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DEVELOPMENT OF AN INTEGRATED DWARF NAPIER GRASS FEED BANK MODEL FOR SUSTAINABLE FORAGE AGRIBUSINESS AND SMALLHOLDER CATTLE PRODUCTION IN GORONTALO, INDONESIA

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Abstract

Seasonal feed insecurity constrains smallholder beef production in tropical mixed-farming landscapes. This study develops an integrated dwarf Napier grass (Cenchrus purpureus syn. Pennisetum purpureum cv. Mott) feed bank model for Gorontalo Province, Indonesia, combining forage production, dry-matter supply, cattle demand, conserved forage inventory, and agribusiness feasibility. Public statistics establish the regional context: Gorontalo had 162,935 beef cattle in 2025 (preliminary figure), while maize harvested area and dry-shelled maize production reached 130,520 ha and 653,290 t, respectively. We specify a monthly mass-balance model and demonstrate transparent scenarios using explicitly hypothetical assumptions rather than measured farm-level observations. For one hectare of planted dwarf Napier grass, assumed annual dry-matter yields of 12, 18 and 24 t ha−1, an 80% usable share, and 2.25 t DM cattle−1 year−1 imply theoretical support for 3.51, 5.26 and 7.01 cattle, respectively, before allowance for other ration components and seasonal constraints. The approach links forage-bank sizing, monthly storage dynamics, crop residues, sensitivity analysis, and farm financial metrics. These figures are simulations, not estimated local odot yields or field-validated stocking capacities. Prospective validation requires repeated harvest measurements, feed inventories, cattle liveweights, ration data and farm cost records.

Keywords: *Dwarf Napier grass; forage bank; crop–livestock integration; dry matter; smallholder cattle*

1. Introduction

Smallholder crop–livestock systems in tropical Indonesia depend on variable supplies of grasses, crop residues and purchased supplements. Napier grass is widely used by smallholders, but its yield and nutritive value vary considerably with cultivar, cutting management, soil and climate (Islam et al., 2023). Studies in eastern Indonesia demonstrate potential benefits from introducing improved forage and leguminous species into mixed crop–livestock systems (Cox et al., 2025). In North Sulawesi, Osak et

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al. (2018) directly evaluated dwarf elephant grass within a coconut–beef cattle integrated farming system, offering a geographically relevant agronomic precedent.

Gorontalo offers an important case for regional feed planning because beef cattle and maize coexist at scale. BPS reported 162,935 head of beef cattle in 2025 (preliminary figures), and maize production of 653,290 tonnes of dry-shelled grain from 130,520 ha harvested in 2025 (BPS, 2026a; 2026b). Grain tonnage cannot be equated with available maize stover: the latter requires locally validated residue-to-product ratios, dry-matter analyses, harvest losses and realistic collection rates.

Previous research has separately addressed cattle feed banks (Mashur et al., 2022), dynamic feed supply models (Malindo et al., 2023), and Napier management (Islam et al., 2023). The research gap addressed here is a single, auditable framework connecting dwarf Napier feed production, storage over dry and wet months, diversified on-farm residues, cattle demand, and enterprise-level economics within a Gorontalo smallholder context. The objective is to develop this framework and demonstrate its numerical behaviour; future empirical testing is explicitly distinguished from the present secondary-data analysis.

2. Literature Review

Sustainable forage production is a fundamental component of livestock development, particularly in tropical regions where smallholder cattle farmers depend on locally available feed resources. The sustainability of these systems is influenced not only by forage productivity but also by seasonal feed availability, nutritional quality, land-use efficiency, economic feasibility, and institutional support. Consequently, improving livestock productivity requires an integrated approach that connects forage cultivation, feed conservation, animal nutrition, and agribusiness development.

Paul et al. (2020), through a meta-analysis of 72 experimental studies in sub-Saharan Africa, demonstrated that improved tropical forage technologies could generate multiple benefits for livestock productivity, crop production, and soil management. Improved forage germplasm produced, on average, 2.6 times more herbage than local controls. However, the authors emphasized the variability of forage responses across environments and the importance of evaluating trade-offs at the farming-system level.

Similarly, Islam et al. (2024) highlighted the substantial potential of Napier grass for supporting ruminant production in tropical and subtropical regions. Nevertheless, they identified persistent limitations associated with inadequate forage management and low nutritional quality. These findings suggest that simply increasing forage biomass is insufficient to ensure improved livestock performance. More recently, Manono (2026) argued that sustainable forage integration should be evaluated through relationships among agricultural productivity, resource efficiency, environmental performance, household livelihoods, and institutional conditions. The review challenged the assumption that higher forage production automatically represents sustainable agricultural intensification.

Collectively, these studies establish that sustainable livestock development depends on the effective integration of biological, economic, and institutional components. However, most forage production studies remain focused on individual

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technical interventions rather than integrated, operationally validated feed-supply systems.

Dwarf Napier grass (*Cenchrus purpureus*, syn. *Pennisetum purpureum*, cv. Mott), commonly known as Odot grass in Indonesia, is increasingly recognized as a promising forage resource because of its relatively short stature, favorable leaf-to-stem ratio, regrowth capacity, and suitability for cut-and-carry feeding systems. Sirait (2017) reviewed the agronomic characteristics and nutritional potential of dwarf Napier grass and identified its advantages for smallholder ruminant feeding. The study emphasized its capacity for repeated harvesting and its potential utilization as fresh forage, hay, and silage. Nevertheless, the review primarily addressed production and utilization characteristics rather than the economic and institutional requirements for organized forage supply.

Dumadi et al. (2021) conducted a quantitative comparison of dwarf and tall Napier grass types in Indonesia. Their synthesis reported higher relative forage quality for dwarf Napier grass, with an RFQ value of 68 compared with 57 for tall-type Napier grass. The results also indicated favorable differences in dry matter and fiber characteristics. However, these findings were based on compiled nutritional data and did not directly establish superior cattle growth or profitability under smallholder conditions. Islam et al. (2023) critically examined management strategies for Napier grass and identified a fundamental trade-off between biomass production and nutritional quality. Their review indicated that forage yield generally increases with plant maturity, whereas crude protein concentration and digestibility tend to decline. Consequently, harvest management should optimize usable nutrients rather than maximize fresh forage weight alone.

Roy et al. (2025) provided further experimental evidence using Napier grass cv. Pakchong. Increasing harvest maturity from six to fourteen leaf stages reduced crude protein concentration from 184 to 118 g/kg dry matter and metabolizable energy from 10.4 to 7.3 MJ/kg dry matter. Although the study demonstrated the importance of harvest management for cattle nutrition, its findings cannot be directly generalized to cv. Mott without cultivar-specific validation.Wadi et al. (2026) demonstrated that composted cattle manure improved biomass production, crude protein content, and digestibility of dwarf-late Napier grass under tropical conditions. This study supports the potential for integrating cattle manure recycling into forage production. Nevertheless, its experimental cultivar and production conditions require careful consideration before applying its results to Odot grass in Gorontalo.

3. Research Method

The geographic scope is Gorontalo Province, Indonesia. This is a secondary-data model-development and scenario study, not a household survey or agronomic experiment. Official BPS figures are used to establish provincial scale; international peer-reviewed articles inform model architecture and possible parameter ranges.

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Table 1. llustrative Assumptions for Sensitivity Assessment in Gorontalo

Item	Value	Date / interpretation	Source
Beef cattle population	162,935 head	2025; preliminary	BPS beef cattle table (2026)
Maize harvested area	130,520 ha	2025; provincial total	BPS Gorontalo release, 2 Feb 2026
Dry-shelled maize grain	653,290 t	2025; grain at 14% moisture	BPS Gorontalo release, 2 Feb 2026
Maize grain production	625,970 t	2024; grain at 14% moisture	BPS Gorontalo release, 3 Mar 2025

The proposed integrated feed bank links: (i) land and agronomic inputs → dwarf Napier forage growth and harvest; (ii) maize biomass residues and optional forage legumes → complementary forage supply; (iii) surplus conservation as silage or hay → storage and spoilage; (iv) cattle dry-matter requirements → withdrawals; (v) manure recovery → nutrient recycling; and (vi) harvest, transport, processing, sale and labour costs → financial returns. Units are harmonized to kilograms or tonnes of dry matter (DM); water-containing fresh weights are not summed with DM without conversion.

Annual usable Napier dry matter: $U = A \times Y \times f$,

where A = established land (ha),
Y = annual harvested biomass (t DM ha−1 yr−1), and
f = usable fraction after harvest, handling and feeding losses (0–1).

Annual demand: $D = N \times W \times r \times 365 / 1{,}000$,

where N = cattle head count,
W = mean cattle liveweight (kg), and
r = daily DM intake fraction of liveweight. A reserve factor k may be added: $D^* = D \times (1 + k)$.

Theoretical cattle-equivalent support: $C = U / [W \times r \times 365 / 1{,}000]$. This is a DM-only ceiling, not a nutritional recommendation or evidence of adequate protein, energy and minerals. Monthly feed-bank inventory: $S(t+1) = \max[0, S(t)(1 - l(t)) + H(t) + R(t) + P(t) - F(t)]$, where S = stored usable DM, l = monthly storage loss, H = conserved Napier DM, R = conserved crop-residue DM, P = purchases, and F = feed withdrawn. Unmet demand is $\max[0, F_{required}(t) - available(t)]$. Seasonal stockouts must be evaluated month by month, even when annual total supply exceeds annual demand.

Economic outputs: gross margin = feed-bank revenue plus attributable feed-purchase savings − variable costs; benefit–cost ratio = discounted benefits / discounted costs; net present value = $\Sigma[(B_t - C_t)/(1+i)^t]$ − initial investment, using a stated discount rate i and horizon. Avoid double counting internal forage transfers and avoided purchases as two independent benefits.

A base demonstration sets A = 1 ha, assumed Y = 18 t DM ha−1 yr−1, usable fraction f = 0.80, W = 300 kg, r = 0.025 kg DM per kg bodyweight per day, and no explicit reserve. Low and high production scenarios use Y = 12 and 24 t DM ha−1 yr−1. These are

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imposed modelling parameters, not Gorontalo agronomic observations. Farm-level calibration should replace them with repeated dry-matter yield measurements and observed animal intakes. Scenario calculations are deterministic; therefore p-values and statistical significance tests are not applicable to this illustrative output.

4. Result

The BPS provincial cattle figure and maize statistics in Figure 2 establish the scale of regional agriculture but do not indicate how many hectares can realistically be allocated to odot grass or what share of maize stover is collectible. The measured quantities required to transform crop production into a sustainable forage bank remain to be collected.

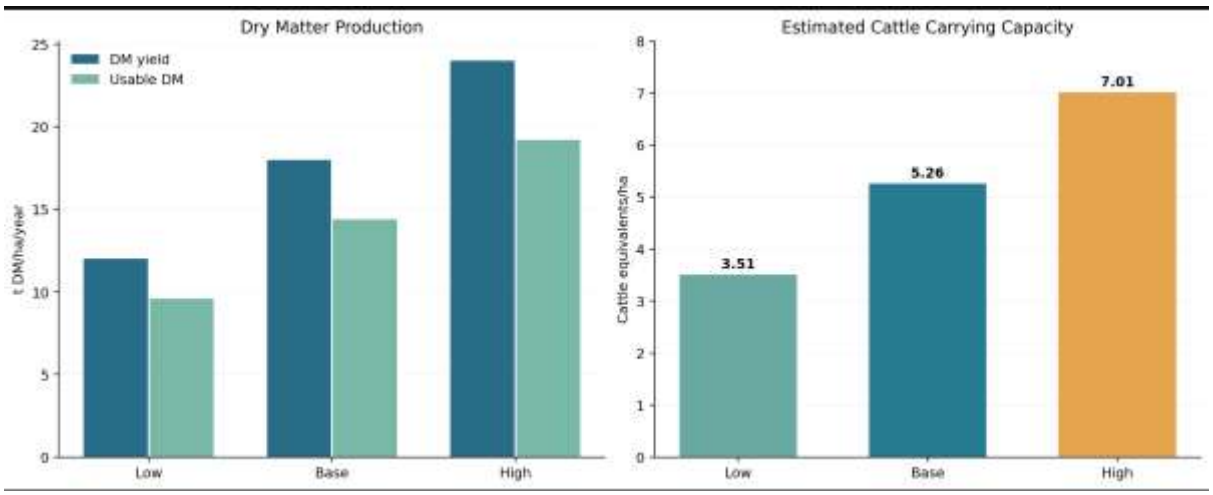


Figure 1. Establish The Scale of Regional Agriculture

For the illustrative base scenario, 18 × 0.80 = 14.4 t usable DM per hectare per year. One 300-kg cattle consuming 2.5% of liveweight as DM per day requires 2.7375 t DM annually; thus 14.4 / 2.7375 = 5.26 cattle-equivalents. These capacities refer to a hypothetical full forage-DM contribution, with no allocation for ration diversity, safety stock or seasonal inventory bottlenecks.

Consider a separate illustrative farm with five 300-kg cattle: annual DM requirements = 5 × 2.7375 = 13.6875 t. A 20% planning reserve raises the target to 16.425 t. At the base case usable productivity of 14.4 t DM ha−1 yr−1, the required established Napier area is 1.14 ha, assuming its DM is theoretically able to cover the specified share of intake. If Napier supplies only 60% of ration DM and the remaining 40% comes from measured supplementary resources, the corresponding Napier area target for demand plus reserve would be 0.68 ha. Actual month-to-month adequacy must be checked from harvest and storage profiles.

5. Discussion

The proposed framework extends the feed-bank literature by integrating on-farm production, seasonal inventory, intake requirements and farm-enterprise accounting.

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Mashur et al. (2022) emphasize institutional sustainability in cattle feed banks, whereas Malindo et al. (2023) demonstrate the usefulness of system dynamics in projecting cattle feed provision. The present approach translates that logic to a decentralized bank built around dwarf Napier grass and the spatially adjacent crop–livestock system of Gorontalo.

The potential regional contribution of maize residues is best treated as an option, not a measured supply. Sustainable recovery depends on competition with soil-cover requirements, soil organic matter maintenance, fodder quality, competing uses, transport and storage. Integration with forage legumes could improve ration protein and soil nitrogen management, as evidenced by eastern Indonesian integrated-forage studies (Cox et al., 2025). Because Napier yields and quality vary substantially, the literature synthesis of Islam et al. (2023) should inform sensitivity limits rather than be used to assert a Gorontalo-specific yield.

A feed-bank enterprise needs predictable harvest schedules, dry-matter testing, transparent quality grades, accessible aggregation points and affordable preservation. Key feasibility indicators include farm-gate cost per kg usable DM, feed supply reliability during the dry season, labour per tonne conserved, spoilage, gross margin and farmer participation. Economic results cannot yet be reported without observed prices, investment costs and market transactions. Further work could compare individual, cooperative and village bank arrangements and test whether predicted dry-season deficits decrease in monitored farms.

6. Conclusion

A transparent integrated dwarf Napier feed-bank model can connect smallholder forage production, inventory dynamics, cattle demand and financial sustainability in Gorontalo. Official 2025 agricultural data establish the regional relevance of the topic. Illustrative scenarios demonstrate how yield, utilization efficiency and intake assumptions affect required forage area, but they do not constitute empirical findings. A prospective field programme is needed to calibrate local productivity, establish dry-season supply profiles, test forecast accuracy, and assess enterprise feasibility before deployment or any claim of validation.

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