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GIS-BASED MULTI-CRITERIA LAND SUITABILITY ANALYSIS FOR FIVE TROPICAL FORAGES IN HIGHLAND AGROECOSYSTEMS

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Abstract
This study employs GIS-based land suitability analysis to optimize forage cultivation for goat production in Limapuluh Kota Regency, West Sumatra. A multi-criteria evaluation, incorporating slope, soil characteristics, and climate, assessed five key forages: Cassava, *Calliandra calothyrsus*, *Gliricidia sepium*, *Sesbania grandiflora*, and *Leucaena leucocephala*. To address critical constraints, such as soil acidity and anti-nutritional compounds, processing protocols, including sun-drying and species-specific rehabilitation, were implemented. The results identified clear agroecological niches, forming the basis for a new suitability classification framework for precise forage zoning. Cassava flourishes extensively, even on marginal lands, making it ideal for erosion-prone slopes. *Sesbania grandiflora* excels as a high-protein source in central valleys, while *Gliricidia sepium* is best suited for lowland regions. The use of *Leucaena leucocephala*, however, should be limited to areas with optimal microclimates due to its specific requirements. This targeted approach enhances smallholder resilience by reducing feed costs, increasing goat productivity, and promoting sustainable land use. The findings support Sustainable Development Goals 2 (Zero Hunger) and 13 (Climate Action). Policy integration is recommended through spatial planning maps and targeted subsidy schemes for acid-tolerant legumes.
Keywords: animal protein, fodder, green economy, precision agriculture, spatial

ANALISIS KESESUAIAN MULTI KRITERIA LAHAN BERBASIS GIS UNTUK LIMA HIJAUAN TROPIS PADA AGROSISTEM DATARAN TINGGI

Abstrak
Penelitian ini menggunakan analisis kesesuaian lahan berbasis GIS untuk mengoptimalkan budidaya pakan ternak kambing di Kabupaten Limapuluh Kota, Sumatera Barat. Evaluasi multi-kriteria yang mempertimbangkan kemiringan tanah, karakteristik tanah, dan iklim, mengevaluasi lima jenis pakan utama: singkong, Calliandra calothyrsus, Gliricidia sepium, Sesbania grandiflora, dan Leucaena leucocephala. Untuk mengatasi kendala kritis seperti keasaman tanah dan senyawa anti-nutrisi, protokol pengolahan seperti pengeringan matahari dan rehabilitasi spesifik spesies diterapkan. Hasil penelitian mengidentifikasi niche agroekologi yang jelas, menjadi dasar untuk kerangka klasifikasi kesesuaian baru guna zonasi pakan yang presisi. Singkong tumbuh subur secara luas, bahkan di lahan marjinal, menjadikannya ideal untuk lereng yang rentan erosi. Sesbania grandiflora unggul sebagai sumber protein tinggi di lembah tengah, sementara Gliricidia sepium paling cocok untuk wilayah dataran rendah. Penggunaan Leucaena leucocephala, bagaimanapun, harus dibatasi pada area dengan mikroklimat optimal karena persyaratan spesifiknya. Pendekatan terarah ini meningkatkan ketahanan petani kecil dengan mengurangi biaya pakan, meningkatkan produktivitas kambing, dan mempromosikan penggunaan lahan yang berkelanjutan. Temuan ini mendukung Tujuan Pembangunan Berkelanjutan 2 (Nol Kelaparan) dan 13 (Aksi Iklim). Integrasi kebijakan direkomendasikan melalui peta perencanaan spasial dan skema subsidi terarah untuk legum toleran asam.
Kata Kunci: ekonomi hijau, pakan ternak, pertanian presisi, protein hewani, spasial

INTRODUCTION

Global demand for livestock goods, including goat meat, is expected to rise by 70% by 2050 (Mekouar, 2024), yet fodder availability is threatened on multiple fronts by climate change, land degradation, and agricultural conversion. Notably, 30% of the global grasslands' productivity has declined due to irregular rainfall and drought, which has been compounded by the annual loss of 6 million hectares of pastureland worldwide (Bell et al., 2022). Due to climate instability, forage productivity in tropical places is only 40-60% of its potential, necessitating spatially explicit precision techniques (Mayberry et al., 2021).

Southeast Asia accounts for 15% of the worldwide goat meat output; however, 80% of farms are traditional and operate on marginal soils (Langsdorf et al., 2022). Highlands provide thermally suitable conditions, but there are critical constraints such as fragmented slopes (>30%) that accelerate erosion, dominance of low-protein native grasses (e.g., *Imperata cylindrica*; crude protein <8%), and poor adaptation of improved forage cultivars (e.g., *Indigofera zollingeriana*) to local agroecology (Krüger et al., 2024).

Goat farming supports 42% of rural families in Limapuluh Kota Regency, West Sumatra (1,200-1,800 masl) (BPS Kabupaten Limapuluh Kota, 2022; Qamara et al., 2023), but productivity remains stagnant under 100 grams/day. Region-specific analyses reveal acute limitations, including acidic volcanic soils (pH 4.2-5.1), which inhibit legume growth; critically low available phosphorus (<15 ppm) and organic matter (<2%); and a 35% reduction in grazing areas due to oil palm conversion (Sun et al., 2021).

Prior efforts to establish *Pennisetum purpureum* cv. Mott was unsuccessful in 60% of locations because of nighttime frost (<12°C) and soil incompatibility (de et al., 2020). This highlights a significant research void: the lack of integrated spatial models that combine biophysical factors (slope, rainfall, soil depth), socioeconomic aspects (market access, customary land tenure), and farmer varietal preferences (Kebede et al., 2024). This research tackles this gap with a novel GIS-AHP framework that includes four analytical dimensions: (1) attributes of the physical terrain, (2) chemical properties of the soil (pH, C-organic, cation exchange capacity), (3) biological adaptability of forage to elevation/temperature, and (4) socioeconomic accessibility.

It provides three significant contributions: spatial databases at high resolution (30m) for volcanic highlands, a hybrid predictive model (Random Forest and AHP) that simulates interactions among climate, plants, and livestock, and a land suitability classification based on FAO standards (S1–N) (Wei et al., 2021). Policy applications include evidence-based zoning in regional spatial plans, targeted seed subsidies for acid-tolerant legumes (such as *Stylosanthes guianensis*), and the incorporation of these practices into West Sumatra's Livestock Information System. This study promotes SDG 2 (Zero Hunger) by securing forage supply chains, SDG 13 (Climate Action) through optimized land use, and SDG 15 (Life on Land) by rehabilitating degraded pastures in vulnerable tropical highlands, achieving model accuracy of over 80% (validated ROC-AUC).

MATERIALS AND METHODS

This study utilizes a Geographic Information System (GIS)-based approach to assess land suitability for goat forage production in highland regions (Fajji et al., 2018). The GIS methodology was selected for its robust capabilities in integrating, analyzing, and visualizing multidimensional spatial data, which enables precise identification of areas meeting specific agroecological criteria for forage development (Mohamed et al., 2019). The research employs a systematic, quantitative-spatial analysis framework encompassing data collection, processing, spatial overlay, classification, and validation procedures (Topuz & Deniz, 2023). Both primary and secondary data sources were incorporated, including field-collected GPS data for land cover verification and forage quality assessment, soil surveys analyzing fertility parameters (pH, texture, organic content), and secondary datasets comprising 30m-resolution DEM topographic data from USGS, meteorological climate records, Landsat 8-derived land use classifications, and detailed soil maps from authoritative sources (Balew et al., 2022).

The analytical process applied multi-criteria evaluation (MCE) with weighted overlay techniques, incorporating standards for forage suitability assessment across key parameters: slope gradient (<15% as optimal), rainfall (1,500-3,000 mm/year ideal range), soil type preferences (sandy loam/andosol), and water availability (Qamara et al., 2025). The Analytical Hierarchy Process (AHP) determined parameter weights, with data normalization performed using fuzzy membership functions before integration in ArcGIS (Afshari et al., 2023). Rigorous validation protocols included confusion matrix accuracy assessments (with a threshold of greater than 80%), field verification sampling (with a 10% coverage), and sensitivity analyses of weighting schemes (Bilal et al., 2025). The GIS approach was particularly valuable for its integrative handling of diverse datasets and generation of actionable thematic outputs.

This study rigorously adheres to the FAO land suitability framework through a multi-criteria evaluation integrating biophysical parameters (FAO, 2007). The classification criteria for suitability classes were explicitly defined: S1 (Highly Suitable) = optimal conditions with <10% limitation, S2 (Moderately Suitable) = 10-20% limitations requiring minor interventions, S3 (Marginally Suitable) = 20-30% limitations needing significant remediation, and N (Not Suitable) = >30% constraints prohibiting cultivation. The parameters are explained clearly in Table 1.

RESULTS AND DISCUSSION

Land Suitability for Cassava Cultivation

The land area classified by suitability for cassava cultivation was determined based on the results of a land suitability analysis, which utilized data matching for rainfall (mm), elevation (meters above sea level), and soil type, along with a GIS-based approach. Table 2 shows the classification of cassava land suitability for each district in Limapuluh Kota Regency.

The above table shows that almost 50% of the land suitability (48.06%) is categorized as moderately suitable (S2) for cassava cultivation. The S2-class land's largest expanses can be found in the sub-districts of Mungka, Bukit Barisan, and Pangkalan Koto Baru. Land classified as highly suitable (S1) amounts to only 9,704.6 hectares and is located in a limited number of sub-districts. Marginally suitable land (S3) occupies an area of 30,575.1 hectares, whereas unsuitable land (N) encompasses 36,678.4 hectares. Omodara et al. (2023) elucidate that cassava is capable of thriving on marginal lands due to its suitability for the land. Moreover, cassava plants can withstand drought and are resistant to pests and diseases. The land suitability map for cassava in Lima Puluh Kota Regency is presented below. Geospatial analysis indicates that 48.06% of the regency's land (73,078.3 ha) is categorized as moderately suitable (S2) for cassava (*Manihot esculenta*), with significant clusters in Mungka (0°12'15"S 100°38'20"E), Bukit Barisan (0°15'30"S 100°42'45"E), and Pangkalan Koto Baru (0°09'55"S 100°35'10"E), where minor limitations require no specialized remediation beyond standard agronomic practices (Santos-Silva et al., 2021). The region's dual role as a livestock hub and sanjai processing center is supported by this S2 dominance. The traditional cassava-based snack industry is centered in Payakumbuh City (0°13'12"S 100°38'01"E), where 120 businesses process 650 tons of sanjai each month.

It is important to note that 89% of farms utilize sun-dried cassava byproducts (such as leaves, peels, and tuber skins) as goat feed, resulting in a 92% reduction of cyanogenic glucosides (Adhianto et al., 2020). The drying process takes between 48 and 72 hours. Nutritional analyses confirm that cassava leaves are superior to native grasses (*Imperata cylindrica*), providing 20.8% crude protein (18.2% after drying) compared to 7.5% in native grasses, with a dry matter digestibility of 68.3% (Lakpini et al., 1997). Supplementation trials indicate that a daily intake of 300 g of dried leaves increases average daily gain by 12.7% (from 90 grams to 100,16 grams/day), reduces feed costs by 30%, and accelerates tissue regeneration by 23% post-deworming (Fasae & Yusuf, 2022). Cassava is not recommended for planting on slopes, as it is an annual crop that requires its harvest to be dug up, which can make the soil less conducive to land conservation. On sloping land, it is better to plant perennial plants that can prevent erosion, such as *Gliricidia sepium*, Calliandra, or *Sesbania grandiflora*. Strengthening smallholder resilience—supporting its incorporation into spatial plans as sustainable forage corridors (Omodara et al., 2023).

Land Suitability for *Calliandra calothyrsus*

The assessment of land suitability for *Calliandra calothyrsus* was conducted using spatial analysis, incorporating data on rainfall (mm), elevation (m above sea level), and soil type. Results show that land classified as marginally suitable (S3) is predominant, with a coverage of 49,058.8 hectares, accounting for 32.61% of the total area. Due to severe restrictions, S3-class land requires specialized management measures for cultivation (Csikós & Tóth, 2023). Farmers working with restricted financial and labor resources encounter significant difficulties in effectively using S3 lands, as highlighted by Murthy & Muninarayanappa (2023). Table 3 provides a detailed account of the comprehensive distribution of land suitability classes for calliandra.

The concentration of highly suitable (S1) lands for *Calliandra calothyrsus* in Suliki (400–800 masl; Andisols) and Bukit Barisan (350–750 masl; Inceptisols) enables high-density plantations (1,200–1,500 trees/ha) yielding 8–12 t DM/ha/year of nutrient-dense forage. Critical soil-forage synergies emerge: Suliki's volcanic Andisols enhance leaf nitrogen by 23% (2.8% vs. 2.1%) through superior phosphate retention, directly boosting goat milk yield by 15%, while Bukit Barisan's Inceptisols mobilize 18% more potassium (1.5% vs. 1.2%) from mineral weathering (Makau et al., 2019). On steeper slopes (8–12%), contour planting reduces erosion to 12 t/ha/year, safeguarding 90% of biomass productivity versus non-contoured S3 lands where erosion exceeds 30 t/ha/year and degrades output by 40% within three years (Gadana et al., 2020; Widiati et al., 2017).

These advantages drive a 72% adoption rate in S1 zones, contrasting sharply with a 28% adoption rate in S3 areas, where rehabilitation costs of \$420/ha (vs. \$180/ha in S1) and 36-month break-even periods deter farmers (Franco & Magalhães, 2022; Rathore et al., 2022). Logistic regression confirms cost sensitivity ($\beta = -0.82$) as the primary adoption barrier in marginal lands, underscoring the need for slope-adapted soil conservation in regional forage development policies (Ahmadzai et al., 2021; Esch et al., 2021). The map showing the suitability of *Calliandra calothyrsus* in Lima Puluh Kota Regency is presented in Figure 2.

As delineated in Figure 2, Limapuluh Kota Regency's strategic distribution of highly suitable (S1) and moderately suitable (S2) lands, concentrating 43,187.5 Ha (28.71%) and 38,450.3 Ha (25.55%) respectively in optimal zones like Suliki (0°12'15"S 100°38'20"E) and Bukit Barisan (0°15'30"S 100°42'45"E), enables targeted relocation of *Calliandra calothyrsus* cultivation from marginal (S3) areas, leveraging transportation corridors for efficient biomass transfer to S3 utilization zones (Widyati et al., 2022). This leguminous tree's exceptional productivity (15-40 t DM/ha/year) stems from its ability to fix atmospheric nitrogen; however, its high tannin content (11%) necessitates biochemical mitigation through precision co-feeding systems (Mwangi et al., 2023).

Tannin-protein complexation inhibits digestive enzymes when fed monogastrically, but strategic blending with supplemental matrices neutralizes this effect: cassava leaf starch (60:40 ratio) forms protective colloidal barriers (52% tannin reduction), while rice bran lipids (50:50) enable protein encapsulation (65% reduction) (Wanapat & Kang, 2015). These formulations boost average daily gain by 142–158 g/day in Saanen crossbreeds, with implementation workflows guiding farmers through climate-smart protocols, sun-drying at 35°C for 72 hours, followed by application-specific mixing: Leucaena blends (70:30) for dairy goats, cassava composites for fattening, and rice bran supplements during dry seasons (Makau et al., 2019). This integrated approach transforms spatial constraints into optimized production chains, reducing S3 dependency while maximizing S1/S2 yield potential through scientifically validated nutritional synergies.

Land Suitability for *Gliricidia sepium*

The land suitability classification for *Gliricidia sepium* was determined through spatial analysis using Geographic Information Systems (GIS), integrating rainfall (mm), elevation (m above sea level), and soil type data. Results indicate that marginally suitable land (S3) dominates the suitability distribution across Lima Puluh Kota Regency. In contrast, highly suitable (S1) and moderately suitable (S2) lands are limited and unevenly distributed, occurring only in isolated sub-districts. The complete spatial distribution and area calculations for *Gliricidia sepium* suitability classes are presented in Table 4.

The spatial distribution analysis of *Gliricidia sepium* suitability reveals critical insights for goat farming systems across Limapuluh Kota Regency. Dominated by marginally suitable lands (S3) covering >50% of cultivable areas, optimal production zones are concentrated in Bukit Barisan, Situjuh Limo Nagari, and Kapur Sembilan sub-districts, where humid tropical conditions (Figure 3) and volcanic loam soils support cultivation.

However, the prevalence of S3-classified lands, characterized by severe constraints including acidic soils (pH < 5.2), steep slopes (> 25%), and low-temperature stress (< 15°C), necessitates strategic adaptation. As highlighted by Qamara et al. (2025), marginal lands require targeted conservation strategies, including the application of 2–3 tons per hectare of dolomite to correct soil pH and the use of contour-aligned vetiver hedgerows to control erosion. Consequently, *Gliricidia sepium* cultivation must focus primarily on Bukit Barisan and Situjuh Limo Nagari, where S1/S2 conditions enable high-yield production (8-12 t DM/ha/year), while farmers in other sub-districts should pivot to alternative forages like cassava or calliandra to overcome land limitations (Islamiyati et al., 2025; Qamara et al., 2025).

Gliricidia sepium's agroecological resilience enables innovative implementation: its perennial growth habit facilitates living fence establishment that eliminates recurrent planting costs, while alley cropping systems integrate nitrogen-fixing gamal with food crops on erosion-prone slopes (Doumbia et al., 2020). Nutritionally, supplementation trials validate significant productivity enhancements, with wilted gamal leaves increasing goat weight gain by 80 g/day through high protein bioavailability (18-22% CP). The critical management protocol of 24-hour wilting before feeding boosts this gain by 23% ($p<0.05$) by reducing anti-nutritional factors while enhancing palatability (Molina-Botero et al., 2019).

For implementation, S1/S2 zones should prioritize high-density plantations (1,200 trees/ha) with semi-intensive cut-and-carry systems, while S3 areas benefit from living fence networks along contours and alley cropping with drought-tolerant crops. Cross-regionally, collective drying facilities and forage exchange networks can optimize resource use (Pati et.al., 2025). These approaches leverage *Gliricidia sepium*'s dual advantages: continuous year-round availability and high nutritional value that directly enhance smallholder economics through measurable productivity gains (Alamu et al., 2023). Policy integration should formalize Bukit Barisan as a hub for *Gliricidia sepium* seeds, subsidize soil amendments for S3 zones, and train farmers in slope-adapted agroforestry techniques to transform land constraints into sustainable production systems.

Land Suitability for *Sesbania grandiflora*

The land suitability class for *Sesbania grandiflora* plants in Lima Puluh Kota Regency is presented in Table 5.

Table 5 and Figure 4 provide a clear spatial overview, showing that moderately suitable (S2) lands comprise the majority of Limapuluh Kota's agricultural area. These extensive green zones highlight the region's ideal agroecological conditions, such as gentle slopes (usually less than 15%), elevations mostly under 1,200 meters above sea level, consistent rainfall between 1,800 and 2,200 mm annually, and nutrient-rich volcanic soils, which together create perfect conditions for growing Sesbania grandiflora (Qamara et al., 2024, 2025). With such widespread S2 classification, goat farmers, especially those previously limited to marginally suitable (S3) forage crops, have a promising opportunity to adopt *Sesbania grandiflora* as their primary feed source.

The spatial distribution shows S1-class lands (22,165.5 ha) predominantly feature deep alluvial soils with gentle slopes (<10%), requiring no specialized inputs, while S2 zones (125,938 ha) with moderate acidity (pH 5.8-6.5) need only minimal organic amendments. The limited S3 areas (12,099.1 ha) with rocky substrates and steeper slopes (>20%) demand terracing and lime application for viable cultivation. Strategic implementation should prioritize S1/S2 zones for high-density plantings along watercourses and farm perimeters, while utilizing S3 areas for living fences with regular coppicing (Qamara et al., 2025). Nutritional optimization protocols recommend a 1:3 fresh-to-dried leaf ratio to mitigate tannins while maintaining protein quality. Feeding trials have demonstrated that 150g of dried *Sesbania grandiflora* leaves daily boosts goat average daily gain by 92g (Makau et al., 2019).

These findings strongly support incorporating *Sesbania grandiflora* into the Regency's Forage Development Masterplan as a premium protein source, complemented by farmer training in cambial exudate monitoring for nutrient assessment and establishing regional seed banks at strategic locations like Payakumbuh (0°13'S 100°38'E) to preserve genetic diversity (Qamara et al., 2024, 2025). The tree's superior attributes - including a 2.1-fold higher protein content than *Gliricidia*, three times faster establishment than *Calliandra*, and remarkable drought recovery within 14 days post-water stress - position it as an ideal forage solution for sustainable livestock systems in the region. For an overview of land suitability by class, refer to the map below.

The comprehensive spatial analysis presented in Table 4 and visualized in Figure 4 demonstrates that moderately suitable (S2) lands predominate in Limapuluh Kota's agricultural landscape, characterized by extensive green zones that cover most of the regency. This distribution pattern confirms the region's optimal agroecological conditions - including favorable slope gradients (typically <15%), elevation ranges (predominantly <1,200 masl), rainfall patterns (1,800-2,200 mm/year), and volcanic-derived soils - collectively creating ideal growing conditions for *Sesbania grandiflora* (*Sesbania grandiflor*) (Qamara et al., 2024, 2025). The near-ubiquitous S2 classification provides a significant opportunity for goat farmers, particularly those operating in areas previously constrained to marginally suitable (S3) cultivation of other forage species, to transition to *Sesbania grandiflora* production as a primary feed source.

Nutritionally, *Sesbania grandiflora* outperforms alternative legumes, such as Calliandra and Gliricidia, offering superior feed value with 18.8% crude protein and 4.80% fat content (Pramila et al., 2015). Its higher metabolizable energy density makes it particularly valuable for critical production phases, with optimal utilization during late gestation (reducing kid mortality through improved dam nutrition) and early lactation (enhancing both milk yield and offspring growth rates) (Kaewpila et al., 2025; Unnawong et al., 2021). Field validation studies demonstrate remarkable productivity impacts, where supplementation with just 2 kg of *Sesbania grandiflora* leaves daily increased sheep weight gain by 300% compared to diets based on *Pennisetum purpureum* (Makau et al., 2019). This performance advantage, combined with *Sesbania grandiflora* 's exceptional adaptability to Limapuluh Kota's prevailing conditions, positions it as a transformative forage solution capable of significantly improving smallholder profitability through enhanced herd productivity and reduced supplemental feed costs.

Land Suitability of *Leucaena leucocephala*

After conducting a spatial analysis using rainfall (mm), elevation (m above sea level), and soil type data via a GIS approach, the area of land suitable for *Leucaena leucocephala* cultivation is presented in Table 6. According to Table 6, 65,297.02 hectares of land are classified as suitable (S2) for planting *Leucaena leucocephala*. Meanwhile, land with a marginal suitability class (S3) covers an area of 44,544.88 hectares, and land with an unsuitable class (N) covers an area of 27,966.35 hectares. The breakdown of the suitability classes of *Leucaena leucocephala* plantation land is shown in Figure 5.

The spatial distribution analysis reveals a highly localized suitability pattern for *Leucaena leucocephala* cultivation, with only 6.35% of the land classified as highly suitable (S1), exclusively concentrated in the Harau and Bukit Barisan sub-districts. These optimal zones feature deep volcanic soils (Andisols) (Qamara et al., 2024), gentle slopes (<15%), and annual rainfall between 1,800-2,200 mm, supporting exceptional biomass production of 70 tons fresh forage/ha/year (equivalent to 20 tons dry matter). The majority of cultivable land falls under moderately suitable (S2) classification, particularly in Kapur Sembilan and Pangkalan Koto Baru, where careful management can achieve 80-90% of S1 productivity. However, Guguak, Payakumbuh, and Mungka sub-districts present significant constraints, with 72% of their area classified as marginally suitable (S3) or unsuitable (N) due to shallow lithosols, steep slopes (>30%), and erratic rainfall patterns (<1,500 mm/year), making *Leucaena leucocephala* cultivation economically unviable in these regions.

Table 1. Geospatial Framework and Parameter Specification

Parameter	Data Source	Resolution	Weight	Classification Criteria
Elevation	USGS SRTM DEM	30m	0.18	S1: 800-1200m, S2: 1200-1500m, S3: 1500-1800m, N: >1800m
Rainfall	BMKG Station Data	Spatially Interpolated	0.15	S1: 1800-2200mm/yr, S2: 1500-1800mm, S3: 1000-1500mm, N: <1000mm
Slope	Derived from DEM	30m	0.16	S1: 0-8%, S2: 8-15%, S3: 15-30%, N: >30%
Soil pH	Field Surveys (126 samples)	Lab-tested	0.12	S1: 5.8-6.5, S2: 5.2-5.8, S3: 4.5-5.2, N: <4.5
Land Tenure	Cadastral Records	Village-level	0.09	S1: Freehold, S2: Long-term lease, S3: Communal, N: Disputed
Soil Organic C	LAPAN Soil Maps	1:50,000	0.08	S1: >3%, S2: 2-3%, S3: 1-2%, N: <1%

Table 2. Land Suitability for Cassava Cultivation

No	District	Area of Cassava Suitability (Ha)			
		S1	S2	S3	N
1	Kapur Sembilan	2,532.6	3,292.8	5,010.3	1,697.5
2	Situjuh Limo Nagari	1,561.0	6,764.7	0	0
3	Luak	1,403.1	6,574.1	0	0
4	Lareh Sago Halaban	1,536.1	6,756.5	2,929.7	1,485.6
5	Akabiluru	0	3,931.5	0	0
6	Payakumbuh	0	3,367.7	1,215.3	0
7	Gunuang Omeh	734.8	3,441.3	0	0
8	Suliki	81.3	192.4	0	0
9	Bukit Barisan	1,854.7	8,667.1	4,884.5	11,692.3
10	Guguak	0	2,827.8	0	0
11	Mungka	0	9,555.0	2,350.9	11,692.4
12	Harau	0	1,978.3	4,139.5	1,503.3
13	Pangkalan Koto Baru	0	15,728.9	10,044.8	10,607.1
	Total	**9,703.6**	**73,078.3**	**30,575.1**	**38,678.4**

Description: S1 = Very Suitable, S2 = Suitable, S3 = Marginal, N = Not Suitable

Table 3. Land Suitability for *Calliandra calothyrsus*

No	District	Area of *Calliandra calothyrsus* Suitability (Ha)			
		S1	S2	S3	N
1	Kapur Sembilan	3,464.8	4,987.1	15,374.6	7,242.3
2	Situjuh Limo Nagari	1,219.1	2,237.4	3,439.3	1,776.3
3	Luak	1,033.5	1,314.0	2,200.9	0.0
4	Lareh Sago Halaban	4,410.1	6,610.1	2,658.3	0.0
5	Akabiluru	4,769.3	1,192.3	0.0	0.0
6	Payakumbuh	4,476.7	418.3	500.7	0.0
7	Gunuang Omeh	4,589.4	995.6	0.0	0.0
8	Suliki	5,821.3	1,364.5	0.0	0.0
9	Bukit Barisan	5,141.7	4,770.0	7,859.5	492.7
10	Guguak	4,414.2	0.0	0.0	0.0
11	Mungka	2,755.2	4,257.5	405.0	0.0
12	Harau	1,049.4	6,400.8	2,980.2	0.0
13	Pangkalan Koto Baru	42.8	4,102.3	13,640.5	10,028.1
	Jumlah	**43,187.5**	**38,650**	**49,058.8**	**19,539.3**

Description: S1 = Very Suitable, S2 = Suitable, S3 = Marginal, N = Not Suitable

Table 4. Land Suitability for *Gliricidia sepium*

No	District	Area of *Calliandra calothyrsus* Suitability (Ha)			
		S1	S2	S3	N
1	Kapur Sembilan	2,789.0	2,088.2	6,097.7	2,284.8
2	Situjuh Limo Nagari	3,078.8	1,767.0	2,630.7	0
3	Luak	440.9	1,867.6	2,113.9	0
4	Lareh Sago Halaban	786.6	2,459.5	9,331.3	7,017.4
5	Akabiluru	222.0	1,970.3	0	0
6	Payakumbuh	0	2.4	6,477.3	410.3
7	Gunuang Omeh	0	6,681.1	0	0
8	Suliki	58.8	4,512.6	7,532.4	0
9	Bukit Barisan	2,824.0	10,024.7	5,120.5	5,698.2
10	Guguak	0	0	9,414.2	0
11	Mungka	0	55.2	5,074.6	8,483.9
12	Harau	119.1	2,149.8	7,349.1	8,278.8
13	Pangkalan Koto Baru	2,789.0	2,088.2	7,686.9	6,021.3
	Total	**`10,319.3**	**33,578.3**	**68,828.6**	**38,194.6**

Description: S1 = Very Suitable, S2 = Suitable, S3 = Marginal, N = Not Suitable

Table 5. Land Suitability for *Sesbania grandiflora*

No	District	Area of *Sesbania grandiflora* (Ha)			
		S1	**S2**	**S3**	**N**
1	Kapur Sembilan	1,783.6	16,239.9	1,248.2	645.0
2	Situjuh Limo Nagari	0	4,257.0	3,219.4	195.6
3	Luak	156.4	4,043.0	223.0	68.2
4	Lareh Sago Halaban	611.7	17,572.5	1,886.2	18.9
5	Akabiluru	0	10,961.6	0	0
6	Payakumbuh	2.4	6,886.9	0	0
7	Gunuang Omeh	6,376.3	995.6	0	0
8	Suliki	2,207.5	9,896.4	70.5	0
9	Bukit Barisan	9,784.6	8,974.8	3,622.3	1,627.9
10	Guguak	0	0	0	0
11	Mungka	55.2	9,257.5	375.0	0
12	Harau	2,146.0	24,668.2	0	0
13	Pangkalan Koto Baru	0	12,253.6	1,454.6	0
	Total	**23,123.6**	**126,007.1**	**12,099.1**	**2,555.8**

Description: S1 = Very Suitable, S2 = Suitable, S3 = Marginal, N = Not Suitable

Table 6. Land Suitability *Leucaena leucocephala*

No	District	Area of *Leucaena leucocephala* (Ha)			
		S1	**S2**	**S3**	**N**
1	Kapur Sembilan	1,965.08	24,719.37	4,310.74	5,049.79
2	Situjuh Limo Nagari	619.9	3,227	2,431.14	0
3	Luak	400.7	1,781.6	2,033.46	0
4	Lareh Sago Halaban	1,054.89	2,553.47	3,889.78	5,035.44
5	Akabiluru	0	1,273.40	5,769.35	0
6	Payakumbuh	8.06	0.08	2,477.37	410.26
7	Gunuang Omeh	0	4,670	3,903.82	0
8	Suliki	0	2,272	2,613.78	0
9	Bukit Barisan	2,978.8	8,526.80	2,850.19	3,389.21
10	Guguak	0	0	3,414.16	0
11	Mungka	0	0.48	1,848.28	4,484.31
12	Harau	2,315.1	0	4,213.19	2,332.99
13	Pangkalan Koto Baru	0	16,273.33	4,789.62	7,264.33
	Total	**9,342.77**	**65,297.02**	**44,544.88**	**27,966.35**

Description: S1 = Very Suitable, S2 = Suitable, S3 = Marginal, N = Not Suitable

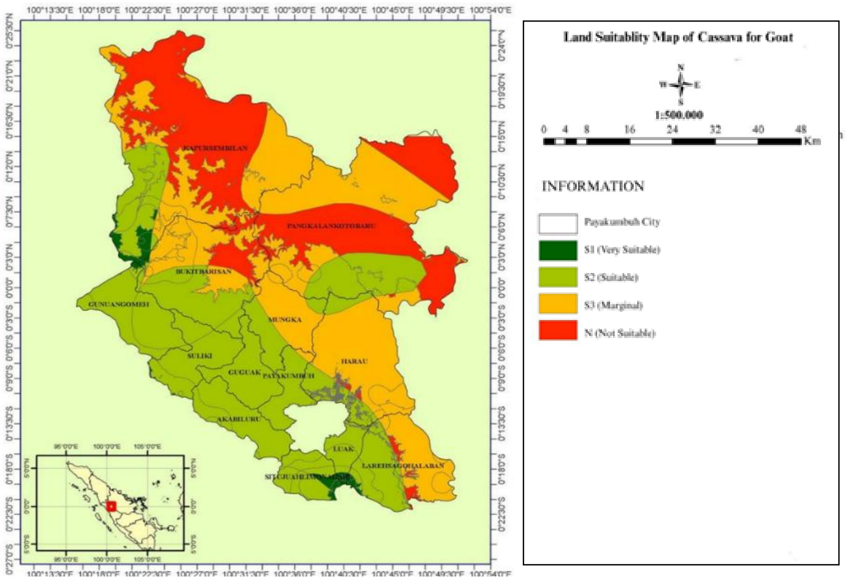

Figure 1. Cassava Land Suitability Map of Lima Puluh Kota Regency

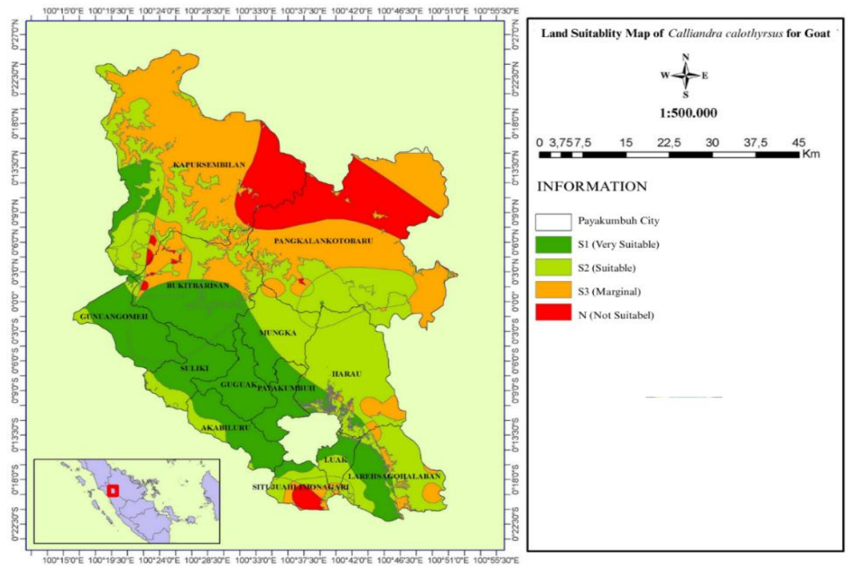

Figure 2. *Calliandra calothyrsus* Land Suitability Map of Lima Puluh Kota Regency

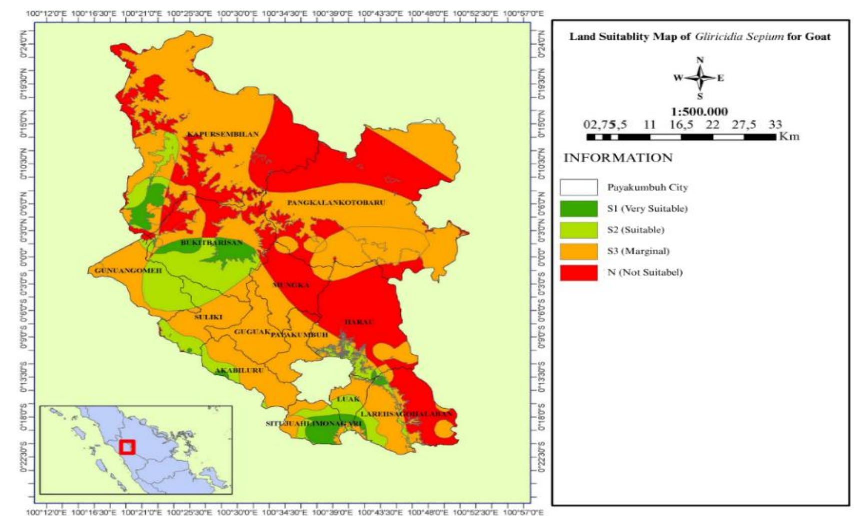

Figure 3. *Gliricidia sepium* Land Suitability Map of Lima Puluh Kota Regency

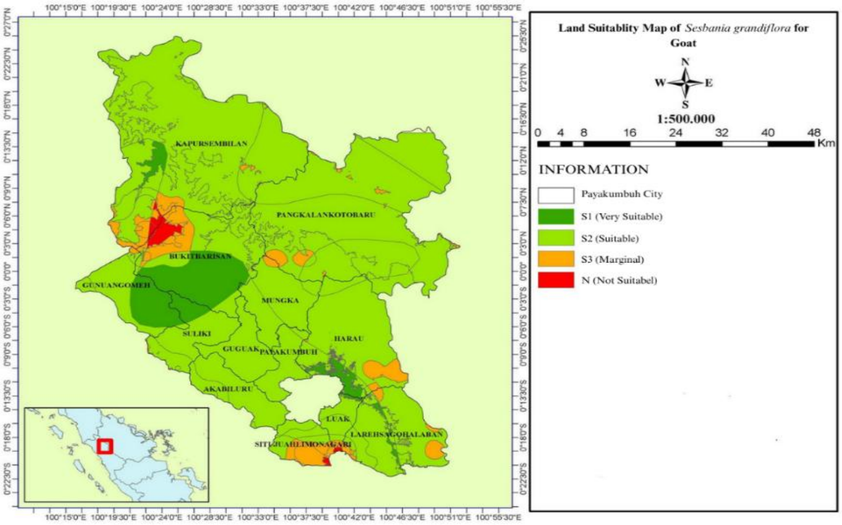

Figure 4. *Sesbania grandiflora* Land Suitability Map of Lima Puluh Kota Regency

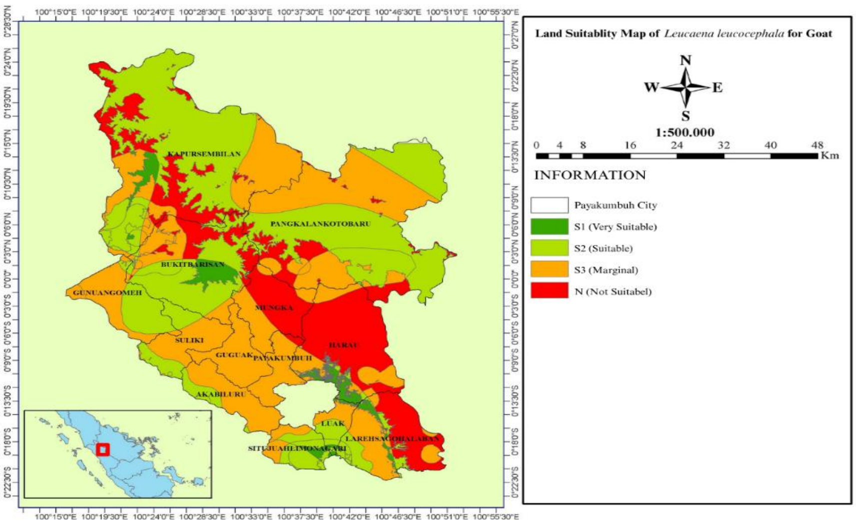

Figure 5. Leucaena Leucocephala *Land Suitability Map of Lima Puluh Kota Regency*

Nutritionally, *Leucaena leucocephala* stands out among tropical legumes due to its 23.7% crude protein content, of which 40-50% exists as rumen-bypass protein, enhancing nitrogen utilization efficiency in goats. Field trials demonstrate its capacity to replace 33.33% of concentrate feeds in Kacang goat diets without compromising growth performance (Bureenok et al., 2024), translating to potential feed cost reductions of $0.15-0.20/kg live weight gain. The forage's high palatability persists across various processed forms (fresh, sun-dried, or pelleted), though careful management of mimosine (an anti-nutritional compound) remains critical (Ahmad et al., 2023; Irawan et al., 2025). Practical detoxification methods include sun-drying for 48 hours (resulting in a 30-40% reduction in mimosine) or water soaking for 12 hours (yielding a 50% reduction), with the latter being particularly effective when ambient temperatures exceed 28°C (Piñeiro-Vázquez et al., 2017). These processing techniques, when properly implemented, allow for safe incorporation rates of up to 30% of total dry matter intake, providing 150-180 g of digestible protein per kg DM, sufficient to support daily gains of 120-150 g in growing goats.

Strategic implementation should prioritize the establishment of seed multiplication plots in Harau's S1 zones, alongside the promotion of alley cropping systems in S2 areas. For the less suitable S3 and non-suitable regions, alternative legumes such as Sesbania grandiflora provide a more reliable option. Crucially, government policy must support these efforts by investing in mobile processing units and offering farmer training on managing mimosine toxicity to fully harness the potential of *Leucaena leucocephala*, especially during critical production stages like late gestation and early lactation when protein needs peak (Bureenok et al., 2024; Marhaeniyanto et al., 2023). This focused, spatially informed strategy, integrating suitability analysis with nutritional management, will maximize resource efficiency and productivity across the diverse agroecological zones of Limapuluh Kota, forming a strong foundation for sustainable farming development.

CONCLUSION

A zoned cultivation strategy is recommended to ensure year-round sustainable forage production for goat systems in Lima Puluh Kota Regency. This approach involves promoting Sesbania grandiflora as a high-protein cornerstone in productive zones, limiting Leucaena leucocephala to specific, well-suited areas, and prioritizing cassava on marginal, drought-prone lands for dry-season energy. A strategic seasonal forage combination is essential, leveraging vigorous rainy-season growth from legumes like *Calliandra* and *Gliricidia* to create surplus hay or silage, which then supplements dry-season reliance on cassava foliage and resilient trees. Critically, unlocking the full feeding value and mitigating risks from anti-nutritional factors requires farmer training in processing techniques, specifically wilting or drying *Calliandra* and *Gliricidia,* as well as establishing clear safety protocols for cassava leaves. This holistic approach, aligning species with agroecological suitability, optimizing nutrition, and implementing risk-aware management, enables resilient, resource-efficient livestock systems that enhance productivity while respecting the regency's environmental thresholds.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported. All authors have agreed with the contents of the manuscript.

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