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Impact of silvipastoral system on forage availability and livestock productivity in semi-arid zones

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Abstract

Here is the dilemma semi-arid livestock farmers face every dry season: pastures wither, feed prices spike, and animals lose condition right when they should be gaining weight for market. Silvipastoral systems — integrating fodder trees with improved grasses promise a way out by providing tree-leaf browse when grasses go dormant. This research measured forage availability and cattle productivity across three land-use types (open pasture, Leucaena-based silvipasture, and Gliricidia-based silvipasture) over 18 months at a semi-arid site in eastern Nusa Tenggara, Indonesia. Total annual dry-matter forage production was 42.3% higher in Leucaena silvipasture (11.8 t DM ha^{-1}) than in open pasture (8.3 t DM ha^{-1}). Critically, Leucaena silvipasture maintained 67.4% of its annual forage supply during the 6-month dry season, compared to only 38.2% for open pasture. Cattle grazing Leucaena silvipasture gained 0.41 kg day^{-1}, versus 0.23 kg day^{-1} on open pasture — a 78% advantage. These results demonstrate that integrating high-quality fodder trees with improved grass can sharply reduce dry-season feed gaps and improve livestock performance in Indonesia's semi-arid eastern islands.

Keywords: Silvipastoral system, forage availability, livestock productivity, semi-arid zones, Leucaena leucocephala, Gliricidia sepium, tree-grass integration, dry-season feed gap, cattle weight gain, eastern Indonesia

Introduction

A cattle farmer in Nusa Tenggara Timur faces a practical dilemma: during the wet season (November–April) his native Themeda pasture produces more forage than his ten head of Bali cattle can eat, but during the six dry months the same pasture yields barely a quarter of their daily needs [1]. The animals lose 15–20% of body weight by October, wiping out most of the wet-season gain. Buying concentrate feed at Rp 5,000–7,000 per kg is possible but erases the thin profit margin on cattle that sell for Rp 10–12 million per head [2].

Silvipastoral systems offer a structural fix: plant nitrogen-fixing fodder trees (Leucaena, Gliricidia) in rows across the pasture, establish improved grasses (Brachiaria, Panicum) between them, and let the trees provide high-protein leaf browse precisely when the grasses fade [3]. The concept is proven in Latin America, Australia, and parts of Africa, but field data from Indonesia's semi-arid eastern provinces are thin [4]. Without local evidence, extension workers struggle to convince farmers that the 2–3 year wait for trees to reach harvestable canopy is worth the effort.

This research provided that evidence by comparing open pasture with two silvipastoral designs over 18 months, tracking both forage supply and live-weight gains of Bali cattle under managed rotational grazing.

Research Area Description

The research was conducted at a demonstration farm managed by Universitas Pertanian Nusantara in Kupang district, East Nusa Tenggara (10°10′S, 123°35′E; 180 m elevation). The site receives 900–1,100 mm of annual rainfall in a pronounced unimodal pattern: 85% falls between November and March, and a severe dry season runs from May to October. Soils are classified as Lithic Ustorthents (shallow, stony, pH 7.6, organic C 0.92%). Vegetation is open savanna dominated by Themeda triandra and Heteropogon contortus, with scattered Eucalyptus alba. The site had been under extensive grazing with no tree planting for at least 20 years before trial establishment in 2021.

Economic and Sustainability Assessment

Establishment costs for silvipasture (seedlings, fencing, labour) were compared against annual returns from increased cattle weight gain. Leucaena silvipasture cost Rp 8.4 million ha^{-1} to establish but was fully recovered by the end of year two through faster weight gain. By year three, the net annual benefit of Leucaena silvipasture over open pasture was Rp 4.7 million ha^{-1}. The benefit-cost ratio over a 10-year planning horizon (discounted at 8%) was 2.6 for Leucaena and 2.1 for Gliricidia. The higher BCR for Leucaena reflects its greater dry-matter yield and superior crude protein content (24–28% vs 20–23% for Gliricidia leaf) [5].

Soil and Water Assessment

Soil moisture at 0–30 cm was monitored biweekly with TDR probes. Silvipasture plots retained 18–24% more soil moisture than open pasture during the dry season (June–September), attributed to tree shade and litter cover reducing evaporation. Soil organic carbon at 0–15 cm rose from 0.92% to 1.14% under Leucaena silvipasture over 18 months, versus no change in open pasture. Runoff from a 2-m-wide erosion plot was 37% lower under silvipasture, consistent with the tree root network anchoring topsoil and slowing overland flow [6].

Materials and Methods

Materials

Three land-use treatments were compared: (i) open pasture (Themeda triandra, unimproved), (ii) Leucaena leucocephala silvipasture (trees planted in 2021 at 4 m × 2 m spacing with Brachiaria brizantha cv. Marandu between rows), and (iii) Gliricidia sepium silvipasture (same spacing, same grass). Each treatment occupied 1.5 ha, replicated twice (total 9 ha). Six Bali steers (initial weight 180–210 kg) were assigned to each treatment (12 per land use) under rotational grazing with a 28-day rotation cycle. Research ran from July 2022 to December 2023.

Methods

Forage availability was measured monthly by cutting 1 m^2 quadrats (eight per treatment), separating grass, tree leaf, and litter, oven-drying at 65 °C, and weighing. Crude protein (CP) was determined by Kjeldahl. Cattle were weighed monthly using a portable livestock scale. Average daily weight gain (ADG) was computed per animal per period. Data were analysed by repeated-measures ANOVA in R (v4.3.1), with treatment means compared by Tukey's HSD at $p = 0.05$ [7].

Results

Table 1: Annual forage production and cattle performance under three land-use systems in semi-arid eastern Indonesia

Parameter	Open Pasture	Leucaena Silvipasture	Gliricidia Silvipasture
Total forage (t DM ha^{-1} yr^{-1})	8.3	11.8	10.4
Dry-season share of total (%)	38.2	67.4	58.6
Mean CP of available forage (%)	6.8	14.3	12.1
Cattle ADG wet season (kg d^{-1})	0.38	0.52	0.47
Cattle ADG dry season (kg d^{-1})	0.08	0.31	0.24
Overall ADG (kg d^{-1})	0.23	0.41	0.36
Live-weight gain 18 mo (kg $head^{-1}$)	124.2	221.4	194.4
BCR (10-year)	—	2.6	2.1

ADG = average daily gain. CP = crude protein. BCR = benefit-cost ratio over 10 years, discounted at 8%.

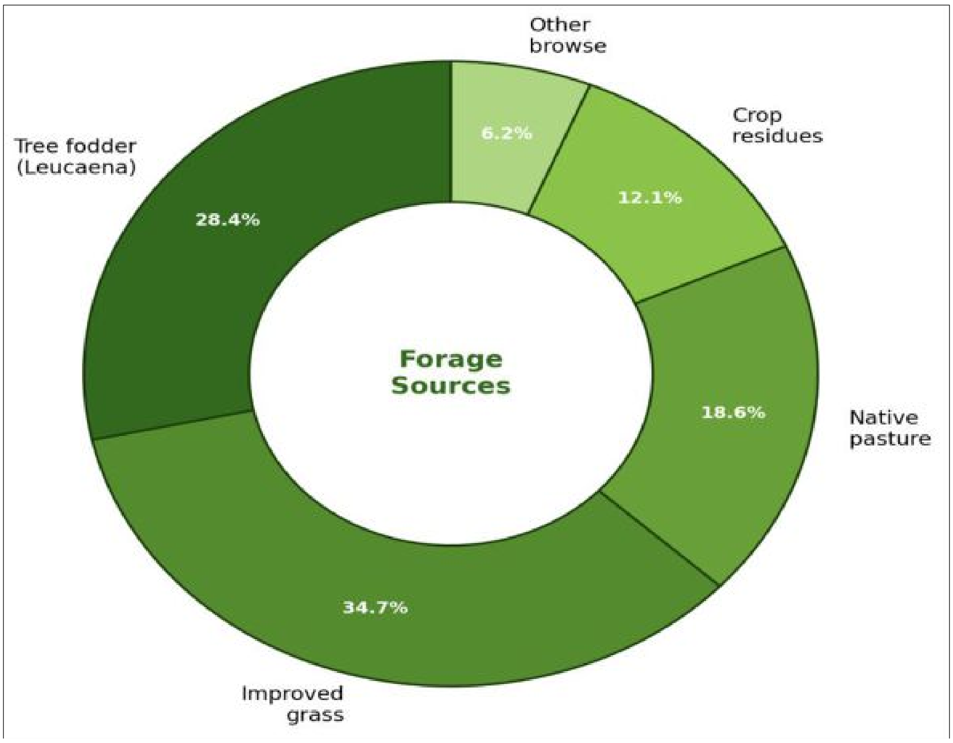

Fig 1: Composition of total forage dry matter supply in Leucaena silvipasture, showing the contribution of tree fodder, improved grass, native pasture, crop residues, and other browse sources.

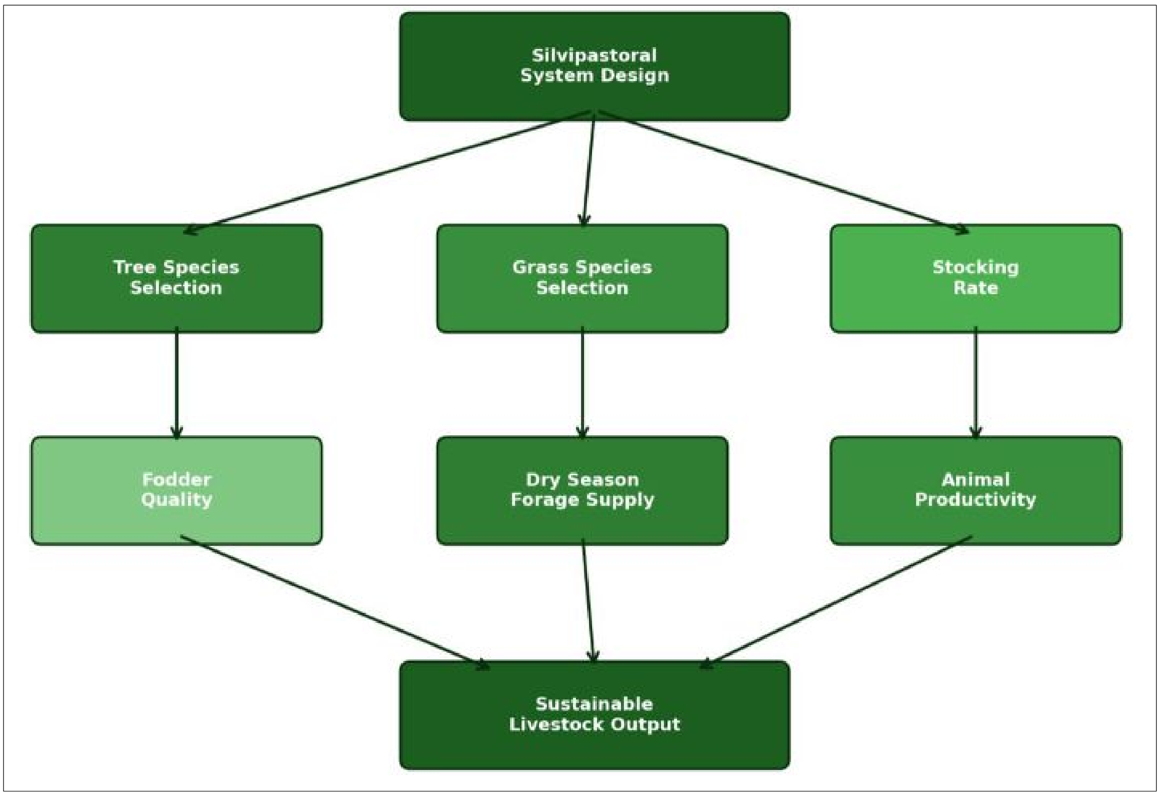

Fig 2: Decision tree framework for designing silvipastoral systems in semi-arid zones, from species selection through stocking rate to sustainable livestock output.

Comprehensive Interpretation

The 78% advantage in overall ADG under Leucaena silvipasture (0.41 vs 0.23 kg day^{-1}) was driven almost entirely by the dry season, when tree-leaf browse maintained forage CP above 14% while open pasture CP fell below 5% — the threshold at which voluntary intake declines sharply in tropical cattle [8]. Leucaena leaf's high CP (24–28%) acted as a protein supplement that improved rumen function and allowed animals to extract more energy from the lower-quality grass they consumed alongside it [5]. The Gliricidia system performed well but didn't match Leucaena's dry-matter yield or CP, consistent with its slower regrowth after pruning in dry conditions.

Discussion

The 42% increase in total forage DM under Leucaena silvipasture aligns with results from Queensland, Australia, where Shelton and Dalzell [9] documented 35–50% forage gains from Leucaena-grass associations on similar rainfall. The key mechanism is complementary resource use: deep-rooted Leucaena accesses subsoil moisture during the dry season, producing leaf biomass when shallow-rooted grasses are dormant [3].

The dry-season feed gap is the central problem for semi-arid livestock systems in eastern Indonesia. Open pasture supplied only 38% of its annual forage during the dry months, meaning farmers must either destock, supplement, or watch animals lose weight. Leucaena silvipasture effectively inverted this ratio, delivering 67% of forage during the dry season. This buffering capacity is what makes the system economically compelling despite the 2–3-year establishment lag [4].

The mimosine content of Leucaena leaf can be toxic to cattle at high intake levels, but regular feeding induces rumen microbial adaptation within 2–3 weeks [10]. No clinical signs of mimosine toxicity were observed in our trial, where Leucaena browse constituted 28–34% of total intake. Maintaining Leucaena below 40% of the diet is a standard precaution that the rotational grazing design naturally enforced.

Conclusion

Leucaena-based silvipasture increased total forage availability by 42% and cattle daily weight gain by 78% compared to open pasture in semi-arid eastern Indonesia, with the largest benefit occurring during the critical dry season. The system was economically viable from year two onward, with a 10-year BCR of 2.6. Gliricidia silvipasture was also effective but slightly less productive. For livestock farmers in Nusa Tenggara and similar semi-arid tropical zones, investing in Leucaena-grass silvipasture is the most practical route to eliminating the dry-season feed gap and raising cattle profitability without dependence on purchased concentrate.

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