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SOIL CHARACTERISTICS OF UDIPSAMMENTS AND LAND SUITABILITY EVALUATION FOR MAIZE IN THE ALAS RIVER RIPARIAN ZONE, ACEH TENGGARA

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Abstract

The increase in national corn demand has triggered the utilisation of marginal land, including riverbank areas. This study aims to identify soil characteristics and evaluate land suitability for corn (Zea mays L.) cultivation in the Alas River border area, Southeast Aceh Regency. The research method used is descriptive exploratory with field surveys through pedon (soil profile) creation and laboratory analysis of soil physical and chemical properties. Morphological observations showed soil profiles developed from fluvial sedimentation material with A1, A2, C, and R horizons. Based on USDA Soil Taxonomy, the soil at the study site was classified into the Entisol order, Psamments suborder, and Udipsamments great group, dominated by sand fractions (78.42%–89.30%). Chemical analysis results show that the soil has an acidic pH (4.53–4.86), very low organic carbon content (0.15%–0.71%), and low cation exchange capacity. Based on the matching method, the land suitability class for maize cultivation is determined as N1 (currently unsuitable) with the main limiting factors being shallow effective depth (30 cm), very sandy soil texture, acidic pH, and low organic matter content. However, land potential can be improved through appropriate management strategies, such as liming to raise pH and adding organic fertiliser to increase water and nutrient retention capacity.

Keywords: Udipsamments, Alas River Border, Land Suitability Assessment, Corn, Alluvial Soil.

INTRODUCTION

National food demand, particularly for maize (Zea mays L.), continues to escalate significantly in line with population growth and the expansion of the animal feed industry. As a strategic commodity, maize not only plays a role in food security but also drives the agribusiness sector economy. However, efforts to increase national production are currently facing serious challenges in the form of fertile land degradation and productive land conversion in the upstream sector. This phenomenon has forced the agricultural sector to look to suboptimal or marginal lands that were previously underutilised, one of which is the Alas river border area as a potential land (Suryani et al., 2021). The Alas River border area in Southeast Aceh Regency has vast potential for alluvial land resulting from fluvial sedimentation processes. Taxonomically, the soil in this region is dominated by the Entisol order with the Psamments suborder, which is characterised by a high sand fraction. The use of marginal land such as Udipsamments for food crop cultivation faces complex biophysical constraints. Based on recent literature, sandy soils have very low water retention capacity and very fast infiltration rates, resulting in very low water and nutrient use efficiency (Naharuddin et al., 2020). In addition, the coarse texture of Psamments results in unconsolidated soil, which increases the risk of erosion and low Cation Exchange Capacity (CEC) (Dickson et al., 2022). The chemical characteristics of soil in humid tropical regions such as Southeast Aceh are also a critical factor. High rainfall and constant temperatures throughout the year accelerate the process of mineral weathering and nutrient leaching, especially nitrogen and soil bases (Kabała, 2022). This is in line with field findings on the banks of the Alas River, which show acidic soil pH and very low organic carbon content, directly limiting the vegetative growth of maize during the critical phase. Without management based on soil characteristic data, the use of this land risks damaging the riverbank ecosystem and causing economic crop failure. The success of transforming marginal land into productive land is highly dependent on the accuracy of land suitability assessments. The study of morphological characteristics through soil profile dissection and laboratory analysis of soil chemical properties is an imperative step in mapping specific limiting factors (Choudhury et al., 2024). Land suitability assessment is not only about classifying potential, but also serves as the basis for determining land improvement measures. Technological interventions such as liming to neutralise acidity and intensive application of organic materials to improve soil structure and increase water retention are essential strategies for sustainably increasing the productivity of the Alas riverbank area (Tufaila & Alam, 2024). This research was conducted as an effort to provide spatial and agronomic databases for corn development in the Alas River riparian zone. By understanding physical limitations such as effective depth and chemical limitations such as nutrient deficiencies, it is hoped that this suboptimal land can be utilised optimally without neglecting environmental conservation aspects.

LITERATURE REVIEW

Corn (Zea mays L.) is an annual cereal crop from the Poaceae family that has a single stem structure with nodes and internodes. Morphologically, corn leaves grow opposite each other on each node of the stem. This plant is monoecious (single-sex), where male and female flowers are located separately but still within a single plant. In addition, corn is classified as a protandric plant, a phenomenon in which pollen is released one to two days before the female flowers appear (Warrier and Tripathi, 2011). As a growing medium, corn requires soil with sufficient nutrients, good drainage, and an optimal pH of 5.5–6.5 to support the vegetative to reproductive phases (Harniati, 2000). Udik Psamments land in riverine areas has varying tolerance to climatic and biophysical conditions, which are highly dependent on the type of commodity and rainfall (Daly et al., 2018). Riverine areas have strategic prospects for corn cultivation because they can improve water quality and environmental biomass (Feng et al., 2017). This land is part of alluvial soil, which is young soil formed from river sedimentation. Its characteristics are greatly influenced by the parent material carried by river flows, so that its physical and chemical properties can vary from fertile to marginal (Choudhury et al., 2024; Dharmawijaya, 1992).

The Udik Psamment land is dominated by sand fractions, which cause the soil structure to become loose, with low water retention capacity and high infiltration and evaporation rates (Rajiman, 2015). Physically, this land has poor porosity and rapid permeability (Naharuddin et al., 2020), so it is often categorised as suboptimal land with low economic value (Strijker, 2005). In addition to physical constraints, the main problem with this land is the low nitrogen content due to leaching and evaporation (Suharta, 2010). In some cases, alluvial soils can also have extreme acidity levels ($pH < 4$) that require special treatment (Kabała, 2022). The humid tropical conditions in Indonesia cause intensive weathering due to high temperatures and rainfall, which can reduce soil quality if not managed properly (Arsyad, 2006). Efforts to optimise corn production on sandy soils can be done through the use of superior varieties and the application of organic fertilisers to improve soil structure and nutrient availability (Aribawa, 2012). The sustainability of agriculture on this land requires an evaluation of land suitability as a crucial instrument in assessing resource potential and predicting production yields (Ministry of Agriculture, 2002). The implementation of spatial modelling technology and computer analysis is now an urgent need for planning land use quickly, accurately, and sustainably to minimise the risk of crop failure on marginal land.

METHOD

1. Research Location and Time

This research was conducted in the border area of the Alas River in Batumbulan Village, Baussalam Subdistrict, Southeast Aceh Regency, Aceh. At coordinates N 03º28'42.4‘ E 097º48'21.2’ (Figure 3.1) with a research area of 100 m2 and an altitude of ± 216 metres above sea level, from August to November 2024.

Figure 1. Research Location Map (Google Earth)

2. Tools and Materials
The tools used are: hoe, shovel, field knife, tape measure, Munsell Soil Colour Chart (to determine soil colour), notebook, camera, and writing instruments.
The materials used are: soil samples from the pedon profile, chemicals for laboratory analysis (pH-H2O, pH-KCl, organic carbon, N, P, K, and texture).

3. Research Procedure
This research uses an exploratory descriptive method with a field survey through the creation of a soil profile (pedon).

3.1 Soil Profile Creation
Soil profiles were created by digging holes 1 metre wide, 1.5 metres long, and deep enough to reach the parent rock (horizon R) or the water table. Soil profiles were used to observe the morphological properties of the soil directly in the field.

3.2. Morphological and Physical Characteristics Observation
Field observations include:
a) Horizon Differentiation: Determining the boundaries of soil layers (A1, A2, C, and R).
b) Soil Colour: Determined using the Munsell Soil Colour Chart.
c) Soil Texture: Determined in the field by feel and validated by laboratory analysis.
d) Effective Root Depth: Measuring the range of active plant roots.
e) Drainage and Environmental Conditions: Observing the rate of water infiltration and vegetation growth (grass and reeds).

3.3. Sampling and Laboratory Analysis
Soil samples were taken from each horizon layer for laboratory analysis of their chemical and physical properties, including:
a) Physical Properties: Texture (percentage of sand, silt, and clay).
b) Chemical Properties: pH (H_2O and KCl), Organic Carbon, macro nutrients (N, P, K, Ca, Mg, Na), and Cation Exchange Capacity (CEC).

3.4. Soil Classification
Soil classification is determined based on USDA Soil Taxonomy criteria. The determination of order to sub-group is based on horizon development, moisture regime (udik), and soil texture dominated by sand (psammen).

3.5 Land Suitability Analysis

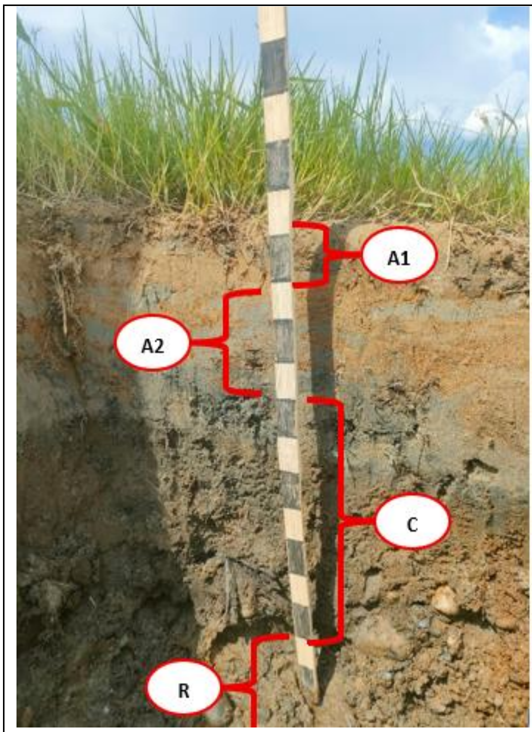
Land suitability was evaluated using a matching method between the characteristics of the land at the research site and the growing requirements of maize. Land suitability classes were divided into:

- S1 (Very Suitable): No limiting factors.
- S2 (Moderately Suitable): There are minor limiting factors.
- S3 (Marginal Suitable): There are significant limiting factors.
- N1 (Currently Unsuitable): There are very significant limiting factors, but they can be remedied.
- N2 (Permanently Unsuitable): The limiting factors are very difficult to overcome.

RESULTS AND DISCUSSION

1. Characteristics of Sandy Alluvial Soil

Direct observation of soil profiles in the field allows for accurate identification of the morphological properties of each layer. A complete description of the development of the horizon, effective depth, and parent material of the soil is presented in the soil profile below. This information reflects the history of fluvial sedimentation on the banks of the Alas River and shows the variability in texture from the surface layer to the parent rock.



Description

A1. Horizon A1 (0–7 cm): Dark greyish brown, clayey sand, many active roots and organic matter, humification and eluvial processes.

A2. Horizon A2 (7–23 cm): Blueish grey, sandy loam, iron spots, fluvial deposits with signs of gleying and redox, few roots.

C. Horizon C (23–73 cm): Dark yellowish brown, coarse texture, many pebbles and rounded stones, no roots, parent material of river deposits.

R. Horizon R (+ 73 cm): Light brown and rounded stones, varying in size, at a depth of 73 cm water accumulation is visible.

Figure 2. Soil Profile and Soil Morphology Description

Alluvial soil in the Alas River basin is formed through the deposition of fluvial materials such as mud, sand, silt, and organic matter. This continuous natural sedimentation process results in young soils with high spatial variability, where pedogenesis is often interrupted by new deposits (Prasetyo et al., 2021). Physically, this soil is dominated by sandy loam fractions (80% to 89%). Such high sand content typically leads to high macroporosity but extremely low water-holding capacity, making the soil prone to drought stress (Wicaksono & Sugiyanto, 2020). Based on Table 1, the chemical properties show acidic pH and low organic matter. The low Cation Exchange Capacity (CEC) in these soils is a direct consequence of the dominance of sand fractions, which lack the surface area to bind essential nutrients effectively (Hidayat et al., 2022).

Table 1. Soil Analysis of the Study Area

Description	Research Results
pH-H_{20}	4.5300>4.8600
Mg %	0.8435>4.1700 %
Sand %	78.4200-89.3000
Silt%	9.2100-20.0700
Clay %	1.4900 -1.5000
pH-KCL	1.4900-4.0900
C-organic	0.1500-0.7100
Na	0.2462-0.2613
N	0.1154-0.1403
P	155.2000-245.7500
K	0.1649-0.2491 me/100g
Cation	4.1132-7.0934 me/100g
Ca	4.2241-1.8664 me/100g

The existing vegetation conditions at the research site on alluvial soil pedons are dominated by grasses and reeds. The alluvial land on the banks of the Alas River was formed from floodplain deposits with a sandy loam texture. Based on soil profile observations, it was found that this soil has not yet shown any significant (independent) horizon development and only has a surface horizon (epipedon), thus it is classified as Entisol. The high proportion of fine sandy loam or coarser fractions, reaching more than 35%, meets the criteria for the suborder Psamments. Given that the land never dries out for more than 90 consecutive days in a year, the soil moisture regime is classified as Udik, so at the great group level, this soil is classified as Udipsamments.

2. Soil Classification

Based on observations in Figure 4.1, the soil is classified as relatively young with limited profile development. These characteristics place the soil in the Entisol order. Entisols in riparian zones are characterized by the absence of diagnostic subsurface horizons because the rate of erosion or deposition exceeds the rate of soil development (Suryani et al., 2023). Morphologically, the profile shows A1, A2, C, and R horizons. The presence of bluish-grey colors and iron mottles in the A2 horizon indicates redoximorphic features caused by seasonal water saturation from the Alas River (Ramadhan et al., 2024). Due to the sand fraction exceeding 35% and an Udic moisture regime, the soil is classified as Udipsamments.

Table 2. Soil Classification

No	Taxonomy Criteria	Alluvial Soil Characteristics	Soil Classification
1	Soil texture: Sand (%) Silt (clay) Clay (%)	Pasir 78-89 % 9,2-20% 1,4 -1,5%	Dominant texture sandy to sandy loam → slightly developed (young profile).
2	Colour	Dark brown to greyish, blue-grey, dark yellowish brown and light brown	Not specific, common in Entisols/Inceptisols
3	Effective Root Depth	< 25cm	Not suitable for deep roots
4	Drainage	Good–moderate; may be restricted in floodplains	Fluvents (good), Aquents (poor)

Horizon C was found at a depth of 40–60 cm as the parent material of the soil. This layer has a dark yellowish-brown colour with a composition of rock fragments in the form of gravel and rounded rocks, indicating ancient river deposits. The coarse texture and dominance of sand fractions in Horizon C show no signs of intensive chemical weathering. The Horizon R layer below is massive bedrock that has not been weathered and acts as the base of the soil profile. The morphological characteristics of each horizon provide fundamental data on soil genesis while identifying the potential and technical constraints in land management for the agricultural sector.

3. Land Suitability Classification

Table 3. Land suitability

Land use requirements/ land characteristics	**Land suitability class**			
	S0	S1	S2	N
Average temperature (°C)	20 - 26	- 26 – 30	16 - 20 30 - 32	< 16 > 32
Rainfall	500 – 1.200	1.200 - 1.600 400 - 500	> 1.600 300 – 400	< 300
Drainage	good, somewhat restricted	somewhat fast, moderate	restricted	very restricted
Texture	fine, somewhat fine, moderate	-	somewhat coarse	coarse
Sand texture	<50-60%	60-70%	<70-80%	>80%
Active root depth (cm)	> 60	40 – 60	25 - 40	<25
pH H2O	5,8 - 7,8	5,5 - 5,8 7,8 – 8,2	< 5,5 > 8,2	<5
C-organic (%)	> 0,4	≤ 0,4		<0,3
Slope (%)	< 8	8 – 16	16 - 30	6
Erosion hazard	very low	low - moderate	severe	very severe
Flooding	F0	-	F1	< F1
Rock content (%)	< 5	5 – 15	15 - 40	> 40

The comprehensive land suitability analysis, as detailed in Table 3 and Table 4, reveals that while macro-environmental parameters such as climate and slope are highly favorable (S1/S2), the biophysical soil constraints present a severe challenge to optimal cultivation. The effective soil depth, measured at only 30 cm, serves as a critical limiting factor that hinders the plant's physiological potential. According to Andriyani et al. (2021), maize requires a significantly deeper soil volume to facilitate extensive root architecture, which is essential not only for efficient nutrient acquisition but also for providing the necessary physical anchorage to prevent lodging during high-velocity winds.

Table 4. Classification of Land Suitability for Corn Cultivation

Suitability Factor	**Status**	**S1**	**S2**	**S3**	**N1**	**N2**
Average Temperature (°C)	26-30		✓			
Rainfall	1.473,7		✓			
Slope	Flat	✓				
Active depth (cm)	30 cm				✓	
Texture	Slightly coarse			✓		
Sand texture %	89%				✓	
pH	4,7				✓	
Drainage	Slightly fast		✓			
C-Organic	0,2				✓	
Erosion	low - moderate		✓			
Rocks %	10%		✓			
Waterlogging	Fo		✓			
Elevation asl.	216					

The chemical profile further complicates this suitability, as the combination of an acidic pH (4.7) and extremely low C-organic content (0.2%) necessitates an Unsuitable (N1) classification. In these sandy alluvial environments, the scarcity of organic carbon acts as a major catalyst for nutrient leaching; the lack of organic 'glue' or stable aggregates means the soil cannot effectively retain ions in the root zone, leading to rapid nutrient depletion. This condition is particularly problematic in Udipsamments, where high porosity often results in poor nutrient use efficiency (Mulyani et al., 2022). Addressing these multifaceted limiting factors requires a shift toward integrated and sustainable soil management strategies. The strategic application of biochar or high-quality compost is considered essential for these sandy alluvial soils to restructure the soil matrix and enhance the 'sponge' effect, thereby drastically improving water holding capacity and nutrient retention (Mulyani et al., 2022). Furthermore, long-term productivity on these riverbank soils can only be achieved through the synergy of balanced fertilization and intensive liming, which together neutralize acidity and restore the chemical equilibrium necessary for sustainable maize production.

CONCLUSION

The soil characteristics in the Alas River border area show a young soil profile with A1, A2, C, and R horizons, where the A1 horizon (topsoil) has an effective depth of only 0–10 cm with a sandy loam texture. Land evaluation results indicate an N1 suitability class (Currently Unsuitable) for maize cultivation, which is influenced by the main limiting factors of shallow effective depth, very high sandy texture (>80%), acidic pH (4.7), and very low organic matter content. Nevertheless, this land remains viable for development through a gradual soil quality improvement (amelioration) approach using liming and intensive organic matter application to enhance land suitability and maize productivity in the future.

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