District

Baucau Sub-District is one of the most promising areas for aquaculture development in Baucau District. However, based on the land suitability evaluation (**Table 10.9**), several significant biophysical limiting factors have been identified for both freshwater and brackish water commodities. Commodities such as gourami, catfish, carp, tilapia, milkfish, mangrove crab, and vannamei shrimp generally face major challenges related to slope gradient and dry season. Nearly all commodities analyzed were rated "not suitable" (N) for slope gradient and dry season under actual conditions. However, there are potential improvements that could enhance the actual suitability of the land by applying land management strategies as outlined in **Table 10.11**.

Slope gradient is a common limiting factor in hilly areas like Baucau Sub-District. The steep topography complicates the construction of conventional ponds due to increased erosion risk, difficulties in water intake and discharge, and higher construction costs. However, this factor can be improved by implementing terraced pond systems. This system is designed to follow the land contours, allowing water to flow by gravity from one pond to another. Although this solution requires higher costs and effort, it can improve land suitability from "not suitable" (N) to "marginally suitable" (S3).

The dry season is a non-improvable limiting factor, as it is directly related to climatic conditions. The availability of water during the dry season is very limited, which directly impacts the viability of fish farming. No technical solutions are available to mitigate this water shortage, so the suitability rating for the dry season remains in the "not suitable" (N) category, even with improvements in other factors. Therefore, adaptive strategies such as planting schedules or closed-system farming may be viable alternatives.

Other limiting factors, such as low rainfall, suboptimal pH, low dissolved oxygen (DO), high temperatures, and low salinity for brackish water commodities, can be improved. To address low rainfall, water conservation methods such as utilizing ponds, rainwater harvesting systems, or drip irrigation could be implemented to ensure water supply during the dry season. For suboptimal pH, methods such as periodic water exchange and the use of natural neutralizing agents like zeolite are recommended. Zeolite helps absorb ions that cause pH imbalances in pond water.

Low DO can be remedied by using aeration systems, either passive aeration or mechanical aerators. This will increase the dissolved oxygen levels, which is essential for fish survival, particularly for oxygen-sensitive commodities like carp and tilapia. High temperatures can be mitigated by planting shade trees around ponds, using shade nets, or implementing indoor aquaculture techniques.

For brackish water commodities such as milkfish and vannamei shrimp, low salinity is a key limitation in Baucau Sub-District. The recommended solution is the mixing of seawater into the ponds, either conventionally or with the use of pumps. However, this method incurs additional costs, and its feasibility depends on access to seawater sources. With appropriate technical interventions, the land in Baucau Sub-District can be improved for aquaculture, particularly for more tolerant commodities like catfish and tilapia. These species have fast production cycles and can tolerate a range of water quality, making them ideal candidates for sustainable fisheries development in the region.

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

Commodity	Current Land Suitability Limiting Factors	Current Final Evaluation	Potential Land Suitability Limiting Factors	Potential Final Evaluation
Gourami (*Ospronemus gouramy*)	N: Slope, dry season S3: Rainfall S2: pH	3.15	N: Dry season S3: Rainfall, slope	3.34
Catfish (*Clarias batrachus*)	N: Slope, dry season S3: Rainfall	3.22	N: Dry season S3: Rainfall, slope	3.34
Carp (*Cyprinus carpio*)	N: Slope, dry season S3: Rainfall S2: DO, high temperature	3.07	N: Dry season S3: Rainfall, slope	3.34
Tilapia (*Oreochromis niloticus*)	N: Slope, dry season S3: Rainfall S2: DO	2.99	N: Dry season S3: Rainfall, slope	3.34
Milkfish (*Chanos chanos*)	N: Slope, dry season S3: Low salinity S2: Rainfall	3.08	N: Dry season S3: Slope S2: Rainfall	3.34
Mangrove crab (*Scylla serrata*)	N: Low salinity, slope, dry season S2: DO	2.89	N: Dry season S3: Slope	3.46
Vannamei (*Litopenaeus vannamei*)	N: Slope, dry season S3: Low salinity, rainfall S2: DO	2.87	N: Dry season S3: Rainfall, slope	3.34

b. Land Suitability Evaluation in Vermasse Sub-District

Based on data from **Table 10.10**, the overall land suitability results for aquaculture commodities in Vemasse Sub-District reveal significant challenges for aquaculture development. The actual land suitability evaluation indicates that nearly all the commodities analyzed, including gourami, catfish, carp, tilapia, milkfish, mangrove crab, and vannamei shrimp, face serious constraints. Factors such as suboptimal pH, slope gradient, dry season, high TDS (Total Dissolved Solids), and low salinity for brackish water commodities are the main obstacles that need to be addressed in aquaculture development strategies. These challenges can be tackled with a range of management approaches, from simple interventions to more complex high-difficulty solutions.

One of the main limiting factors in Vemasse Sub-District is slope gradient, which affects the technical feasibility of building conventional ponds. Almost all commodities have been rated "Not Suitable" (N) for this parameter under current conditions. However, this factor can still be improved by using terraced pond systems. This system allows ponds to be built in stages, following the land's contours, and utilizing gravity for water distribution. Although this solution requires higher construction costs, it can raise the land suitability rating from N to S3 (marginally suitable) for most of the commodities analyzed.

The dry season is another major limiting factor that cannot be technically improved. The lack of water during the dry season severely affects the viability of aquaculture. As in other regions, this parameter remains in the "not suitable" (N) category in the potential scenario. To address this impact, adaptive strategies such as the use of closed-system ponds, water-use efficiency, and adjustments in planting or farming schedules are realistic options.

The suboptimal pH of water is also a significant limiting factor, especially for gourami, catfish, carp, and tilapia. pH values outside the optimal range can disrupt fish metabolism, reduce growth rates, and even increase mortality. To mitigate this issue, management strategies such as periodic water exchange and the use of zeolite are recommended. Zeolite is a natural substance that helps stabilize pH levels and absorb heavy metal ions that affect water quality.

High TDS is another challenge, particularly for commodities like carp and mangrove crab. High TDS can disrupt osmoregulation and cause stress in fish. Technical recommendations for reducing TDS include simple filtration methods, such as using sand filters or activated charcoal, as well as more advanced filtration systems using reverse osmosis (RO) technology, depending on the scale of production and the resources of the farmers. For brackish water commodities like milkfish, vannamei shrimp, and mangrove crabs in Vemasse Sub-District, low salinity is also a major constraint. This can be addressed by mixing seawater into the ponds, either conventionally or with the help of pumps. While this method involves moderate to high costs, its effectiveness depends on the proximity of seawater sources and the distribution system used.

Table 10.10 Land Suitability Analysis for Aquaculture Commodities in Vemasse Sub-District

Commodity	Current Land Suitability Limiting Factors	Current Final Evaluation	Potential Land Suitability Limiting Factors	Potential Final Evaluation
Gourami (*Ospronemus gouramy*)	N: pH, slope, dry season S3: Rainfall S2: TDS	2.94	N: Dry season S3: Rainfall, slope	3.34
Catfish (*Clarias batrachus*)	N: Slope, dry season S3: Rainfall S2: pH	3.15	N: Dry season S3: Rainfall, slope	3.34
Carp (*Cyprinus carpio*)	N: Slope, dry season S3: Rainfall S2: pH, TDS, high temperature	3.03	N: Dry season S3: Rainfall, slope	3.34
Tilapia (*Oreochromis niloticus*)	N: Slope, dry season S3: Rainfall S2: pH, TDS	2.93	N: Dry season S3: Rainfall, slope	3.34
Milkfish (*Chanos chanos*)	N: Slope, dry season S3: Low salinity S2: pH, rainfall	3.01	N: Dry season S3: Slope S2: Rainfall	3.4
Mangrove crab (*Scylla serrata*)	N: Low salinity, slope, dry season S2: pH, TDS	2.9	N: Dry season S3: Slope	3.46
Vannamei (*Litopenaeus vannamei*)	N: Slope, dry season S3: Low salinity, rainfall S2: pH	2.95	N: Dry season S3: Rainfall, slope	3.34

Considering all these factors, the aquaculture development strategy in Vemasse Sub-District should focus on commodities that have high resilience to environmental conditions, such as catfish and tilapia. These species have good adaptability and high production efficiency. Implementing water quality management technologies and designing appropriate ponds will be key to improving overall land suitability, making the area suitable for developing sustainable fisheries.

C. Aquaculture Land Improvement Efforts

The actual land suitability evaluation results in Baucau District show various limiting factors that render much of the area either unsuitable or only marginally suitable for aquaculture. To improve the land suitability class, corrective actions or improvements to limiting factors are necessary, where possible. Land improvement efforts in aquaculture involve technical interventions aimed at improving the biophysical conditions of the land and the quality of the aquatic environment to better meet the optimal needs of the cultivated commodities. These improvements can include habitat modification (such as physically improving pond conditions), water quality manipulation, and the provision of supporting infrastructure.

Based on **Table 10.11**, there are different levels of management difficulty for improvement efforts. Management difficulty is divided into three categories: low, medium, and high. These levels are used to assess the potential to improve the actual land quality to potential suitability as shown in **Table 10.12.**

Table 10.11 Recommendations for Land Improvement Efforts for Limiting Parameters

No	Parameter	Improvement Measures	Management Difficulty Level
1	High temperature	- Planting shading trees - Using hapa/paranet net roofs - Building indoor ponds	- Low - Medium - High
2	Low salinity	- Conventional seawater mixing - Seawater mixing with pump	- Medium - High
3	Water pH	- Regular water exchange - Use of zeolite	- Medium - High
4	TDS	- Using simple filtration methods - Using modern filtration methods (RO filter machine)	- Medium - High
5	DO	- Using simple gravity aeration system - Using aerator/circulators	- Low - High
6	Slope	- Using terraced pond systems	- High
7	Rainfall	- Cannot be improved	-
8	Dry season	- Cannot be improved	-

Description :

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

Table 10.12 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)*

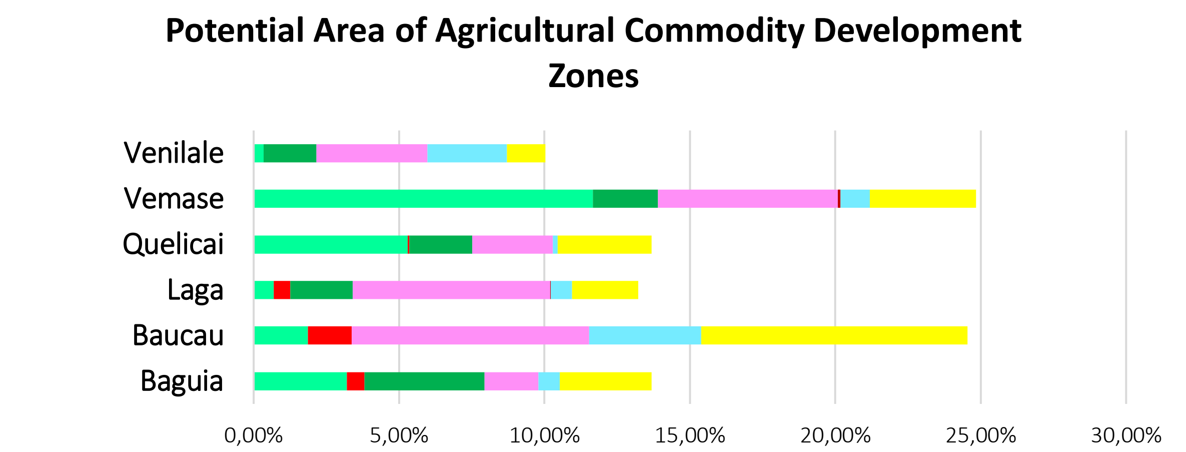
+++ *Improvement will increase the suitability class by three levels (N to S1)*

XI. AGRICULTURAL COMMODITY DEVELOPMENT ZONING

11.1 AGRICULTURAL COMMODITY DEVELOPMENT ZONING

Baucau District has significant land resource potential to support the development of agriculture, forestry, and livestock sectors. To maximize this potential, land suitability evaluation is conducted using a comprehensive scientific approach, including field observations, laboratory testing of soil samples, and matching plant growth requirements with regional agroclimatic maps. This evaluation results in a scientifically-based zoning system to identify the development potential of various strategic commodities, such as rice, corn, horticulture, industrial crops, and forestry areas. The zoning is expected to support efficient and sustainable land resource management, thereby contributing to national food security and improving the welfare of the local population.

Baucau District's land development potential is divided into several main categories: irrigated rice fields covering 139.517 km² (9.26%), rainfed rice fields 342.94 km² (22.77%), grazing areas 41.54 km² (2.76%), dryland farming or mixed gardens 445 km² (29.55%), agroforestry 347.21 km² (23.05%), and protected forests and conservation areas covering 188.30 km² (12.50%). Data on the potential development area for agricultural commodities in Baucau District is presented in Figure 11.1, with its spatial distribution shown in Figure 11.2. This zoning reflects the diversity of land utilization potential to support sustainable agriculture, forestry, and livestock, contributing to food security, environmental protection, and the improvement of community welfare.



	Baguia	Baucau	Laga	Quelicai	Vemase	Venilale
Agroforestry	3,20%	1,87%	0,68%	5,30%	11,67%	0,34%
Grazing Area	0,62%	1,50%	0,58%	0,06%	0,00%	0,00%
Conservation Forest	4,13%	0,00%	2,14%	2,16%	2,24%	1,83%
Mixed garden	1,84%	8,17%	6,78%	2,76%	6,18%	3,81%
Mangrove	0,00%	0,00%	0,02%	0,00%	0,09%	0,00%
Irrigated Rice Field	0,73%	3,85%	0,75%	0,18%	1,01%	2,74%
Rainfed Rice Field	3,15%	9,15%	2,26%	3,23%	3,65%	1,32%

Figure 11.1 Potential Agricultural Commodity Development Zones in Baucau District

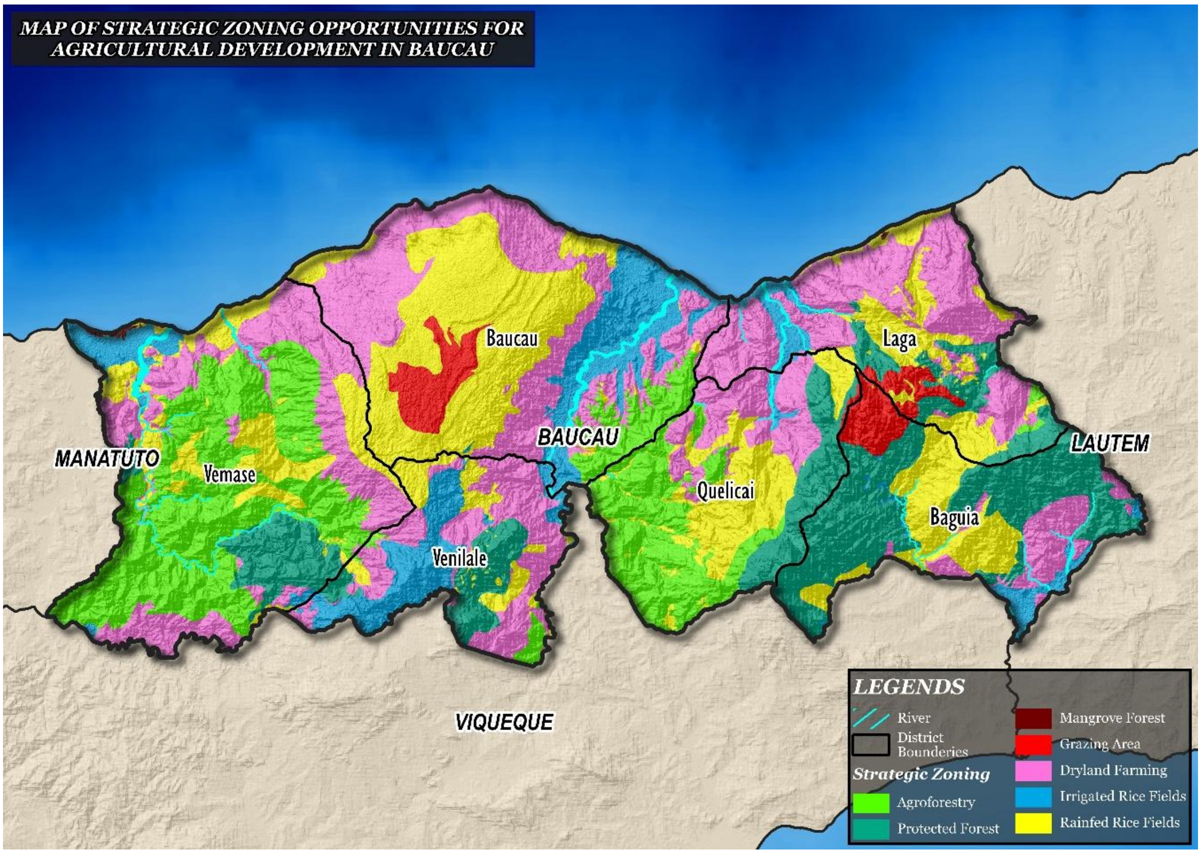


Figure 11.2 Map of Agricultural and Forestry Commodity Development Potential in Baucau District

A. Irrigated Rice Fields

The irrigated rice field zone covers an area of 139.51 km² or 9.26% of the total area of Baucau District. It is located in lowland areas (0–100 meters above sea level) with slopes of 0–8%. This area falls within agroclimatic zones A and C, which have a wet season lasting 4 to 5 months per year. The presence of river networks in this area allows for efficient irrigation, supporting the high productivity potential of rice. Discussions with stakeholders are needed to identify development opportunities in Baucau District through irrigation system construction, such as piped water from rivers, even though the region has a shorter wet season. The largest distribution of irrigated rice fields in this District is found in Baucau Sub-District, with an area of 58.05 km², followed by Venilale Sub-District with 41.25 km² and Vemasse Sub-District with 15.22 km².

B. Rainfed Rice Fields

The rainfed rice field zone covers an area of 342.94 km² or 22.77% of the total area, dominated by agroclimatic zones A, B, C, D, and E, with a wet season of 4 to 8 months per year. Located at an elevation of 100–500 meters above sea level, this area is suitable for developing rainfed rice fields. Key locations include Baucau Sub-District with an area of 137.85 km², Vemasse with 54.96 km², Laga Sub-District with 34.05 km², Baguia Sub-District with 47.47 km², and Quilicai with 48.67 km², while Venilale Sub-District has the smallest area at 19.93 km². The productivity of rainfed rice fields highly depends on seasonal rainfall. Recommended strategies include the construction of water reservoirs, the use of drought-resistant rice varieties, and water management to improve harvest yields.

C. Dryland Farming (Mixed Gardens and Dry Fields)

Dryland farming is the largest sector, covering an area of 445 km² or 29.55% of the total area. This zoning is located at an elevation of 100–500 meters above sea level with slopes of 8–25%. The area supports a variety of commodities such as corn, cassava, peanuts, soybeans, and taro (food crops); vegetables, fruits, and flowers (horticulture); and tobacco, cotton, cocoa, and spices (industrial crops). Mixed cropping systems in this zone can increase land productivity and farmers' income. To prevent erosion on moderate slopes, soil conservation methods such as strip cropping and crop rotation are recommended. The main distribution of dryland farming in Baucau District is found in Baucau Sub-District, covering 123.03 km², followed by Laga Sub-District with 102.19 km², Vemasse with 93.14 km², Venilale with 57.31 km², and Quilicai with 41.63 km². Baguia Sub-District has the smallest area for dryland farming at 27.71 km² of the total area of Baucau District.

D. Grazing Areas

Grazing areas cover 41.54 km² or 2.76% of the total area, dominated by grasslands and savannahs. This area supports livestock grazing such as goats and cattle, with the main distribution in Baucau Sub-District covering 22.52 km², followed by Baguia Sub-District with 9.37 km², Laga Sub-District with 8.68 km², and Quilicai Sub-District with the smallest grazing area at 0.97 km². Management of this area includes the implementation of rotational grazing systems to avoid land degradation and enhance livestock feed productivity. Integration with agroforestry is also recommended to increase both ecological and economic benefits.

Table 11.1 Recommendations for Agricultural Commodity Development for Food Crops, Industrial Commodities, Horticulture, Spices and Medicinal Plants, and Forestry in Baucau District

NO	SUB-DISTRICT	FOOD COMMODITIES	DRYLAND AGRICULTURE (CROPS & HORTICULTURE)	FORESTRY	FORAGE FEED & GRAZING AREA
1	Baguia	WETLAND COMMODITIES S3: Irrigated Rice DRYLAND COMMODITIES S2: Peanut, Sorghum, Corn, Soybean, Mung Bean, Cowpea, Taro, S3: Upland Rice, Cassava, Sweet Potato	INDUSTRIAL COMMODITIES S2: Coconut, Robusta Coffee, Tobacco, Sugar Cane, Kapok, Cotton S3: Rubber, Coconut Oil Palm, Kakao, Clove, Tea, Quinine FRUIT COMMODITIES S2: Rambutan, Manggo, Guava, Jackfruit, Watermelon, Melon, Banana, Papaya, Orange, Avocado, Soursop, Breadfruit, Snakefruit, Longan, Custard Apple, Durian, Pineapple, Strawberry, Grape S3: Passion Fruit VEGETABLE COMMODITIES S2: Shallot, Chilli, Paprika, Caisim, Green Bean, Broccoli, Cucumber, Cabbage, Eggplant, Bitter Melon, Vegetable Tomato, Long bean S3: Snow Pea FLOWER COMMODITIES S2: Rose, Aster, Sunflower SPICES & MEDICINAL COMMODITIES S2: Vanilla, Candlenut, Jatropha, Aromatic Ginger, Galangal, Cardamom, Turmeric S3: Ginger, Vetiver Root, Lemongrass, Cinammon, Nutmeg, Pepper	S3: Taek, Mahogany, Agathis, Altingia, Sengon, Leucaena, Acacia, Eucalyptus, Melaleuca, Pine, Sandalwood	S3: Grazing, Elephant Grass, Setaria, Legumes

2	Baucau	WETLAND COMMODITIES **S3**: Irrigated Rice DRYLAND COMMODITIES **S2:** Peanut, Sorghum, Corn, Soybean, Mung Bean, Cowpea, Taro, **S3:** Upland Rice, Cassava, Sweet Potato	INDUSTRIAL COMMODITIES **S2:** Coconut, Robusta Coffee, Tobacco, Sugar Cane, Kapok, Cotton **S3:** Rubber, Coconut Oil Palm, Kakao, Clove, Tea, Quinine FRUIT COMMODITIES **S2:** Rambutan, Manggo, Guava, Jackfruit, Watermelon, Melon, Banana, Papaya, Orange, Avocado, Soursop, Breadfruit, Snakefruit, Longan, Custard Apple, Duriann, Pineapple, Strawberry, Grape **S3:** Passion Fruit VEGETABLE COMMODITIES **S2:** Shallot, Chilli, Paprika, Caisim, Green Bean, Broccoli, Cucumber, Cabbage, Eggplant, Bitter Melon, Vegetable Tomato, Long bean **S3:** Snow Pea FLOWER COMMODITIES **S2:** Rose, Aster, Sunflower SPICES & MEDICINAL COMMODITIES **S2:** Vanilla, Candlenut, Jatropha, Aromatic Ginger, Galangal, Cardamom, Turmeric **S3:** Ginger, Vetiver Root, Lemongrass, Cinammon, Nutmeg, Pepper	**S3:** Taek, Mahogany, Agathis, Altingia, Sengon, Leucaena, Acacia, Eucalyptus, Melaleuca, Pine, Sandalwood	**S3:** Grazing, Elephant Grass, Setaria, Legumes

3	Laga	WETLAND COMMODITIES S3: Irrigated Rice DRYLAND COMMODITIES S2: Peanut, Sorghum, Corn, Soybean, Mung Bean, Cowpea, Taro, S3: Upland Rice, Cassava, Sweet Potato	INDUSTRIAL COMMODITIES S2: Coconut, Robusta Coffee, Tobacco, Sugar Cane, Kapok, Cotton S3: Rubber, Coconut, Oil Palm, Kakao, Clove, Tea, Quinine FRUIT COMMODITIES S2: Rambutan, Manggo, Guava, Jackfruit, Watermelon, Melon, Banana, Papaya, Orange, Avocado, Soursop, Breadfruit, Snakefruit, Longan, Custard Apple, Durian, Pineapple, Strawberry, Grape S3: Passion Fruit VEGETABLE COMMODITIES S2: Shallot, Chilli, Paprika, Caisim, Green Bean, Broccoli, Cucumber, Cabbage, Eggplant, Bitter Melon, Vegetable Tomato, Long bean S3: Snow Pea FLOWER COMMODITIES S2: Rose, Aster, Sunflower SPICES & MEDICINAL COMMODITIES S2: Vanilla, Candlenut, Jatropha, Aromatic Ginger, Galangal, Cardamom, Turmeric S3: Ginger, Vetiver Root, Lemongrass, Cinammon, Nutmeg, Pepper	S3: Grazing, Elephant Grass, Setaria, Legumes

4	Quelicai	WETLAND COMMODITIES **S3**: Irrigated Rice DRYLAND COMMODITIES **S2:** Peanut, Sorghum, Corn, Soybean, Mung Bean, Cowpea, Taro, **S3:** Upland Rice, Cassava, Sweet Potato	INDUSTRIAL COMMODITIES **S2:** Coconut, Robusta Coffee, Tobacco, Sugar Cane, Kapok, Cotton **S3:** Rubber, Coconut Oil Palm, Kakao, Clove, Tea, Quinine FRUIT COMMODITIES **S2:** Rambutan, Manggo, Guava, Jackfruit, Watermelon, Melon, Banana, Papaya, Orange, Avocado, Soursop, Breadfruit, Snakefruit, Longan, Custard Apple, Duriann, Pineapple, Strawberry, Grape **S3:** Passion Fruit VEGETABLE COMMODITIES **S2:** Shallot, Chilli, Paprika, Caisim, Green Bean, Broccoli, Cucumber, Cabbage, Eggplant, Bitter Melon, Vegetable Tomato, Long bean **S3:** Snow Pea FLOWER COMMODITIES **S2:** Rose, Aster, Sunflower SPICES & MEDICINAL COMMODITIES **S2:** Vanilla, Candlenut, Jatropha, Aromatic Ginger, Galangal, Cardamom, Turmeric **S3:** Ginger, Vetiver Root, Lemongrass, Cinammon, Nutmeg, Pepper	**S3:** Taek, Mahogany, Agathis, Altingia, Sengon, Leucaena, Acacia, Eucalyptus, Melaleuca, Pine, Sandalwood	**S3:** Grazing, Elephant Grass, Setaria, Legumes

5	Vemasse	WETLAND COMMODITIES **S3**: Irrigated Rice DRYLAND COMMODITIES **S2:** Peanut, Sorghum, Corn, Soybean, Mung Bean, Cowpea, Taro, **S3:** Upland Rice, Cassava, Sweet Potato	INDUSTRIAL COMMODITIES **S2:** Coconut, Robusta Coffee, Tobacco, Sugar Cane, Kapok, Cotton **S3:** Rubber, Coconut Oil Palm, Kakao, Clove, Tea, Quinine FRUIT COMMODITIES **S2:** Rambutan, Manggo, Guava, Jackfruit, Watermelon, Melon, Banana, Papaya, Orange, Avocado, Soursop, Breadfruit, Snakefruit, Longan, Custard Apple, Duriann, Pineapple, Strawberry, Grape **S3:** Passion Fruit VEGETABLE COMMODITIES **S2:** Shallot, Chilli, Paprika, Caisim, Green Bean, Broccoli, Cucumber, Cabbage, Eggplant, Bitter Melon, Vegetable Tomato, Long bean **S3:** Snow Pea FLOWER COMMODITIES **S2:** Rose, Aster, Sunflower SPICES & MEDICINAL COMMODITIES **S2:** Vanilla, Candlenut, Jatropha, Aromatic Ginger, Galangal, Cardamom, Turmeric **S3:** Ginger, Vetiver Root, Lemongrass, Cinammon, Nutmeg, Pepper	**S3:** Taek, Mahogany, Agathis, Altingia, Sengon, Leucaena, Acacia, Eucalyptus, Melaleuca, Pine, Sandalwood	**S3:** Grazing, Elephant Grass, Setaria, Legumes

6	Venilale	WETLAND COMMODITIES **S3**: Irrigated Rice DRYLAND COMMODITIES **S2:** Peanut, Sorghum, Corn, Soybean, Mung Bean, Cowpea, Taro, **S3:** Upland Rice, Cassava, Sweet Potato	INDUSTRIAL COMMODITIES **S2:** Coconut, Robusta Coffee, Tobacco, Sugar Cane, Kapok, Cotton **S3:** Rubber, Coconut Oil Palm, Kakao, Clove, Tea, Quinine FRUIT COMMODITIES **S2:** Rambutan, Manggo, Guava, Jackfruit, Watermelon, Melon, Banana, Papaya, Orange, Avocado, Soursop, Breadfruit, Snakefruit, Longan, Custard Apple, Durian, Pineapple, Strawberry, Grape **S3:** Passion Fruit VEGETABLE COMMODITIES **S2:** Shallot, Chilli, Paprika, Caisim, Green Bean, Broccoli, Cucumber, Cabbage, Eggplant, Bitter Melon, Vegetable Tomato, Long bean **S3:** Snow Pea FLOWER COMMODITIES **S2:** Rose, Aster, Sunflower SPICES & MEDICINAL COMMODITIES **S2:** Vanilla, Candlenut, Jatropha, Aromatic Ginger, Galangal, Cardamom, Turmeric **S3:** Ginger, Vetiver Root, Lemongrass, Cinammon, Nutmeg, Pepper	**S3:** Taek, Mahogany, Agathis, Altingia, Sengon, Leucaena, Acacia, Eucalyptus, Melaleuca, Pine, Sandalwood	**S3:** Grazing, Elephant Grass, Setaria, Legumes

Description: S1: Highly Suitable S2: Moderately Suitable S3: Marginally Suitable N: Not Suitable

11.2 POTENTIAL FOOD CROP ZONES

Baucau District has significant potential for food crop development, which can support national food security and reduce dependency on imports. Agroclimatic zoning indicates that the region has large areas suitable for the development of rice (both irrigated and rainfed) as well as various other food crops such as corn, soybean, peanut, cassava, and sweet potato (**Figure 11.3**). Food crops are a priority in efforts to achieve food self-sufficiency in Baucau District. Research has shown that this district produces food crop development zones that contribute to national food security. Of the total area of Baucau District, 445 km² is allocated to mixed gardens/dryland farming, enabling large-scale production of corn, soybean, peanut, and horticultural crops.

The development of both irrigated and rainfed rice also supports food self-sufficiency in Baucau District. With the vast land potential, rice cultivation, whether through irrigated or rainfed fields, becomes an essential component of this sustainable strategy. The irrigated rice fields in Baucau District cover 139.51 km², with agroclimatic characteristics that support agricultural intensification. Additionally, the river network pattern in this district is highly strategic for irrigation management, enabling stable rice production throughout the year. The monomodal rainfall in the region allows rainfed rice to thrive, although long-term success will require drought-resistant rice varieties and efficient water management strategies.

According to the agricultural production analysis in Baucau District from the Crop and Food Security Assessment Mission (CFSAM), the agriculture sector in Baucau made a significant contribution to food security in 2021. Corn production during the planting season covered 6,000 hectares, with a productivity rate of 2.4 tons per hectare. The total corn production for the season reached 14,400 tons, with an additional 300 tons from the second harvest, bringing the total corn production to 14,700 tons. Rice production, with an area of 5,100 hectares, yielded 3 tons per hectare of rice, which translates to 1.8 tons per hectare of rice. As a result, total rice production in Baucau District amounted to 9,200 tons. Root crop production also contributed to food production, reaching a total of 2,500 tons. Overall, the total food production in the district, when converted to cereal equivalents, reached 25,100 tons. Cereal equivalent conversion is the process of standardizing the production data of various agricultural commodities to a single unit. This process is done because each commodity, such as corn, rice, root crops, and others, has different nutritional and caloric values. To facilitate analysis and comparison, the production of various commodities is converted into a uniform value based on calorie or energy content equivalent to cereal (e.g., rice or wheat).

Figure 11.3 Potential Development of Food Crops and Horticultural Crops in Baucau District

With a comprehensive management strategy, Baucau District contributes to the goal of achieving food self-sufficiency. The development of both irrigated and rainfed rice, supported by dryland farming diversification, can serve as the foundation for strengthening the country's agricultural sector.

XII. RECOMMENDATIONS

12.1 LAND MANAGEMENT RECOMMENDATIONS

These recommendations are based on scientific research that comprehensively maps the potential areas in the Democratic Republic of Timor-Leste for the development of food/horticultural commodities, plantations, forestry, and grazing areas. The zoning of the region identified through land suitability evaluation serves as the primary basis for designing land management strategies focused on food security, economic sustainability, and environmental protection. Based on the analysis, the total area is divided into six main categories: irrigated rice fields cover 9.26% of the total area, rainfed rice fields cover 22.77%, dryland agriculture/mixed farming covers 29.55%, agroforestry covers 23.05%, grazing areas cover 2.76%, protected forests cover 12.50%, and mangroves cover 0.11%. This division reflects the diversity of the region's biophysical potential and the importance of a specific approach in managing each zone.

The food zones play a strategic role in supporting national food security. Areas identified as food production centers, such as Baucau Sub-District, Laga, and Venilale, and Vemasse in Baucau District, are vital. By optimizing the irrigation network, focusing land management on improving soil fertility, and applying sustainable agricultural technologies, these food zones can directly contribute to achieving SDGs related to hunger elimination and improving the quality of life for rural communities.

Agroforestry and protected forest zones, covering a combined 35.55% of the total area, are important for economic diversification through the development of high-value commodities. Areas such as Baucau Sub-District, Laga, and Vemasse are identified as having significant potential for industrial crops like Robusta coffee, oil palm, and coconut, as well as horticultural fruits and vegetables such as avocado, mango, tomato, and chili. An integrated agroforestry system with horticultural crops not only increases land productivity but also plays a role in soil and water conservation, reducing erosion risk, and supporting climate change adaptation.

Forestry zones also include protected forests designed for ecosystem conservation, prioritizing biodiversity protection, water resource management, and climate change mitigation. Protected forest areas are recommended for development across the district to reduce greenhouse gas emissions, enhance carbon stock, and maintain ecosystem stability. Additionally, production forests with species like teak, mahogany, and Albizia are proposed to provide economic value while involving local communities in sustainable forest management.

These strategies also directly support the SDGs, particularly those related to food security, climate change, and water resource conservation. By integrating scientific approaches and zonal-based management, these recommendations are expected to provide solutions not only to agricultural challenges in Baucau District but also to promote balanced sustainable development that considers both economic and ecological needs.

Efforts to address each limiting factor are crucial for improving the productivity and sustainability of 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. Recommendations for addressing each limiting factor, as the basis for implementing improvements in land suitability for agricultural and forestry commodity development, are presented in Table 12.1.

Table 12.1 Recommendations for Improvement Efforts for Each Limiting Factor

No	Soil Quality/Characteristics	Improvement Effort Types	Management Level
1.	**Temperature (tc)** Annual average temperature	Cannot be improved Replacement with suitable commodities/varieties	Cannot be improved
2.	**Water Availability (wa)** Annual rainfall Rainfall during growing season	Irrigation/creating reservoirs/drip irrigation Planting pattern/sowing calendar	Moderate, High
3.	**Root media (rc)**		
	Drainage	Improvement of drainage system, such as constructing drainage channels, ridges/beds	Moderate, High
	Texture	No improvement can be made, but it can be mitigated by adding organic material	High
	Effective soil depth	Generally, no improvement can be made except in soft, thin hardpan layers by breaking them during land preparation	Moderate, High

	Coarse fragments	Depends on the amount and distribution in the profile (if less than 35%, it is called an obstructing layer; root penetration can be improved by adding organic material and minimal soil management. If more than 90%, it is a restricting layer; root penetration is difficult to improve).	High
4.	**Nutrient retention (nr)** Cation exchange capacity (CEC) Base saturation (KB) pH C-organic	Addition of organic material Liming, addition of organic material Liming is done if soil pH is low; to moderate high pH, sulfur or ZA fertilizer can be added Addition of organic material/fertilizer, and returning litter to the soil	Moderate, High Moderate, High Moderate, High Moderate, High
5.	**Nutrient availability (na)** Total N Available P Available K	Fertilization with N (urea and ZA) Fertilization with P (SP36 and TSP) Fertilization with K (KCl) Compound fertilizer (NPK)	Rendah, Moderate, High Rendah, Moderate, High Rendah, Moderate, High
6.	**Erosion hazard (eh)** Slope (%) Erosion hazard	Erosion reduction, terracing, contour planting, cover crops, mulching, agroforestry practices.	Moderate, High
7.	**Flood hazard (fh)** High Duration	Construct flood control embankments, drainage channels to speed up water disposal, and infiltration wells	High
8.	**Land preparation (lp)** Surface rocks (%) Rock outcrops (%)	If few (remove rocks), if many/very many, conduct no tillage, create planting holes, add organic material	Moderate, High
9.	**Technical culture improvement**	Establishing plantations, pruning, maintenance/care	Moderate, High

Description :

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

12.2 GLOBAL RECOMMENDATIONS

These recommendations are aimed at providing data-driven strategic guidance for policymakers in Baucau District, with a focus on conservation sector management and sustainable weed utilization. This proposal not only addresses complex ecological challenges but also integrates management strategies that strengthen food security, environmental preservation, and the well-being of local communities. One of the main issues to address is the presence of the invasive weed *Chromolaena odorata (C. odorata*), which has exceptional biological properties and regenerative capacity. Conventional eradication efforts are often considered ineffective, expensive, and may worsen the condition of already vulnerable ecosystems.

In contrast, a sustainable utilization approach turns this challenge into an opportunity, emphasizing the economic, social, and ecological benefits of *C. odorata*. In the context of marginal areas that dominate Baucau District, this strategy is highly relevant for supporting sustainable development. By combining soil conservation efforts, agroforestry development, and innovative weed management, these recommendations provide comprehensive solutions to maximize natural resources while having long-term positive impacts on both the environment and local communities.

A. New Paradigm: Utilization of *Chromolaena odorata*

The eradication approach to *Chromolaena odorata* often fails due to its rapid regeneration through roots and stems, prolific seed production, and the harmful effects of herbicides on ecosystems. Destructive approaches like slash-and-burn exacerbate land degradation, making the need for sustainable strategies urgent. Utilizing *C. odorata* can offer economic value by processing biomass into organic fertilizers like vermicompost, which enhances the fertility of marginal soils in an environmentally friendly manner. Furthermore, extracts of this plant have potential pharmaceutical uses with antimicrobial, anti-inflammatory, and anticancer properties, while the biomass can also be utilized for biochar or biofuels, creating rural business opportunities. Successful implementation requires community empowerment, such as training on biomass processing into high-value products, along with collaboration between the government, academia, and the private sector to develop technologies and support marketing. Regulations should also support the mapping of priority areas, providing economic incentives, and educating communities about the benefits of this plant. This strategy transforms the invasive threat of *C. odorata* into opportunities that support integrated sustainability in the environment, economy, and society.

B. Soil and Water Conservation

Soil and water conservation is a strategic step designed for efficiency and ease of implementation. The agroforestry system offers a long-term solution by aligning environmental preservation with economic production. This approach includes various methods, such as agro-silviculture, which combines food crops with timber trees, silvopastoral systems that integrate trees with pasture for livestock feed, and agro-silvopastoral systems that integrate crops, trees, and livestock in a single location. Bio-pore holes and drainage channels are innovative solutions to support water infiltration and prevent flooding, especially in horticultural and rocky areas. These simple technologies help increase groundwater reserves. With the landscape dominated by steep slopes, Baucau District faces a significant risk of erosion. Mitigation strategies include terracing to limit surface water flow, enhance infiltration, and support plant cultivation in sloping areas. Additionally, using cover crops such as legumes and deep-rooted grasses helps effectively reduce erosion risks.

Check dam technology is another key element in controlling erosion in waterways. Three types of check dams are recommended: brushwood, which uses wood branches for small channels; loose stone, using loose stones for rocky areas; and gabions, which use wire baskets filled with stones for larger flows. Regulations play a crucial role in implementing this conservation effort, especially on slopes greater than 45%. Government regulations and customary law should be enforced to ensure effective conservation measures in each village in Baucau District. Through this holistic approach, soil and water conservation can be realized through a combination of technology, policy, and community participation.

C. Organic Matter Addition and Fertilization

Most soils in Baucau District have low organic matter content, which impacts fertility, water-holding capacity, and microorganism activity. Several strategic steps are recommended to address this issue. The use of local organic waste such as manure, compost, and biochar can improve soil structure, reduce toxicity, and enhance biological activity to strengthen soil resilience. This soil quality improvement is an ideal solution to support sustainable cultivation of rainfed rice, sorghum, chili, and tomatoes.

Applying organic mulch on the soil surface can maintain moisture, increase water absorption, and prevent erosion. This method is relevant for use in both flat areas and sloping lands prone to drought. Fertilization tailored to local soil conditions can be carried out using macro fertilizers in specific doses: 200 kg NPK ha^{-1}, 175 kg urea ha^{-1}, 40 kg SP-36 ha^{-1}, and 100 kg KCl ha^{-1}. This strategy aims to increase the availability of nutrients such as nitrogen, phosphorus, and potassium, thereby supporting the optimization of irrigated rice production in accordance with the soil fertility characteristics of the area. This approach is expected to improve soil quality while supporting sustainable agriculture.

D. Drainage and Shallow Soil Depth Management

The rocky and sloped areas in Baucau District face challenges such as poor drainage and shallow soil depth. To address these constraints, various technical solutions have been recommended. Drainage channel management through the creation of raised beds or ridges is designed to prevent waterlogging and support better water management, especially in horticultural areas. This system helps maximize water use, reduce runoff losses, and improve air circulation in the soil.

The application of bio-pore holes or rorak, along with the construction of infiltration wells, is an effective way to improve water absorption in rocky areas. These holes can also serve as places to put organic materials like plant residues or fertilizers, thus improving drainage quality. Additionally, bio-pore systems support optimal water storage during dry seasons. For plants that require strong roots, such as coconut and timber trees, deeper planting holes are recommended. This method allows plants to develop in shallow soil layers and enhances their growth potential. These approaches provide appropriate solutions to the area's conditions and enhance sustainable agricultural productivity.

E. Alternative Plant Development on Rocky Land

Rocky land requires an approach that allows plants to adapt to challenging conditions. Several alternative solutions have been proposed to optimize the potential of these areas. Spice and medicinal plants such as turmeric, ginger, galangal, and aromatic ginger are commodities that grow well in rocky environments. Planting them under the canopy of forestry trees offers additional protection while optimizing land use. To reduce erosion risks and improve soil quality, cover plants such as legumes and Setaria grass are recommended. These plants also help improve soil organic matter content and its structure. Meanwhile, on rocky land with shallow soils, deep-rooted industrial crops such as coconut and timber trees are ideal choices. These commodities can grow and develop in less supportive soil conditions, providing economic value while also serving as natural erosion control. This approach focuses not only on plant adaptation to environmental conditions but also integrates sustainability into land management practices.

F. Implementation Strategy

The implementation strategy developed based on zoning aims to enhance land management in Baucau District. The zoning, which includes irrigated rice fields (9.26%), rainfed rice fields (22.77%), dryland agriculture/mixed farming (29.55%), agroforestry (23.05%), grazing areas (2.76%), and protected forests (12.50%), serves as the main reference for developing strategies that support food security, economic sustainability, and environmental preservation. The following steps are relevant to implement under this zoning approach:

1. Optimizing Food Zone Production

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

a) **Improving the Irrigation Network:** The irrigation network in Baucau Sub-District and Venilale needs to be expanded to maximize its potential as a major rice-producing area in Baucau District. Micro-irrigation and water reservoirs are prioritized to support intensive cropping patterns.

b) **Managing Rainfed Rice Fields:** Drought-resistant rice varieties are highly recommended for areas with monomodal rainfall patterns. Training farmers to use simple methods such as rainwater harvesting is also important for improving harvests.

c) **Diversifying Commodities:** In addition to rice, the area can be used for other food crops such as corn, soybean, and cassava to support food diversification.

2. Utilizing Agroforestry and Protected Forest Potential

The agroforestry and protected forest zones, covering 35.53% of the total area, provide significant opportunities for economic diversification and ecosystem conservation:

a) Developing Agroforestry Systems:
- Industrial Crop: Focus on high-value commodities such as oil palm, Robusta coffee, and coconut in Laga Sub-District, Baucau, and Vemasse.
- Horticulture: Focus on high-value crops like Robusta coffee and coconut in Laga Sub-District, Baucau, and Vemasse.

b) Protected Forest Management:
- Protected forests must be prioritized to conserve biodiversity, reduce climate change impacts, and manage land resources.
- Production Forests: Planting teak, mahogany, and Albizia provides additional economic value while involving local communities in sustainable forest management.

c) Utilizing Weed Biomass: The weed *Chromolaena odorata* can be used as organic fertilizer or bioenergy material to reduce pressure on forest ecosystems.

3. Infrastructure and Technology Development

a) Building Supporting Infrastructure
- Water reservoirs and rainwater harvesting ponds should be built to increase water availability in the rainfed rice and dryland zones during the dry season.

b) Drainage Channels: These should be designed to control water runoff, especially in sloping areas within the agroforestry zone.

c) Penggunaan Teknologi GIS dan Penginderaan Jauh:
- Designed to control water runoff, especially in sloping areas within the agroforestry zone.
- Monitoring land cover changes to evaluate the effectiveness of the conservation strategy implementation.

4. Enhancing Community Capacity

a) Training and Education:
- Training for soil and water management for farmers in each zone.

- Outreach on commodity diversification in agroforestry zones to improve incomes.

b) **Community Empowerment:** Establish farming groups based on zoning to strengthen participatory strategy implementation.

c) **Empowering Women:** Prioritize training in agroforestry product management and weed biomass processing as part of social inclusion and family income improvement efforts.

5. Weed Management Strategy: Utilizing *Chromolaena odorata*

a) **Utilizing Biomass:**

- The biomass from this weed can be processed into organic fertilizer to improve soil fertility.
- Biochar and briquettes can be produced as bioenergy for local use.

b) **Developing Herbal Products:** The potential of *C. odorata* as a traditional medicine can be further developed through collaboration between the government and the pharmaceutical industry.

c) **Multistakeholder Collaboration:** The government, academia, and the private sector need to collaborate on research and technology development for effective weed management.

6. Integrated Spatial Planning Zoning

The spatial zoning approach allows for more effective land use:

a) **Protected Forests and Conservation:** Focus on areas with slopes >45% for ecosystem preservation.

b) **Agroforestry Zones:** Areas with slopes of 15-45% for timber and horticultural crops.

c) **Intensive Agriculture Zones:** Flat areas to slopes of 15% for staple food crops.

7. Policy and Incentives

a) **Economic Incentives:**

- Subsidies and bonuses for farmers applying conservation technologies.
- Microcredit to support agroforestry or weed management-based businesses

b) **Zoning Regulations:** Regulate land use according to suitability zoning to ensure sustainable management.

8. Monitoring and Evaluation

a) **Data-Based Monitoring:** GIS technology should be used to monitor the effectiveness of strategies and land condition changes.

b) **Participatory Evaluation:** Involve local communities, stakeholders, and government in the evaluation process to ensure the strategies remain relevant to needs.

This strategy combines scientific approaches, cutting-edge technology, and community participation. The zonal approach serves as the primary foundation for addressing conservation and food security challenges while driving sustainable local economic development in Baucau District.

12.3 LIVESTOCK SECTOR RECOMMENDATION

Based on the evaluation and potential assessed, Triloka Baucau is highly prospective to be developed as a pilot project for livestock development, specifically in cattle breeding. This potential is fundamentally supported by two main factors: land suitability for forage crops and the presence of farmers who have interacted with the government through grant programs. To transform this potential into reality, an integrated policy intervention from upstream to downstream is required. Specifically, policy guidance should include the implementation of intensive livestock systems, the provision of superior forage varieties and high-quality cattle breeds, and government involvement in post-harvest product development. With this comprehensive strategy, development in Triloka will not only increase productivity but also establish a modern and sustainable livestock system.

12.4 FRESHWATER FISHERIES SECTOR RECOMMENDATION

Baucau District has spatial and technical dynamics that affect the optimal development of aquaculture, both at the household and government levels. Several specific constraints identified based on land suitability evaluation and field conditions include: Dominant biophysical limiting factors such as land slope, long dry periods, low or uneven rainfall, and water quality (pH, TDS, DO, salinity) that are not optimal for some species. A lack of supporting facilities such as aeration systems, water quality management, and seedling equipment, especially in privately owned ponds (Caibada and Triloca Villages), is also a major issue.

Land suitability evaluation in Baucau District shows that freshwater commodities such as catfish, tilapia, and carp have a relatively high actual suitability (values ranging from 3.10–3.25), especially in areas with stable water availability like Vemasse and Caibada Villages. However, the main challenges lie in limited technical infrastructure, inconsistent water quality during the dry season, and suboptimal land use.

Potential suitability values could increase to 3.35 with interventions such as strengthening the technical capacity of fish farmers, managing water sources, and rehabilitating aquaculture infrastructure. Meanwhile, the cultivation of brackish water species such as vannamei shrimp, milkfish, and mangrove crab is recommended in most of the northern coastal areas of Baucau District due to adequate salinity, although good cultivation support systems are not yet available.

1. Specific Location Technical Recommendations

Based on identification results in several aquaculture locations in Baucau Sub-District and Vemasse, various challenges have been found that hinder the optimization of production, including limited infrastructure and water quality management, small-scale operations, and underutilization of government facilities. To address these issues, technical interventions are required, including the improvement of supporting facilities such as aerators, pumps, and filtration systems; strengthening the institutional capacity of fish farmers; developing locally based self-sustaining feed; and utilizing public facilities as demonstration and training centers with support for digital-based monitoring and record-keeping (Table 12.2).

Table 12.2 Specific Location Technical Recommendations.

Location	Main Issues	Technical Recommendations
Caibada Makasai Village (Baucau Sub-District)	The collection ponds function only as transit without aeration, and water quality is not managed.	Installation of portable aerators and simple filtration systems; conversion of some ponds into grow-out ponds with water quality management.
Gari Uai Village (Baucau Sub-District)	The farming system remains individualistic, with limited production scale and access to seedling supply.	Strengthening fish farmers' institutions, access to superior seed subsidies, and training on farming management using technical standard concrete ponds.
Triloca Village (Baucau Sub-District)	Limited to small-scale catfish breeding efforts; dependence on spring water and commercial feed.	Assistance with pump installation and backup water tanks; training on self-sustaining feed production using local materials; facilitating partnerships with seedling centers.
Vemasse Tasi (Vemasse Sub-District)	Government facilities have not been maximized for community empowerment; production has not been consistent.	Development of a Demonstration Farm Center (Demfarm); integration of community training and local seed production; strengthening the production record-keeping system and technical monitoring through digital-based tools.

2. Pilot Project Location Selection

The priority location for the pilot project is the Vemasse Tasi Fishery Center. In this well-equipped government facility, commodities such as milkfish, tilapia, and mangrove crabs have been successfully cultivated with a good survival rate. Considering aspects such as accessibility, institutional readiness, and the potential for technological advancement, Vemasse Tasi Fishery Center is the most strategic location for establishing an integrated aquaculture pilot project in Baucau District.

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

a) Prioritize technical assistance and production facilities (pumps, aerators, fiber ponds) for active stakeholders in Gariuai and Triloca Villages.

b) Encourage the establishment or strengthening of fish farming groups at the village level to facilitate technical support, access to capital, and market developmentar.
c) Strengthen the Vemasse Tasi Fishery Center as a training, field research, and superior seed development center.
d) Diversify strategic commodities such as milkfish, catfish, gourami, and carp through special assistance programs in locations with high actual and potential value.
e) Campaign to increase the consumption of aquaculture fish, considering the low per capita consumption. A nutrition promotion program and processed products based on farmed fish are needed, targeting schools and households.

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Baucau Municipality

Baucau Municipality is a strategic area for comprehensive agricultural development in the northern zone of Timor-Leste, with land-use proportions that include irrigated rice fields (9.26 %), rainfed rice fields (22.77 %), dryland farming (29.55 %), grazing areas (2.76 %), and forestry zoning in the form of agroforestry systems (23.05 %) and protected forest areas (12.50 %). Based on agroclimatic zoning, Baucau Municipality is generally less supportive for food crop development; however, the presence of irrigation technology in Venilale Administrative Post and surrounding areas increases the potential for irrigated rice cultivation. As the largest food production center in the northern region, Baucau has leading potential for the development of irrigated and rainfed rice, as well as other food crops such as upland rice, sorghum, corn, soybean, and cowpea. In addition, the area is recognized as a center of breadfruit production and has strong prospects for the development of coconut as a major plantation commodity.

Horticultural potential in Baucau includes fruit crops such as orange, rambutan, and mango, as well as vegetable crops including shallot, chili, and bell pepper. Suitable spice and medicinal commodities for development include vanilla, cinnamon, and turmeric, while potential industrial commodities comprise Robusta coffee, coconut, cacao, and clove. In the forestry sector, leading commodities include sandalwood, mahogany, and Albizia, supporting natural resource based economic diversification. The livestock sector also shows substantial prospects through the development of buffalo, cattle, goats, pigs, and sheep, supported by the availability of forage feed commodities such as elephantgrass, Leucaena, Gliricidia, and Sesbania. For example, a livestock observation site is located in Triloca Village, with a population of 10 Bali cattle serving as a model for smallholder livestock development.

In addition to agriculture and livestock, the fisheries sector in Baucau shows development potential in several Villages, including Caibada Makasai, Gari Uai, Triloca, and Vemase Tasi, with leading commodities such as Nile tilapia, catfish, giant freshwater prawn, and milkfish. To support food security and sustainable development, multisector integration through an integrated farming system based on the five key farming practices, livestock, and aquaculture intensification is the primary strategy. Four Villages, namely Buruma, Triloca, Vemase, and Gari Uai, are recommended as pilot projects for integrated agriculture, which are expected to strengthen national food security while supporting Timor-Leste's readiness in responding to regional dynamics, including the process of accession to ASEAN.